Bedford Institute of Oceanography

Biennial Review 1977&1978

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The cover shows the CSS Hudson in Scott Inlet, Baffin Island, on September 6, 1977. The cliffs in the background are 300 or more metres high. In the fall of 1976, BIO scientists had observed an oil slick off the Inlet but because of ice conditions at the time they were unable to locate its source or to determine its extent. So in 1977 and again in 1978, Hudson returned to measure the background levels of petroleum residues in the eastern Arctic and also to investigate the geology of the Baffin Island shelf. Together the chemical and geological studies demonstrated that the slick at Scott Inlet is the result of natural seepage of petroleum from the walls and bottom of the submarine trough that cuts across the continental shelf in this area. These studies are discussed further on pages 19 and 20 and 172 to 174.

Cover photograph by Roger Be/anger.

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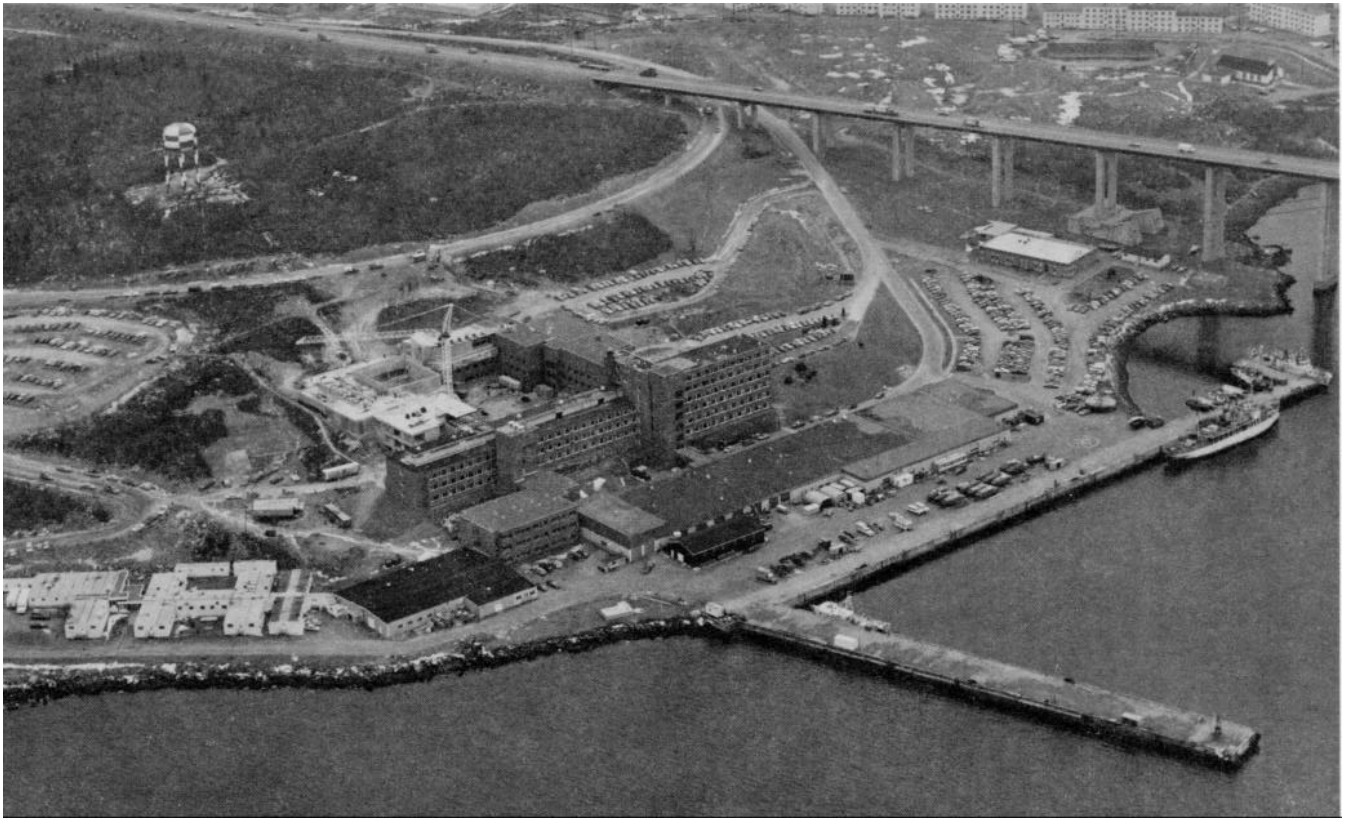

Aerial view looking east of the Bedford Institute of Oceanography. (BIO 5115-4)

A word about organization . . .

The Bedford Institute of Oceanography is a Government of Canada research complex located on the shores of Bedford Basin in Dartmouth, Nova Scotia. The Institute conducts oceanographic studies and hydrographic surveys in a wide range of marine environments. Seven main groups affiliated with two departments are housed at BIO:

- the **Atlantic Oceanographic Laboratory, Marine Ecology Laboratory,** and **Institute Facilities** constitute Ocean and Aquatic Sciences, Atlantic of the Fisheries and Marine Service, Department of Fisheries and the Environment;
- the **Marine Fish Division** is part of the Resource Branch, Fisheries Management, Fisheries and Marine Service, Department of Fisheries and the Environment;
- the **Seabird Research Unit** is part of the Canadian Wildlife Service, Environmental Management Service, Department of Fisheries and the Environment;
- the **Atlantic Geoscience Centre** is part of the Geological Survey of Canada, Science and Technology, Department of Energy, Mines and Resources; and
- the **East Coast Office** of the **Resource Management and Conservation Branch** is part of the Energy Policy Sector of the Department of Energy, Mines and Resources.

Despite the various affiliations of staff at BIO there is a common theme to the work, and a management committee composed of members from some of the different groups directs efforts and keeps communication lines open.

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M. P. Latremouille
Editor

ToC

Abbreviations and Acronyms

AES	- Atmospheric Environment Service
AGC	- Atlantic Geoscience Centre
AIDJEX	- Arctic Ice Dynamics Joint Experiment
AOL	- Atlantic Oceanographic Laboratory
BIO	- Bedford Institute of Oceanography
BIONAV	- Bedford Institute of Oceanography Navigation (system)
BIONESS	- Bedford Institute of Oceanography Net and Environment Sensing System
CAFSAC	- Canadian Atlantic Fisheries Scientific Advisory Committee
CANDU	- Canadian Deuterium Uranium nuclear reactor
CAN/OLE	- Canadian On-Line Enquiry
CCGS	- Canadian Coast Guard Ship
CCIW	- Canada Centre for Inland Waters
CCRS	- Canada Centre for Remote Sensing
CHS	- Canadian Hydrographic Service
CIDA	- Canadian International Development Agency
CODS	- Canadian Ocean Data System
CRT	- Cathode-Ray Tube
CSS	- Canadian Scientific Ship
CTD	- Conductivity-Temperature-Depth (profiler)
DEMR	- Department of Energy, Mines and Resources
DFE	- Department of Fisheries and the Environment
DREE	- Department of Regional and Economic Expansion
DSDP	- Deep Sea Drilling Project
EAMES	- Eastern Arctic Marine Environmental Studies
EDP	- Electronic Data Processing
EG & G	- Edgerton, Germeshausen and Grier
ITS	- Electron Transport Systems
FAO	- Food and Agriculture Organization of the United Nations
FGGE	- First GARP Global Experiment
FM	- Fisheries Management
FS	- Forschungsschiff
GARP	- Global Atmospheric Research Program
GATE	- GARP Atlantic Tropical Experiment
GDP	- Gross Domestic Product
GEOS-3	- Geodetic Earth-Orbiting Satellite (NASA)
GOMADS	- Graphical On-Line Manipulation and Display System
GSC	- Geological Survey of Canada
HBE	- Hudson Bay Experiment
HIAC	- High Accuracy (RADAR)
IAEA	- International Atomic Energy Agency
IAPSO	- International Association of Physical Sciences of the Oceans
ICES	- International Council for the Exploration of the Seas
ICNAF	- International Commission for the Northwest Atlantic Fisheries

IF	- Institute Facilities
IMARPE	- Instituto del Mar del Peru
IOC	- Intergovernmental Oceanographic Commission
ISPG	- Institute of Sedimentary and Petroleum Geology
JASIN	- Joint Air-Sea Interaction Experiment
LNG	- Liquified Natural Gas
LORAN	- Long-Range Aid to Navigation
LOREX	- Lomonosov Ridge Experiment
MARMAP	- Marine Resources Monitoring Assessment Prediction program
MEDS	- Marine Environmental Data Service
MEL	- Marine Ecology Laboratory
MPU	- Microprocessor Unit
MPCTD	- Multiparameter CTD
MV	- Merchant Vessel
NASA	- National Aeronautics and Space Administration
NATO	- North Atlantic Treaty Organization
NB	- New Brunswick
Nfld.	- Newfoundland
NOM	- National Oceanic and Atmospheric Administration
NRCC	- National Research Council of Canada
NS	- Nova Scotia
NWT	- Northwest Territories
OAS	- Ocean and Aquatic Sciences
OBS	- Ocean Bottom Seismometer
OCTUPROBE	- Oceanic Turbulence PROBE
OLABS	- Offshore Labrador Biological Survey
PCBs	- Polychlorinated Biphenyls
POLYMODE	- A name derived from the names of the U.S.S.R. POLYGON experiments and the Mid-Ocean Dynamics Experiment (MODE)
POM	- Particulate Organic Matter
PQ	- Province of Quebec
RALPH	- A device whose name is neither an acronym nor an abbreviation but in stead just a simple, friendly name!
RIOS	- River Inputs to Ocean Systems
RMCB	- Resource Management and Conservation Branch
RODAC	- Regional Ocean Dumping Advisory Committee
RTE	- Real Time Executive (operating system)
R/V	- Research Vessel
Satnav	- Satellite Navigation
SBS	- Short Baseline System
SCOR	- Scientific Committee on Oceanic Research
SEASAT	- Sea Satellite
SSIP	- Scotian Shelf Ichthyoplankton Program
Syledis	- SYsteme LEger de mesure de DIStance
UCLA	- University of California at Los Angeles
UNESCO	- United Nations Educational, Scientific and Cultural Organization
USS	- United States Ship
VACM	- Vector Averaging Current Meter
WHOI	- Woods Hole Oceanographic Institution
WMO	- World Meteorological Organization (UN)

ToC

Foreword

Once again I have the privilege of writing a foreword for the Biennial Review of the work of the Bedford Institute of Oceanography. I do so as the head of the lead agency in the BIO family of agencies, and on behalf of the heads of the various members of these agencies who make\ up the BIO Management Committee. Three new members are represented in this Review: the Marine Fish Division, the Resource Management and Conservation Branch East Coast Office, and the Seabird Research Unit. Their presence has significantly and constructively broadened the spectrum of activities in BIO.

Science is an essential underpinning of the technology upon which today's lifestyle is supported. Our lifestyle, in the future, will remain critically dependent on the progress made in science and technology. It is inconceivable that, without massive scientific and technological effort, mankind will be able to manage successfully its affairs, as the constraints of our limited and closed planetary system become more apparent.

Some nations already have recognized the critical role research and development (R&D) plays in their economies, and there is a growing awareness of the vital nature of R&D performed in Canada for the future economic health of the nation and for an improved quality of life for its people. This is highlighted by three recent releases. One, issued by the Minister of State for Science and Technology in June 1978, set a target of 1.5 per cent of the GDP (gross domestic product) by 1983 for R&D expenditures, up from 0.84 per cent in 1977, with the objective that most of this large increase be in the private sector. The critical role of R&D and the penalties for failure to advance the function are the topics of a report from the Science Council of Canada, "Weakest Link: Technological Perspective on Canadian Industrial Underdevelopment", published in October 1978. On November 8, 1978, a communique was issued on the Federal-Provincial Conference of Ministers concerned with science and technology, which was held to review the current, critical state of industrial research and development in Canada.

Although the greatest need is for very much larger R&D investment in the private sector, the place of government and university must not be overlooked. University research, as part of the educational process, will have to expand considerably if Canadian universities are to meet a substantial part of the demand for science and engineering graduates implicit in the target of R&D national expenditure of 1.5 per cent of GDP by 1983. The demand has been

estimated at 30,000 additional qualified research workers over the five-year period. Meanwhile, the responsibility remains with the governmental sector to provide much of the expert information infrastructure upon which the whole enterprise feeds, and upon which government must rely to discharge its obligations for the regulation of the exploitation of renewable and nonrenewable resources, and for the preservation and enhancement of the quality of the environment. The discharge of these obligations calls for sustained long-term research and survey programs performed in-house, but increasingly backed up by work done in the private sector under contract to government. The Bedford Institute of Oceanography represents a principal focus of the Government of Canada's response to these obligations as they pertain to ocean science and technology.

The development of the Institute over the past two years presents a somewhat ambivalent picture. The "18-million dollar expansion" of the plant, announced in May 1975, has proceeded on schedule and within cost estimates. Two laboratory wings, named the John Strickland building and the John Murray building, have been completed and occupied. Pressure on the old accommodation has been reduced and phasing out of the trailer complex will take place with the occupancy of the common services wing now under construction. When completed, along with the extended fish tank laboratory, the Institute will have a first-rate base facility. Meanwhile, the CSS *Baffin,* launched in 1957, is undergoing a 4-million dollar mid-life refit. This will substantially improve her capabilities for hydrographic surveys (her major function), for oceanographic research, and for operations in ice. Thus, as the seventies draw to a close the Institute will be equipped with excellent physical facilities and staffed with highly qualified and dedicated people. However, the government's policy of fiscal restraint of the past several years has resulted in a significant program reduction. Operating funds are running at least 1.7 million dollars per annum, or 25 per cent, below the level required for optimum utilization of staff, laboratories, and ships.

This Review chronicles the numerous achievements of the staff in a period of considerable fiscal retrenchment, and reveals the solid base upon which future activities will be built. The Institute is ready to meet the challenge and to play a greater part in the national effort to achieve the goal of R&D expenditure of 1.5 per cent of GDP by 1983 and the consequent economic and social benefits down the line.

Dr. Wm. L. Ford
Director-General
Ocean and Aquatic Sciences, Atlantic

ToC

A

Ocean and Aquatic Sciences, Atlantic Department of Fisheries and the Environment

Director-General – Dr. W. L. Ford

- **Atlantic Oceanographic Laboratory**
- **Marine Ecology Laboratory**
- **Institute Facilities**
- **Management Services**[1]

[1]The work of this group is not reported on in this review

ToC

Director's Remarks

During 1977 and 1978 substantial shifts in the Laboratory's program were made towards problems on the continental shelf in support of fisheries investigations, and to the eastern arctic in response to oceanographic and hydrographic problems arising through oil exploration and increasing marine transportation.

A focal experiment at the edge of the continental shelf has shed a great deal of light on the physical oceanographic processes there, and the manner and time scales with which they respond to external forcing by storms and changes in the Gulf Stream. Working with biologists, the physical oceanographers involved in the project have been able to understand and quantify the mechanisms by which nutrients are supplied to the continental shelf. Much has been learned about time and space scales and the knowledge has been put to use in designing further co-operative investigations with biologists in Atlantic Canada. In collaboration with the Biological Station, St. Andrews, NB, a program has been set up to study the changes in temperature on lobster grounds and the effect of these changes on the lobster population. The program has a modest beginning with only a few fishing grounds under study but it could well be the forerunner of an extensive monitoring program of the Atlantic seaboard. A second major effort has been set up in collaboration with the St. John's (Newfoundland) laboratory to study the life cycle of cod on Flemish Cap. The progress has been very heartening since it is my belief that there is, in the next few years, the opportunity to monitor and understand the changes in the physical oceanography of the continental shelf and apply the knowledge to fisheries problems. It is interesting for those who like to philosophize about science that the opportunity has its roots in the vastly expanded array of equipment that has been developed over the last ten years.

The move of the chemistry program to the eastern arctic has also been rewarding. Not only have the chemists been able to obtain badly needed baseline data but they have also delineated a natural oil seepage in the Knight Inlet area, which affords the opportunity to study the reaction of the local biota to the presence of oil.

Our hydrographic service has been expanded to include cartography with the move of a cartographic unit to BIO from Ottawa. The cartographers are becoming an integral part of the Institute and their work is rounding out the hydrographic program. Within the last few years the hydrographic division has digested the problems of resource surveying in collaboration with the Atlantic Geoscience Centre. It is perhaps time again to focus more attention on problems in navigation and geodesy and on provision of information on tidal and ocean currents. Our hydrographic division has an excellent base for this in the navigation and tidal groups.

In these days of extensive application of oceanographic knowledge to practical problems there is a tendency to believe that the oceans and the processes within them have been generally explored and understood. There

is still a great deal to be done. The relative roles of diffusion and advection in the formation of the structure of the North Atlantic Ocean have not been clarified; there are no temperature or salinity measurements, let alone current measurements, in the inshore Labrador Current during the ice season and we do not know how to get the measurements we want. There are also things to be discovered. During work in the Labrador Sea, scientists observed deep convection for the first time and not where they had expected it. There is still room for exploration of the ocean and such work should be part of the future program of AOL.

C. R. Mann
Director
Atlantic Oceanographic Laboratory

ToC

A.1

Atlantic Oceanographic Laboratory
Ocean and Aquatic Sciences, Atlantic
Department of Fisheries
and the Environment

Director – C. R. Mann

- **Chemical Oceanography Division**
- **Coastal Oceanography Division**
- **Hydrography Division**
- **Metrology Division**
- **Ocean Circulation Division**

ToC

Chemical Oceanography

Chemical Oceanography Division conducts research on the transport and behaviour of chemical substances in estuaries and offshore waters, the effects of biological and physical processes on nutrient distributions, gas fluxes at the air-sea interface, sedimentation processes and fluxes, carbon and oxygen isotope geochemistry, and pollution by petroleum residues, organohalogen residues, heavy metals, and radionuclides. Much of this research is related to problems of national and international concern but a core program of pure research is maintained.

Significant changes to our program were introduced during the period of this review. We assumed environmental monitoring of the Point Lepreau Nuclear Generating Station (NB), which is expected to be commissioned within the next two years. This activity will be based on a different approach to that used for environmental health monitoring and is expected to yield both regulatory and biogeochemical information. Greater attention has been paid to northern Canadian waters, particularly the waters within and adjacent to Baffin Bay, to better understand the behaviour and distribution of chemical species and to provide a framework within which to review environmental assessment programs associated with resource exploration. Detection of oil slicks in Buchan Gulf and Scott Inlet has stimulated efforts to examine these in relation to possible natural crude oil seeps. We have also enlarged our studies of the pelagic environment with the conduct of a cruise in the western North Atlantic in 1978. Originally conceived to examine chemical anomalies in the water column, the cruise was broadened to include a wide range of geochemical and geophysical studies in collaboration with McMaster University (Ontario), Dalhousie University (NS), and the University of Rhode Island (USA).

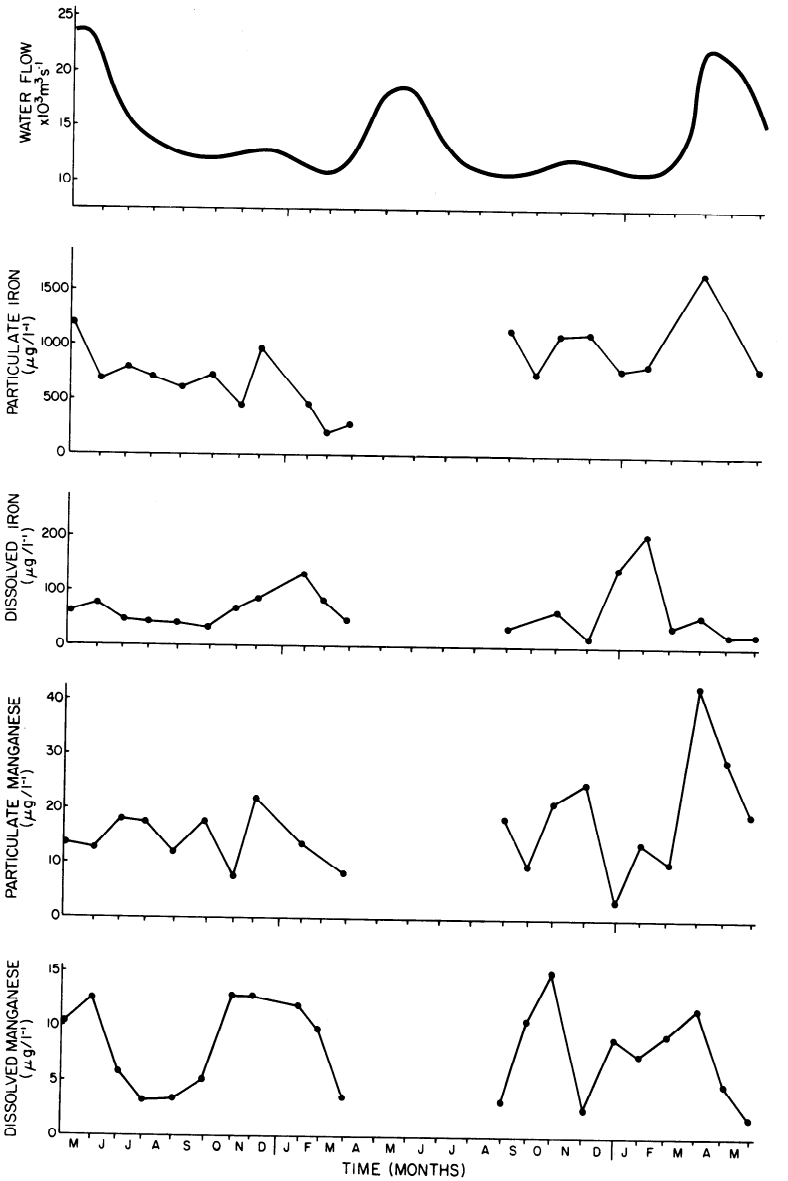
As a consequence of these changes, the effort devoted to the study of the Gulf of St. Lawrence has declined and most of the current effort is toward geochemical processes in the estuary. The present level of activity in the St. Lawrence estuary and the Saguenay fjord will be maintained until we obtain a better appreciation of the subtleties of chemical behaviour there.

We have paid some attention to boundary exchanges that control the fluxes of chemical substances in and out of the ocean. A major landmark has been the first successful measurement of the vertical flux of carbon dioxide at the air-sea interface. We are convinced that wider application of the eddy correlation technique, using more refined instrumentation, will enable the fluxes of other compounds to be measured.

Our involvement in international activities has continued. An intercalibration exercise for trace metals in sea water involving 63 participants in 16 countries is being conducted on behalf of ICES. Participation continues in stable isotope and non-nuclear pollutant intercalibration exercises organised by the IAEA. We have been involved in several programs of ICES and the IOC

as well as the RIOS program of SCOR and participated in two cruises sponsored by CIDA - in 1976 to Senegal and The Gambia and in 1977 to Peru.

J. M. Bewers



Seasonal changes in the concentrations of particulate and dissolved iron and manganese and their relationship to water flow in the St. Lawrence River. No data were collected from May to June of 1975 and 1976. (BIO 5169)

Nearshore and Estuarine Studies

Trace metal geochemistry. The geochemistry of trace metals and suspended particulate matter in estuarine and nearshore waters is being studied in the Gulf and estuary of the St. Lawrence. The distributions of manganese, cobalt, nickel, copper, zinc, and cadmium in the estuary show the extent of removal of these metals from the water column and the influence of the turbidity maximum. The processes of removal and exchange between dissolved and particulate metal phases are being investigated. In the deeper water of the lower St. Lawrence estuary, greatly elevated levels of dissolved manganese resulting from diagenetic releases of manganese from the sediments have been observed.

A time series of analyses of the composition of St. Lawrence River water at Quebec City was also conducted through 1975 and 1976. The results have been used to determine seasonal changes in the metal concentrations and to estimate the annual river discharges of metals in dissolved and particulate form. A rational basis for scaling metal fluxes from the St. Lawrence River, and other intensively studied major rivers, to the global river discharge has been devised. Measurement of the removal of trace metals from the water column within the estuary and Gulf of St. Lawrence, together with estimates of the river-borne metal fluxes, has enabled us to calculate the net influx of metals into the deep ocean. Residence times for trace metals in the deep ocean, calculated on the basis of these net fluvial metal inflows, are considerably shorter than previous estimates. Furthermore they are in better agreement with residence times calculated from pelagic sedimentation rates. We were also able to assess the effect of increased anthropogenic metal fluxes on the composition of waters in the Gulf of St. Lawrence and on the Scotian Shelf. This assessment shows that anticipated increases in industrial activity in the St. Lawrence drainage basin are unlikely to have a noticeable effect on the trace metal levels in coastal waters.

P. A. Yeats, J. M. Bewers

Organic matter studies. The general features of suspended particulate organic matter in the Gulf of St. Lawrence have been described and related to surface primary productivity and water masses. This work has enabled a quantitative comparison to be made between water outside the Gulf and water elsewhere in the World Ocean. The measured concentrations of particulate organic matter in two key sections of the system - at Cabot Strait and at Pointe des Monts - are being used to calculate the net contribution of organic material from the St. Lawrence estuary to the open Gulf and from the open Gulf to the North Atlantic Ocean.

Organic carbon to nitrogen ratios, the presence of lignin, and carbon isotope ratios have also been used to determine the relative contributions of terrigenous and marine organic material to sediments in the Gulf of St. Lawrence. Organic matter deposited within the Saguenay fjord and upper St. Lawrence estuary is predominantly of terrigenous origin. The proportion of terrigenous organic matter in the sediments decreases sharply between the mouth of the Saguenay fjord and Pointe des Monts where organic material of marine origin is increasingly found. Uniform carbon isotope ratios, and low carbon-to-nitrogen ratios, typical of marine values, demonstrate that organic matter in the sediments of the open Gulf is almost

entirely authigenic. There are few indications of significant terrigenous input in the Gulf of St. Lawrence and all are in close proximity of the shore. Thus, from the point of view of added organic material, influxes of terrigenous matter are only of local significance in the area.

R. Pocklington, F. C. Tan, P. M. Strain

Stable isotope studies. Surface values of delta ^{13}C in suspended organic matter in the open Gulf of St. Lawrence and seaward of the Gulf were consistent with delta ^{13}C values in plankton produced at the temperatures found in the local euphotic zone. Higher values were recorded in surface samples from the mouth of the St. Lawrence estuary and these are probably related to intensified carbon demand during periods of high biological productivity. In deep samples the values were lower,. probably due to changes in carbon isotope composition during biological degradation of organic matter. A significant difference (2 to 6 parts per thousand) between the remarkably uniform isotope ratio (-22.4 parts per thousand) of the organic carbon in surface sediments and the isotope ratio of near bottom suspended matter has been observed. In contrast, surface layer delta ^{13}C values are generally closer to those in the surficial sediments. This suggests that organic matter in surface water is a more important source for sedimentary organic carbon than near bottom material. Several observations of large vertical delta ^{13}C gradients in deep-water organic material indicate the presence of resuspended sedimentary material 30 to 60 metres above the sediment-water interface.

Surface water samples from the Saguenay fjord and the upper St. Lawrence estuary have been analysed for delta ^{13}C, total CO_2, and delta ^{18}O. In the Saguenay fjord, the delta ^{13}C concentrations of the total dissolved CO_2 vary from -10.9 parts per thousand and 3.6 millilitres per litre near the head to 0.4 part per thousand and 30.3 millilitres per litre at the mouth. The upper St. Lawrence estuary has delta ^{13}C values of 19.8 to 37.6 millilitres per litre. The measured delta ^{13}C, total CO_2, delta $^{13}0$, and salinity distributions were compared to a conservative mixing model. The excellent agreement between the measured and predicted delta ^{13}C values in the Saguenay fjord indicates that carbon isotope ratios behave conservatively. In the upper St. Lawrence estuary, the much poorer agreement suggests that significant *in situ* processes involving dissolved CO_2 operate. The suggestion that estuarine paleotemperatures may be obtained by extrapolating delta ^{13}C/ delta ^{18}O shell carbonates to marine conditions is thus open to question.

F. C. Tan, P. M. Strain

Recent geochronology studies. There are several naturally occuring radionuclides that can be used as geochemical tracers for the measurement of oceanic residence times and sedimentation rates. Measurements of ^{210}Pb (half-life of 22.3 years) and ^{226}Ra have been used to measure recent sedimentation rates and geochronologies in sediment cores collected in the Saguenay fjord in eastern Quebec. This sediment dating work shows that the sediment accumulation rate decreases with increasing distance from the mouth of the Saguenay River from 8 centimetres per year near the head of the fjord to 0.2 centimetre per year in the deep inner basin, which identifies clearly the Saguenay River and its high load of suspended particulate matter as the main source of sediment deposition in the fjord.

The overall sedimentary flux in the Saguenay fjord is of the order of 5.1×10^5 tonnes per year and almost half of this material is deposited in the shallow waters of the upper 6 square kilometres of the fjord. Anoxic, undisturbed sediments and rapid sedimentation at the head of the fjord have produced a unique environment whose history can be resolved in fine detail. In particular the effects of the massive landslide at St. Jean Vianney in May 1971 are clearly evident in sediment structures near the head of the fjord. The ^{210}Pb geochronologies determined for these cores agree with the time stratigraphies estimated from both pollen and ^{137}Cs profiles in the sediments. Dates of deposition corresponding to the initial appearance of elevated levels of mercury in the sediments range from the 1940s to the early 1950s, which is consistent with the belief that the source of much of the mercury in the fjord is a chlor-alkali plant located at Arvida that began operations in 1947.

Other ^{210}Pb geochronological work has been carried out in the sediments of St. Georges Bay, NS, as part of an effort to determine changes in sedimentation rates and patterns resulting from the construction of the Canso Causeway, NS.

J. N. Smith

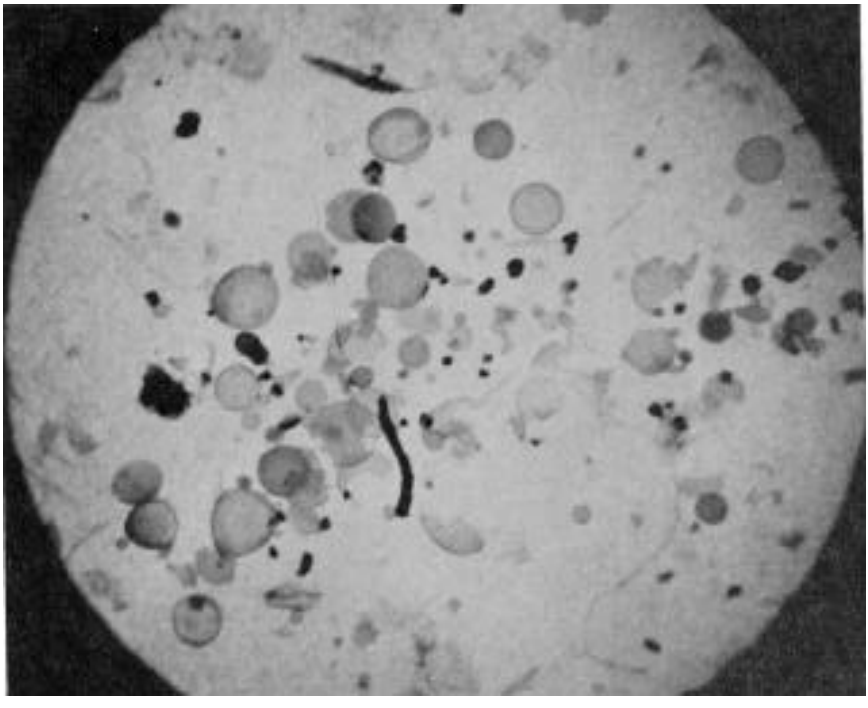
Offshore and Deep Ocean Studies

Nutrient studies. Nutrient data were obtained in 1976, 1977, and 1978 during studies of the physical oceanography of the Labrador Sea undertaken by Ocean Circulation (AOL). These studies included the formation of the deep winter cooling cells and the Labrador Current. Nitrate sections through the Labrador Current show evidence for the entrainment of nitrate into the surface waters along the Labrador coast. Nutrient data (nitrates, phosphates, silicates) from the CSS Hudson arctic cruise in 1977 have been partially analysed. The most interesting result to date relates to the western gyre in the Arctic Ocean. The Arctic Ocean is characterized by a surface layer about 200 metres thick. Bering Sea water and North Atlantic water, which are the main contributors to the Arctic surface water, have markedly different silicate concentrations. While the Arctic surface water is in general a mixture of these two, we found that the flow out of the Arctic Ocean over the sills in Lancaster Sound and Fram Sound has considerably higher silicate concentrations than the flow through Smith Sound and Denmark Strait. These results are consistent with the surface circulation pattern of the western gyre, which must extend to depths at least as great as the sill depths of Lancaster Sound and Fram Sound. Since silicate concentrations are very similar in Fram and Lancaster Sounds, it suggests that the western gyre must extend at least as far east as about Peary Channel in the Queen Elizabeth Islands but not as far as the Lincoln Sea, part of which flows through Smith Sound. The even lower silicate concentrations in Denmark Strait may indicate a sharp east-west gradient of Bering Sea water in the Eurasian Basin or, possibly because of the deeper sill in Denmark Strait, may reflect relatively poor mixing between surface and deep water. Nutrient concentrations in other parts of the eastern arctic await evaluation. Results obtained in Baffin Bay during 1977 and augmented during 1978 should be useful in furthering our understanding of that relatively unexplored body of water.

A. R. Coote, E. P. Jones

Trace metal studies. The distribution of iron, manganese, cobalt, nickel, copper, zinc, and cadmium in Baffin Bay has been studied using samples collected during a cruise in 1977. Techniques are also being developed for aluminum and chromium analysis to augment the compositional data already obtained. Preliminary results indicate that each of the principal water masses of the region has a characteristic trace metal composition. Increases in metal concentration with depth, observed for nickel, copper, zinc, and cadmium in other pelagic waters and assumed to be related to biological uptake and regeneration, have not been observed. In contrast, the metal concentrations in the Centre of Baffin Bay are constant with depth throughout a 2300 metre deep water column. More samples of sea water, sea ice, and glacial ice were collected in 1978 and eventually it is hoped to be able to describe the trace metal budget for Baffin Bay.

From earlier work on the residence times of trace metals in the deep ocean, we developed an interest in the agents of oceanic metal sedimentation. There is much speculation that the vertical transport of metals in the ocean occurs by way of relatively large particles that settle rapidly to the ocean floor. Candidate particles include fecal pellets and exoskeletal debris, but, because of the difficulty of reliably sampling such large particles with water bottles, very little data relating to the fluxes of such materials exist. We recently collected samples of particulate material in the deep North Atlantic using a combination of large volume samplers and a fine-mesh plankton tow. The results will be used to determine the ambient concen-



A microscope photograph of particulate matter collected from the North Atlantic Ocean at a depth of about 2000 metres. (Magnified 60x).

trations of both fine and coarse particles and the settling rates. and compositions of coarse biogenic particles. It is hoped to identify the most important hosts of particulate and dissolved metal sedimentation in the North Atlantic basin.

J. Campbell, P. A. Yeats, J. M. Bewers

Studies of upwelling areas. The transformation of organic matter in sea water is difficult to study in most marine environments because of the low concentrations involved and because the rates of reaction in the open ocean are slow relative to the physical processes of transport into and out of the area of study. An upwelling area provides an excellent system in which to overcome these problems. In these areas organic compounds are biosynthesized in large quantities and are subjected to oxidization in the water column and reduction in the sediments. Thus, rates of diagenesis are fast enough to follow, and differences in transformations and interactions under different redox conditions can be studied within a compact geographical area.

On the CSS *Baffin* Cruise to Peru we investigated the concentration of particulate organic matter (POM) in the water column and determined, in a general way, its chemical nature. Up to 90 per cent of the POM in the wind-mixed layer is phytoplankton. Information additional to organic carbon determinations (C:N ratios) confirms the suitability of the POM as food for the larval anchovy. We analysed subsamples of bottom sediments for accumulated organic matter, which we found to be predominantly of marine origin. *El /Vino* (a temporary reversal of the dominantly northward-flowing current) events did not manifest themselves by discontinuous sedimentation and the presence of terrigenous organic material. The record of organic matter in the surface sediments is an integrated record of production in the overlying water column and as such should relate to survival of anchovy year-classes. We measured the concentration of halogenated hydrocarbons in surface sediments to establish regional background levels. None were found to be above background level.

R. Pocklington, J. D. Leonard

A *view of Sable Island, NS, with the ponies native to the island in the foreground. Sable Island was the site of an experiment to measure CO_2 flux in 1976 and again in 1978. (B/O 5050-211)*

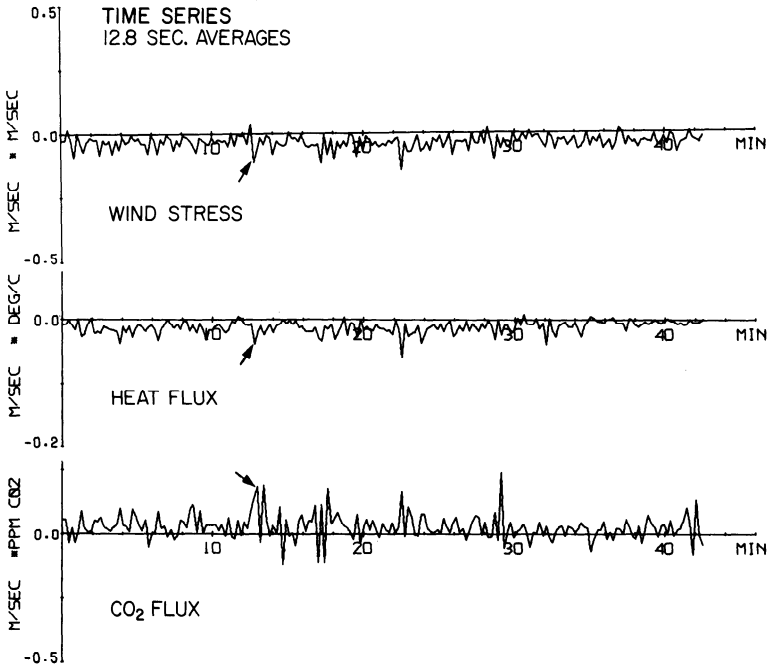
Ocean-Atmosphere Boundary Exchanges

Carbon dioxide flux. Data gathered during the summer of 1976 on Sable Island were analysed during the review period. For the first time, it was demonstrated that direct measurements of the CO_2 flux at the air-sea interface could be made using the eddy correlation method. The flux measured, during a period of surface ocean warming, was within the range of values estimated for CO_2 ocean-atmosphere exchange (1 micromole per square centimetre per second). During the analysis we realized that we must apply a correction to the apparent measured CO_2 flux because of air density fluctuations associated with a heat flux. This resulted in a separate theoretical study.

One major goal of this work is to relate the measured CO_2 flux to environmental parameters such as wind speed. During the 1976 experiment, winds were generally constant and not strong. An experiment carried out during the fall of 1978 should give results at much higher wind speeds and under other different conditions than those of the earlier experiment.

E. P. Jones

Atmospheric precipitation fluxes of chemical substances. Work has commenced on the study of the inputs of organic compounds of natural and anthropogenic origin, and trace metals, into the coastal waters from the overlying atmosphere. Preliminary measurements of single storm event



Events on each graph are reasonably well related - for example, the peaks denoted by arrows. The correlation of fluctuations in CO_2 concentration with vertical wind velocity gives the CO_2 flux; the correlation of temperature fluctuations with vertical wind velocity gives the heat flux; and the autocorrelation of fluctuations in vertical wind speed velocity gives the wind stress. (BIO 4520)

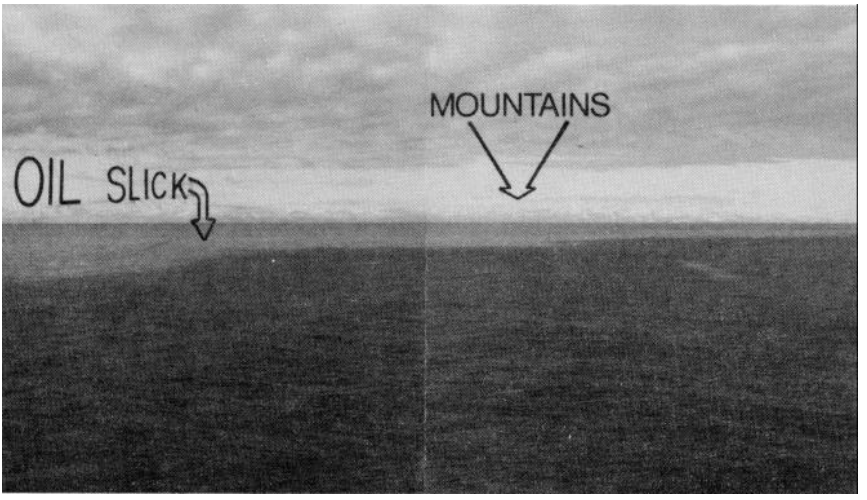
fluxes of trace metals have already been made. The results show that, as a single precipitation event progresses, the metal concentrations decrease, presumably as a result of reductions in washout component concentrations. Methods of obtaining bulk precipitation samples as well as samples of dry particulate and individual aqueous precipitation are presently being devised. Particular attention will be paid to organohalogen compounds in wet and dry precipitation since the atmosphere is probably a primary avenue of transport of such materials. The objective of this work is to estimate the relative importance of atmospheric transport, as compared to river discharge, to the introduction of chemical substances to coastal waters and to obtain a better understanding of the mechanisms of transport of particular chemicals.

P. A. Yeats, R. Pocklington

Pollution Studies

Eastern arctic oil seeps. Our investigation of petroleum residues in the North Atlantic was extended to arctic regions by a cruise to Baffin Bay, Lancaster Sound, Jones Sound, and Smith Sound during the summer of 1977. The general background level in the water column in this region was 0.46 microgram per litre, but substantially higher concentrations were encountered at Scott Inlet, the entrance to Lancaster Sound, and near Resolute. Whereas the last might be of anthropogenic origin, there is strong evidence that natural seepage of petroleum from the seabed is the major source of the petroleum residues 'in the other areas. Concentrations in the surface microlayer were generally an order of magnitude higher than in the water column but, in the seepage areas, surface concentrations were often several orders of magnitude higher. During this cruise shipboard analyses for low molecular weight hydrocarbons (C_1-C_6) were successfully carried out by gas chromatography. Whereas methane is ubiquitous in marine waters, concentrations in the seep area at Scott Inlet were higher than the general background and a much greater diversity of hydrocarbons was present.

In 1978 a second cruise to the arctic was carried out specifically to study, in more detail, potential seep areas, to locate the source(s) of the seepage, to gain more detailed knowledge of the chemical nature of the seep material, and to obtain a preliminary assessment of whether marine life was being affected by the seep. For the latter purpose, the region provides a unique natural laboratory for the study of the effects on arctic organisms of long-term, low-level exposure to petroleum under arctic conditions. Although many samples of water, sediments, and organisms were collected for analyses of light hydrocarbons and heavy residues, we were unable, because of poor weather, to collect a sample of the actual seep material for detailed chemical analyses, but one was later collected by AGC. Shipboard analyses again demonstrated anomalously high concentrations of light hydrocarbons in the Scott Inlet area and preliminary results of studies of the rates of respiration, feeding, and excretion of zooplankton indicate that, even at the low levels of petroleum-derived components in the waters at Scott Inlet, these life processes are being affected. Regions of higher-than-normal concentration levels of light hydrocarbons were observed at Buchan Gulf where there is a geological feature similar to that at Scott Inlet, at the entrance to Lancaster Sound, and in Melville Bay. It seems likely that natural seepage occurs in these areas as well. The next phase



A composite photograph of the oil slick at Scott Inlet taken from the CSS Hudson *about 42 kilometres offshore looking towards Baffin Island. The mountains in the background are 12,000 to 15,000 metres high and about 16 kilometres inland. (BIO 4557-35, 34).*

of this work will involve attempts to characterize by gas chromatography/ mass spectrometry the compounds present.

E. M. Levy

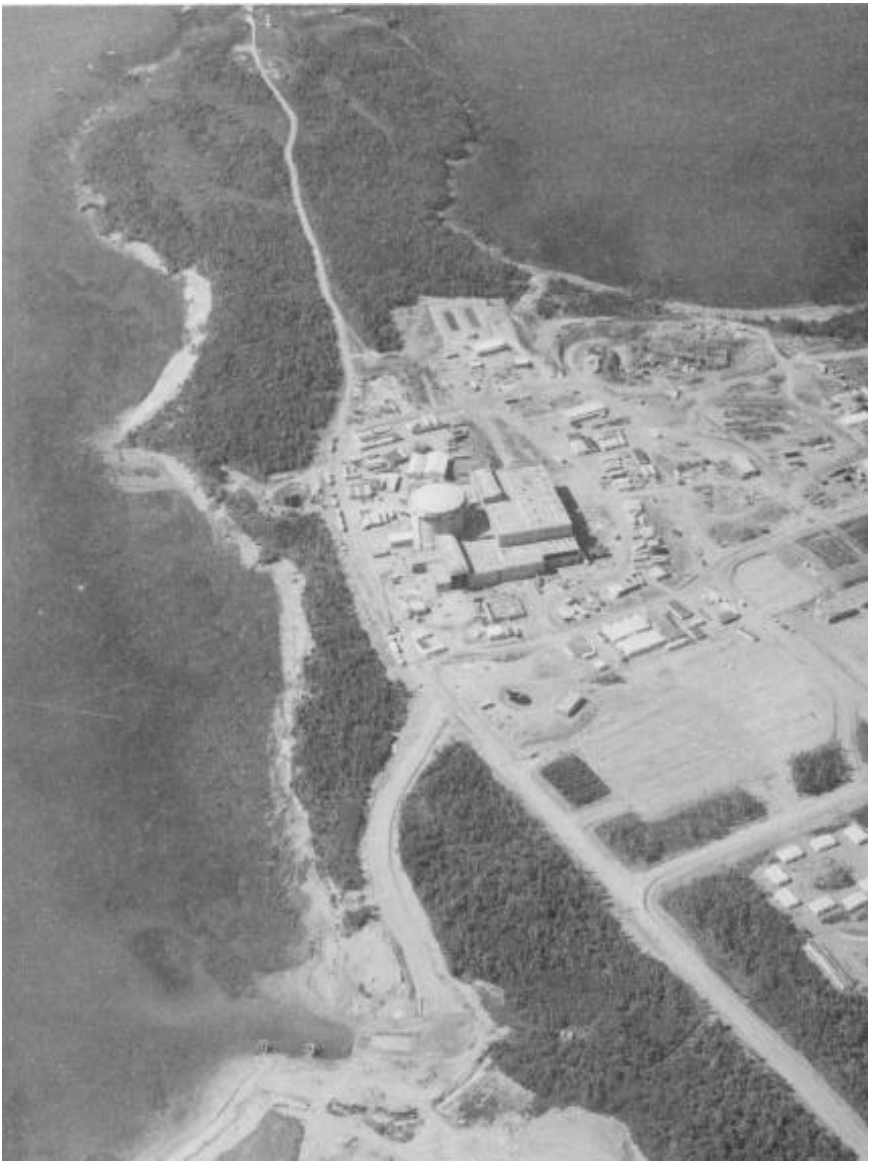
Oil pollution and seabirds. A brief study of the impact of oil on seabirds was carried out when numbers of dead or moribund birds appeared on the shores of Nova Scotia following the *Argo* Merchant spill off Nantucket during the winter of 1976/77. Several of the birds had indeed been fouled with oil from the *Argo Merchant* but most of them were victims of miscellaneous local incidents. This study demonstrated the remarkably minute amount of oil, which, when combined with severe winter conditions, may trigger a series of reactions that lead to the birds' deaths. It also demonstrated a close relationship between the chemical composition of the preen gland waxes and the life habits of the various species of seabirds.

E. M. Levy

Organohalogen compounds. A set of about 60 near shore sediments from the Maritime Provinces was analysed for organohalogen compounds. Occurrences above background (10 parts per billion for PCBs, 2 parts per billion for the sum of DDT compounds) were best related to total organic content of the sediments. A gas chromatography/mass spectrometry system has been used to confirm identifications of specific compounds in these samples and it is our aim to use this instrument for the identification of other compounds. No traces of PCBs or DDT were found in surface sediment samples received from the 1977 arctic cruise.

J. D. Leonard, R. Pocklington

Point Lepreau environmental radioactivity monitoring program. A 630 megawatt CANDU nuclear generating station is presently under construction



The Point Lepreau, NB, nuclear power generating station. Now over 60 per cent complete, the 630 megawatt CANDU station is scheduled to be in commercial operation at about the end of 1980. (Courtesy of the New Brunswick Electric Power Commission.)

at Point Lepreau, NB, and it is expected to be operational in 1980 or 1981. This is the first nuclear reactor to be sited on the Canadian coastline and discharges of low-level radioactive wastes will be principally into the sea. An environmental monitoring program has been implemented to assess the effects of the following types of emissions: (1) thermal emissions result-

ing from the release of sea water used as a coolant at elevated temperatures; (2) biocides, in the event that these are used to reduce fouling in the cooling system; and (3) radioactive isotopes released in stack gases and coolant waters.

Radioactivity monitoring will be performed on marine, atmospheric, and terrigenous samples collected in the vicinity of the reactor site. Analyses of these samples will be performed in the BIO low-level radioactivity laboratory. During the pre-operational phase of the monitoring program, extending through 1980, background radioactivity levels and other baseline environmental parameters will be measured. Monitoring results obtained after the reactor becomes operational will be compared to the pre-operational conditions to assess the environmental impact of the generating station.

J. N. Smith

ToC

Coastal Oceanography

Our Division studies physical processes off the eastern Canadian seaboard from the Canada-United States border through the eastern arctic including inlets, bays, and gulfs. Much of our work is used to answer fisheries management, pollution control, and coastal engineering questions. Projects are often interdisciplinary and involve joint studies with other groups both inside and outside the Institute.

Research during 1977/78 continued in the Gulf of St. Lawrence region with an intensive study of the Gaspé Current and the commencement of long-term current meter moorings in the Laurentian trough. Our work on ocean dumping studies has continued and a major study of sediment dynamics for the Saint John (NB) estuary is nearing completion. Work on the field observation phase of the Scotian Shelf Break Dynamics study is being completed; a study of the movement of water from the Scotian Shelf into the Gulf of Maine has been initiated in the Cape Sable area. We are co-ordinating our storage and retrieval of data with the Marine Environmental Data Service in Ottawa. A program for the laboratory and field calibration of our recording current meters has resulted in the detection and elimination of several sources of error.

The principal investigators have summarized their accomplishments for 1977/78 in the following pages.

C. S. Mason

Near Shore Studies

Rivière au Tonnerre. At the request of the Small Crafts Harbour Branch, DFE, shoaling at the mouth of the fishing harbour of Rivière au Tonnerre, Quebec, on the North shore of the Gulf of St. Lawrence was investigated. Based on surveys conducted in summer 1976 and spring 1977, it was demonstrated that the shoaling arose from the estuarine circulation at the mouth of the river. The salt-water layer of the haline circulation acts as a sand trap, preventing the water of the river from carrying its sediment load seaward and, in conjunction with littoral drift, assists in the transport of sand from the nearshore zone into the mouth of the river system. This process is kept in balance by the larger river discharges of autumn and spring, which flush the salt water from the outlet and with it the sand deposits. The solution is to generate a current field at the bottom of the navigation channel similar to that of the higher river discharges. For the outer shoal, a dyke system is suggested to achieve this, and, for the inner shoal, a change in the distribution of the discharge through the overflow channels of the rock ledge above the basin should provide the required depth.

H. J. A. Neu. F. Jordan

Labrador Current. For oil movement predictions, an effort is being made to establish the current field and the composition of the water along the coast of Baffin Island, Davis Strait, and Labrador. Satellite pictures were used to determine ice movement and hence the speed of the surface layer. The latter varied from 0.1 to 0.3 metre per second along the coast of Baffin

Aerial view of Rivière au Tonnerre harbour (see text). (BIO 5140-1)

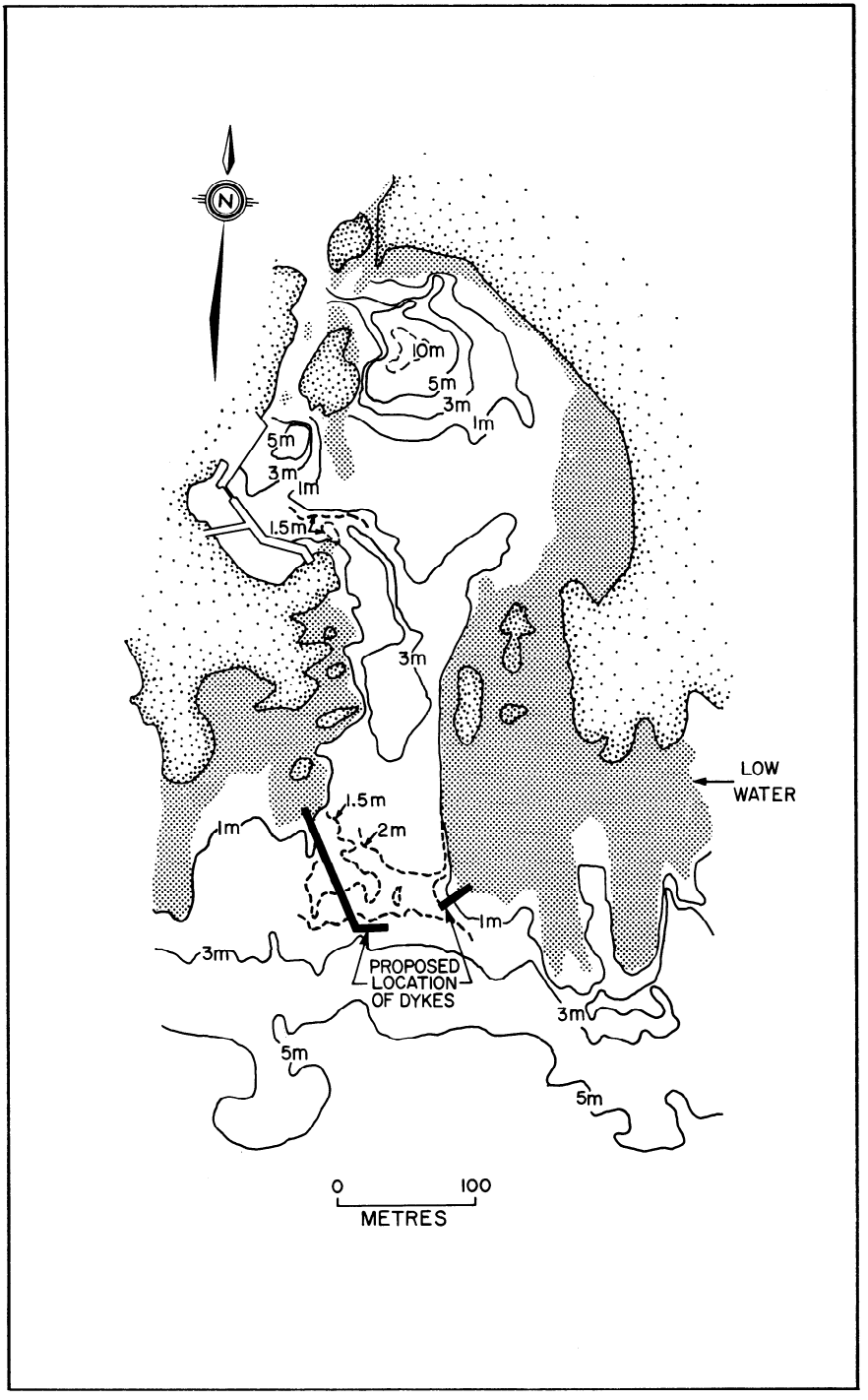
Island and from 0.3 to 0.6 metre per second along the coast of Labrador. In Davis Strait, its direction and strength varied greatly. An analysis of data available up to 1976 clearly indicates that fresh water plays an important role in the composition of the water in this area and in the generation of these coastal currents. There are two main freshwater inputs into these waters: one is seasonal with a peak of at least 0.5 sverdrup in June and July and the other is relatively continuous and of the same magnitude as the seasonal peak. The latter source is presumably fresh water from the surface layer of the Arctic Ocean, the West Greenland Current alone being unable to account for it, and the former is the seasonal run-off of the Arctic Archipelago, Baffin Island, and Hudson Bay drainage area.

H. J. A. Neu

Tiner Point LNG terminal. At Tiner Point, near Saint John Harbour, NB, an LNG Terminal was proposed at the site where formerly two deep-water oil terminals were suggested. As was done for the two previous designs, BIO reviewed the environmental condition of the site for this type of operation and again concluded that the forces acting in this area, particularly those of currents and waves, are significantly larger than assumed for the design and operation of the terminal. It follows that the proposed LNG terminal carries a high risk factor.

The report that contains these conclusions was tabled at the Congressional Hearing in Washington on LNG imports to the U.S. from Tiner Point, and was defended at the National Energy Board's Hearing in Saint John in 1977.

H. J. A. Neu, P. E. Vandall



Proposed improvements to Rivière au Tonnerre harbour (see text). (BIO 5140-1)

Freshwater regulation. Estuaries, embayments, and continental shelves are among the most fertile and productive regions on earth. One reason for this is the supply of fresh water from land run-off, which, on entering the ocean, induces mixing and the entrainment of nutrient-rich deep water into the surface layer. For temperate regions such as Canada the freshwater supply varies sharply with season - it is low during the winter when precipitation and run-off is stored as snow and ice, and very large during spring and early summer when the winter storage melts. Nearshore biological processes and adjacent ocean activities are tuned to this massive influx of fresh water; this is the time when reproduction and early growth occur. To modify this natural seasonal run-off for human convenience is to interfere with the physical and biological balance of the coastal region. Artificially storing the spring and summer run-off to generate power the following winter must have a significant impact on the ocean environment.

Canada is in the forefront in the development of power from water storage. More than half a dozen storage lakes - each the equivalent of Lake Nasser in Egypt - have been built, and more are to come. The run-off to the St. Lawrence River in particular has been -heavily exploited. Not one of these storage projects has been assessed with respect to the individual or, even worse, the cumulative impact on the ocean environment.

The energy 'crisis' is accelerating the demand for more storage schemes. In view of the strong indication that freshwater regulation is one of the most significant changes man can impose on nature, the wisdom of increasing artificial storage is highly questionable.

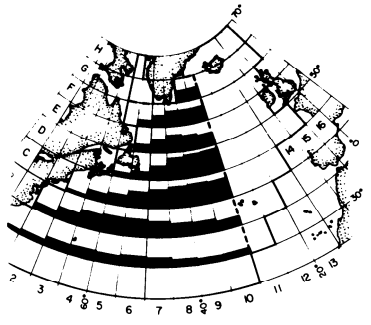
H. J. A. Neu

Wave Climate Studies

Waves are important in almost any phase of ocean activity and this knowledge is becoming crucial to the future management of the ocean's resources. For this purpose a wave climate was developed that describes the sea state of the North Atlantic Ocean in a rational and understandable way. The improvement of this wave climate and the development of more detailed analyses are on-going activities.

North Atlantic wave climate. The sea state across the North Atlantic Ocean varies greatly with season and location. During the winter the wave energy is six to ten times greater than during the summer, and in the middle and northeastern Atlantic Ocean four to six times that of the western Atlantic. The largest waves, 21 to 24 metres in height, occur near the west coast of Ireland. Based on wave heights, there is 2 to 12 times more wave activity in the northeastern part of the ocean than in the western and southern part. Long term probability statistics indicate that the 'design' wave (100-year wave) height varies from 14 to 25 metres along the east coast of North America and from 28 to 38 metres along the coast of Europe.

Canadian coastal wave climate. The increased interest of oil companies and governmental agencies in northern Canadian waters, particularly in the Labrador Sea, Davis Strait, and Baffin Bay, encourages further studies into a more detailed wave climate of these areas. The result of an analysis of the 1976-1977 data is shown on the graph. The annual largest significant wave heights in the Gulf of St. Lawrence were between 3.5 and 6 metres, in the Bay of Fundy and Gulf of Maine between 5 and 7 metres, along the



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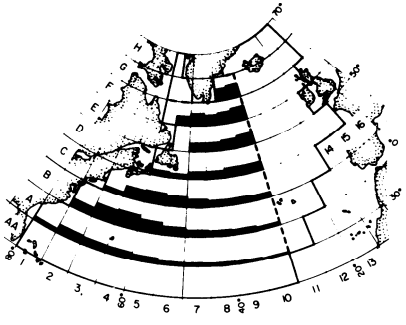

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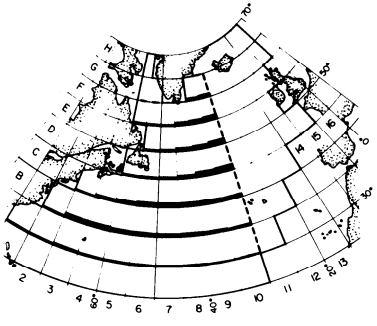

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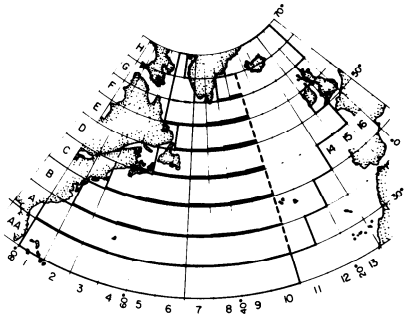

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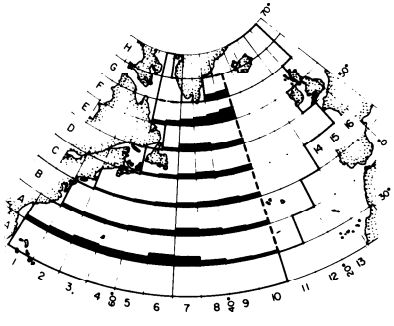

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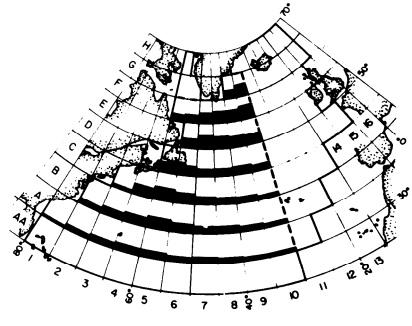
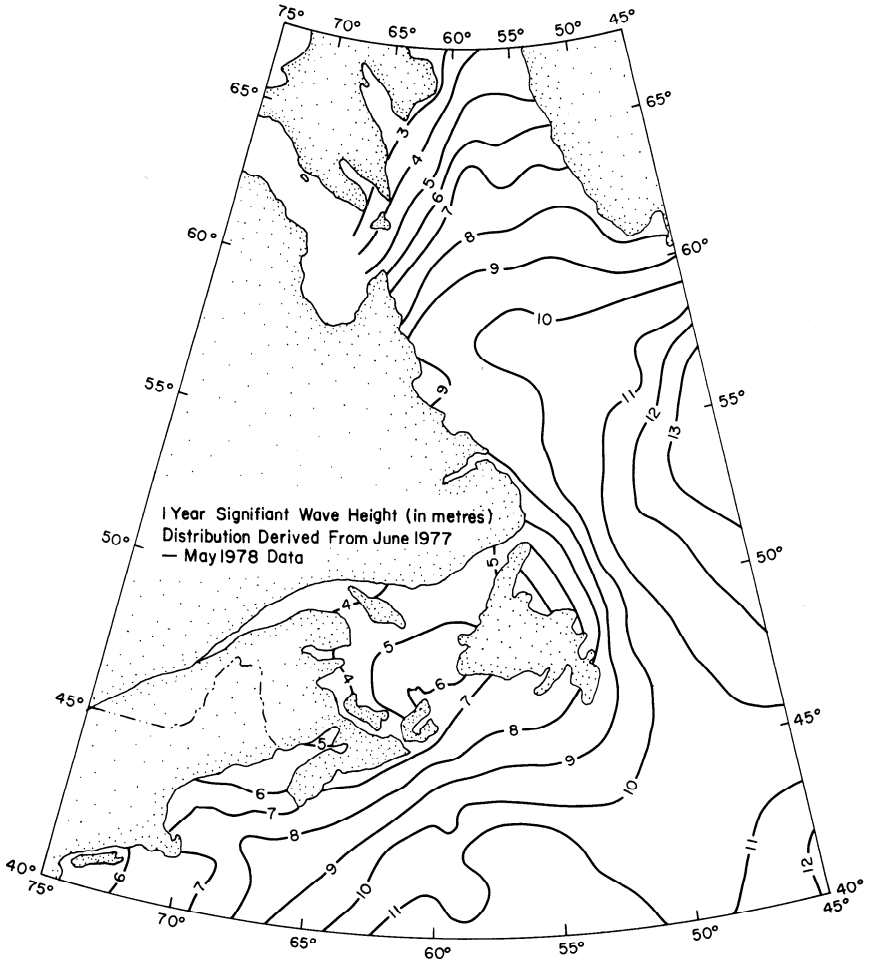


NOVEMBER

Representative wave energy levels across the North Atlantic Ocean (see text). (BIO *3046)*

coast of Nova Scotia and Newfoundland between 7 and 8 metres and along the coast of Labrador 9 metres. In Davis Strait the wave heights diminished from about seven to four metres. These results, though consistent and in agreement with previous investigations, suffer from lack of information. A data base of at least five years is required to determine monthly variations and the effect of ice.

H. J. A. Neu, R. E. Walker



The annual largest significant wave heights in the Atlantic Ocean. (BIO 5094-2)

Gaspé Current Project

The Gaspé Current (PQ) is a strong narrow surface current flowing seawards along the Gaspé coast. Its formation, oscillation, and seasonal variation pose many interesting questions to oceanographers. Recent biological studies indicate that the Gaspé Current region may be a local source of nutrient production and an important factor in the life cycle of certain fish populations in the western Gulf. To study the various aspects of the Current, a field program was launched in 1978, which consisted of nine current meter moorings and two hydrographic surveys, one in June and one in September. The University of Quebec at Rimouski also participated in this project and placed four moorings in the area.

Apart from the scientific objectives, a further aim of the field program was to evaluate the performance and to determine the accuracy of various types

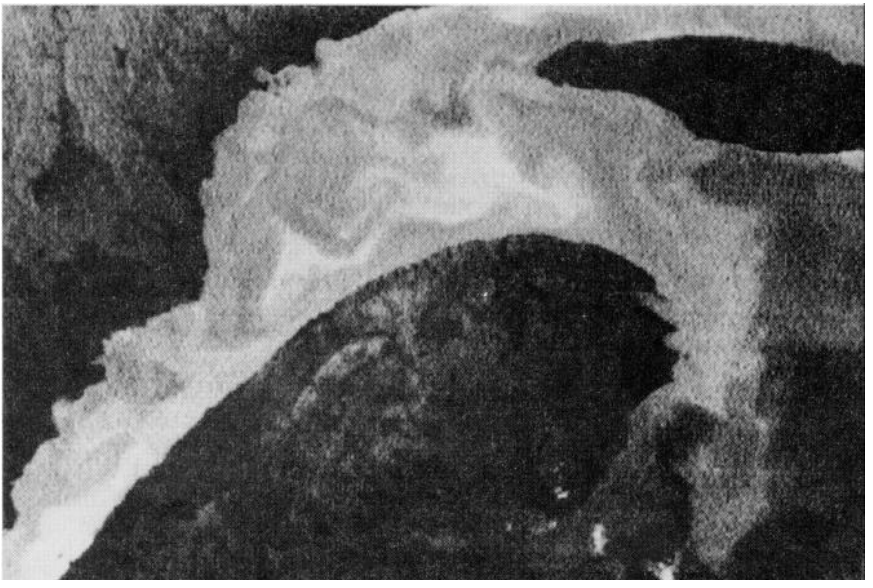
of current meters. For this purpose, two tilting current meters and two vector-averaging current meters were deployed along with other Aanderaa meters Laboratory and *in situ* calibrations of the conductivity cells, rotors, and thermistors of the Aanderaa meters were conducted by the instrument shop of Coastal Oceanography.

Preliminary analysis of the data indicates that variability of a wide range of time scales exists in the Gaspé Current and in the waters beneath it. There were occasions when the temperature-salinity characteristics of the water changed drastically over a period of one or two days. A correlation analysis will be carried out to determine the cause and the space-time scale of such events. Information on variability of a greater length scale was obtained from daily infra-red satellite (NOAA-5) imagery of the area. The satellite pictures frequently show a surprising wave-like structure along the coast (see figure). This is in contrast to the notion that the Gaspé Current is a relatively stable coastal jet hugging the Gaspé coast all along its course. Instability is probably responsible for such wavy motion, the same way it causes the Gulf Stream to meander.

C. L. Tang

Theoretical Studies

Stability of currents in coastal waters. Stable currents are seldom found in coastal waters. This is partly due to the intrinsically unstable nature of any stratified shear flow. There are two main types of instabilities: baroclinic instability and Kelvin-Helmholtz instability. They are usually thought to occur on very different length scales. Actually, in shallow waters, there



A NOAA-5 satellite photo of the Gaspé coast section of the St. Lawrence River. Lighter areas indicate colder water; darker areas, warmer water.

is a continuous range of length scales over which small disturbances can grow. The transition from one type of instability to another as the Richardson number varies was investigated analytically. The results show the important role played by inertial waves, and the appearance of a mixed type of instability, which has distinct characteristics in structure.

Generation of inertial waves. Inertial oscillations in the ocean are usually attributed to excitation by winds. However, in the current meter records of the Gulf of St. Lawrence, there were instances where bursts of inertial oscillations were not correlated to wind events. To explain this observation, a two-layer model was used to investigate the generation mechanism of inertial waves. It was found the non-geostrophic transient currents could generate inertial oscillations as efficiently as wind stresses.

Eddies and radiation fields in the ocean. The time development of eddies generated by baroclinic instability and the Rossby waves radiated from the eddies were examined theoretically by using an analytical model. The results show how wave dispersion and instability control the evolution of the eddies. The Rossby waves associated with the eddies can propagate to great distances without being suppressed by baroclinic instability. This suggests that if eddies are produced in the Gulf Stream system, then the energy generated can be transmitted to the ocean interior in the form of barotropic Rossby waves.

C. L. Tang

Gulf of St. Lawrence Studies

Magdalen shallows mixed layer study. Changes in freshwater discharge induced either through climate or by river regulation for the purpose of hydroelectric power production can have a profound effect upon the physical oceanographic regime of regions such as the Gulf of St. Lawrence. Results of earlier work by the Marine Ecology Laboratory seem to indicate good correlations between St. Lawrence River discharge and both subsequent commercial fish catches and water temperature.

Over the past two years, available temperature and salinity data from the Gulf of St. Lawrence have been collected and analysed to examine the effect of freshwater discharge on the surface mixed layer. The figure following shows the average temperature and depth of the mixed layer over the Magdalen Shallows determined from bathythermograph data for June. These are plotted against freshwater discharge for April. The data seem to indicate that increased freshwater discharge leads to more intense stratification and thus a shallower warmer surface layer in this region. If the three earliest data points (from the late 1940s and early 1950s) are dropped, the correlations rise to 0.90 and -0.71 for temperature and depth respectively.

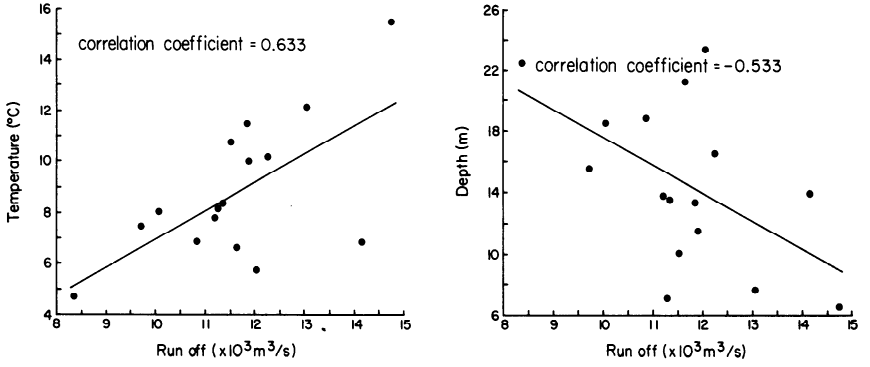
Present efforts are directed toward placing these correlations on a firmer physical basis, and evaluating the effect of variations in wind mixing and heat flux as well as freshwater discharge on the circulation and mixing of the waters of the Gulf of St. Lawrence.

Laurentlan Channel mooring program. One of the main features of the bathymetry of the Gulf of St. Lawrence is the Laurentian Channel extending from the continental shelf south of Newfoundland to almost the mouth of

the Saguenay River. The minimum depth over this over 1200 kilometre distance is slightly less than 300 metres, which permits water of oceanic origin to extend far into the Gulf. Below a depth of about 200 metres the channel contains water of relatively constant temperature-salinity characteristics believed to be formed from a mixture of Labrador and slope waters. Very little is known of the dynamics of these deeper layers.

In order to examine their role in the general circulation of the Gulf of St. Lawrence and to evaluate the importance of annual variations in freshwater discharge and wind forcing on their movement, five current meters equipped with temperature and salinity sensors were deployed in the fall of 1978 as shown in the map following. The mooring positions were chosen on the basis of the historical data available and the threat of fishing activity to mooring safety. It is planned to maintain these moorings for at least one year.

G. Bugden

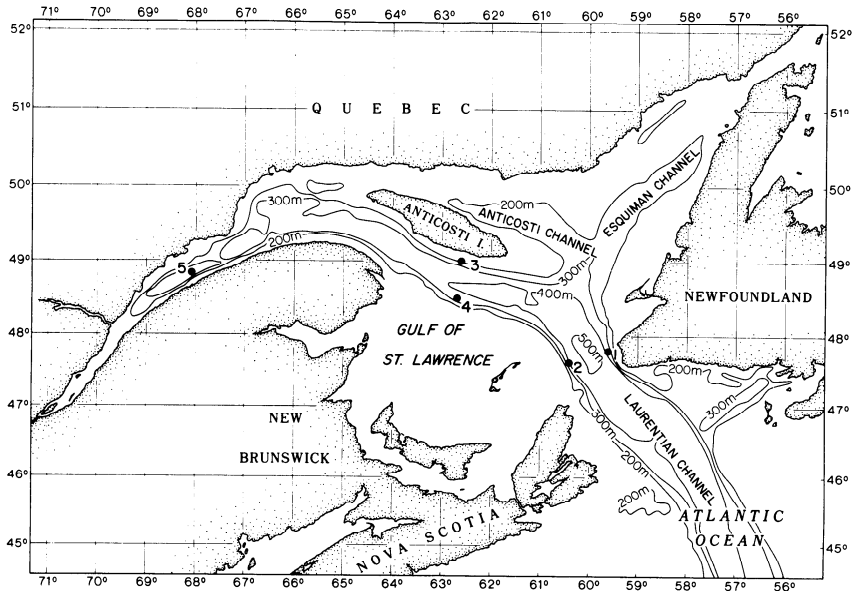


The temperature and depth of the mixed layer over the Magdalen Shallows plotted against April river run-off. (BIO 5094-1)

Normal modes in the Gulf of St. Lawrence. For any basin of arbitrary geometry the frequency and wave shape of its resonant modes can be considered as an intrinsic and fundamental property. These modes can be classified into 'rotational' and 'gravity' types - the former owe their existence to gradients in the undisturbed potential vorticity and the latter depend primarily upon the earth's gravitational field and are similar to the sloshing of water back and forth in a tub.

A numerical model has been developed to calculate these modes for the Gulf of St. Lawrence. In this model, lateral boundaries and bottom topography are resolved on a grid of nine minute squares on a Mercator projection. Calculations have been made by treating the Gulf of St. Lawrence as a closed system, i.e., Cabot and Belle Isle Straits and Pointe des Monts are considered closed, and searching for solutions in the period range from 6 to 120 hours. The slowest rotational mode found had a period of 51.46 hours and can be considered as a rotational shelf wave propagating along the Laurentian Trough. The slowest gravitational mode had a period of 12.03 hours and represents the fundamental mode of the Northumberland Strait region.

For resonances to be observed, the energy must be pumped into the mode faster than it is dissipated. We are currently examining residual sea level and current meter records for the presence/absence of some of these modes and plan further calculations with the connecting straits opened.



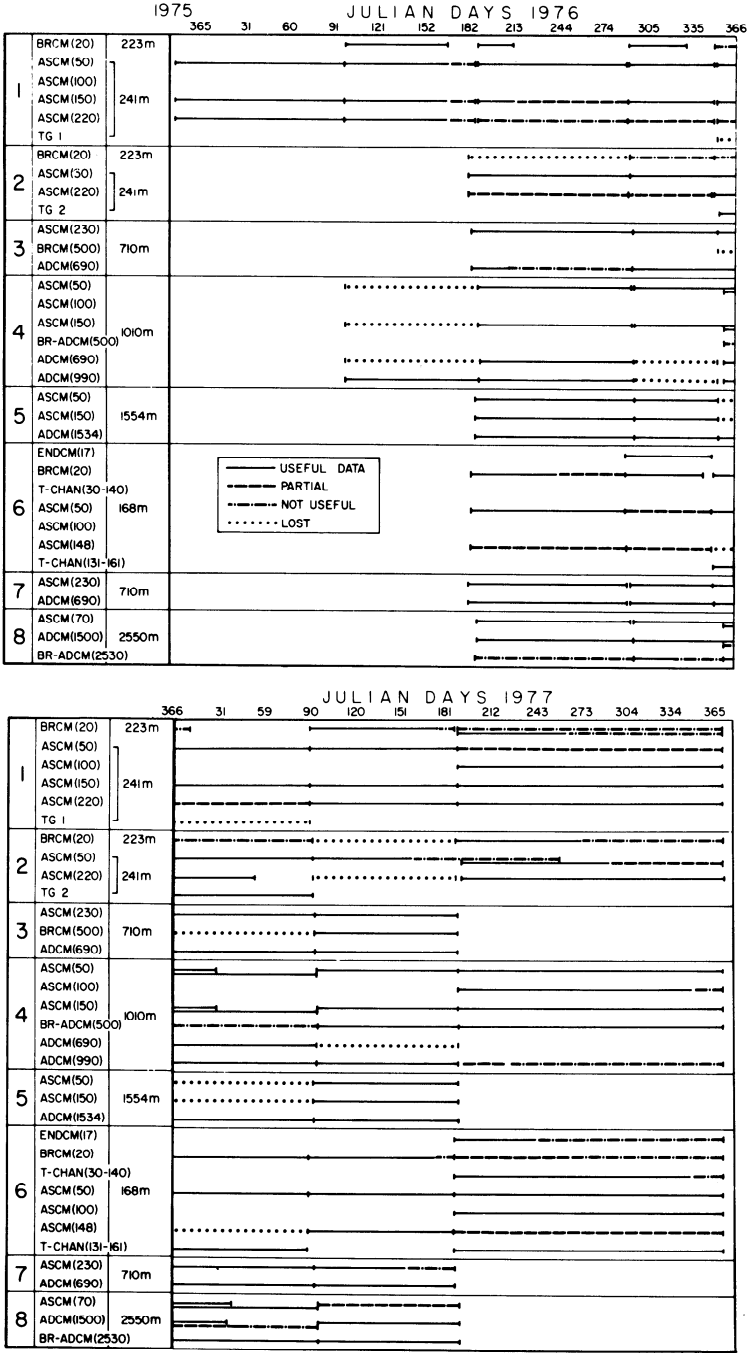
Mooring locations for the Laurentian Channel long-term mooring program. (BIO 5130)

St. Lawrence estuary - Rimouski triangle currents. This project was designed to determine the horizontal and vertical scales of currents in the lower St. Lawrence estuary as a function of frequency. The current meters were deployed in a triangular array, separated by about 6 kilometres with current meters at nominal depths of 15, 25, *75,* and 150 metres. Sampling was done at 5 minute intervals for 28 days. These data show that motions are coherent vertically in the upper 30 metres of the water column at frequencies lower than semi-diurnal but only marginally coherent horizontally in the same frequency band. Scales in the long channel direction in this band seem to be larger than cross-channel scales. The data also show that events in the atmospheric forcing band of about five days are dominant in the variability of the currents and lead to the conclusion that data covering a much longer time span (say at least two months) are needed to define average or mean currents.

G. Seibert

Shelf Break Dynamics Program

The Shelf Break Experiment, located at the edge of the Scotian Shelf south of Halifax, was designed to investigate: low-frequency dynamics at the shelf break; mixing and exchange processes between the shelf and slope water; and nutrient fluxes at the shelf break. The field portion of this program ended in January 1978 with the recovery of the final array. All data have been edited and are presently being analysed. In addition, studies of the performance of various instruments (e.g., Aanderaa and Endeco current meters, CODS discus buoys) have been completed. The returns of equipment (>90 per cent) and useful data (>80 per cent) make the experiment successful from both engineering and scientific viewpoints.



Data returns from the Shelf Break Dynamics Experiment (mooring sites were identified in the previous Biennial Review). BRCM; Braincon current meter; ASCM and ADCM, Aanderaa current meter; ENDCM, Endeco current meter; TG, Aanderaa tide gauge; and T-chain, Aanderaa thermistor chain. (BIO 5133-1)

Analysis of the early records from the mooring array has indicated the following:

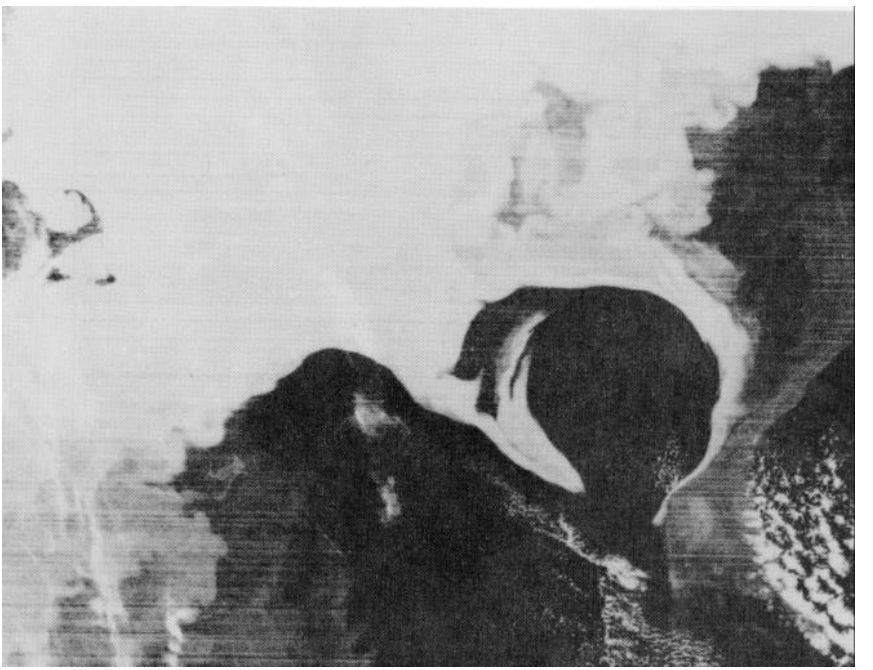
(1) the interaction of Gulf Stream eddies with the shelf water (see photograph) is an important mechanism for injecting salt and heat into the shelf water,
(2) low-frequency nutrient fluxes at the shelf break are capable of supporting the high levels of primary productivity observed there, and
(3) the low-frequency fluxes of salt and heat contribute about 30 per cent of the annual heat and salt inputs to the shelf water.

Using results from the entire program, various long-term studies will be conducted including: (1) quantitative analysis of the motions of the Gulf Stream, Gulf Stream eddies, and slope water boundary from sea surface temperature data; (2) investigations of the seasonal variations in the circulation and exchange processes at the shelf break; (3) assessment of the role of atmospheric and deep-ocean forcing on the shelf break variability; and (4) dynamical modelling of the low-frequency shelf break circulation.

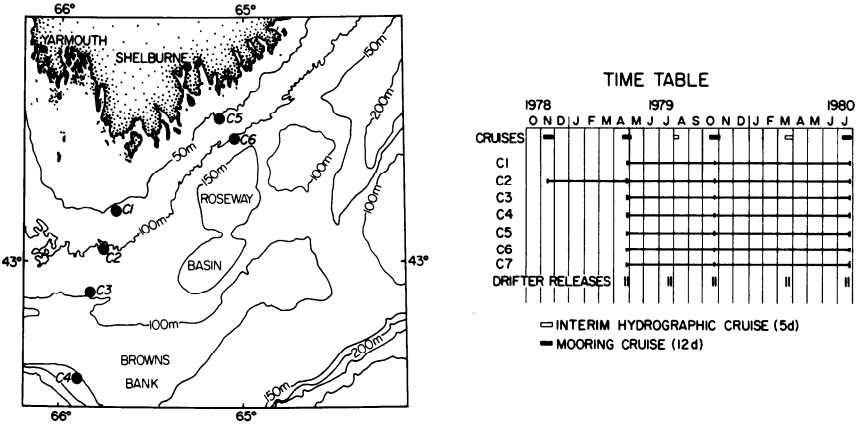
P. C. Smith, B. D. Petrie

Cape Sable Experiment

An 18-month experiment begun in November 1978 is examining the coastal circulation of one of the most biologically productive regions on the east coast of North America - the continental shelf waters off southwestern Nova Scotia. The experiment is designed to: determine the mean and seasonal



A NOAA-4 satellite infra-red photo of sea surface temperature on March 27, 1976, which shows the interaction between the warm core Gulf Stream and the surface shelf water. (BIO 4616-22)



Mooring array and timetable for the Cape Sable experiment. (BIO 5133-2)

inflow past Cape Sable into the Gulf of Maine; investigate the local upwelling phenomenon; assess the role of low-frequency atmospheric and deep-ocean events of circulation and mixing; and measure secondary circulation associated with the formation of fronts by variations in tidal mixing. The main elements of the program are a mooring array, a series of seasonal hydrographic surveys, and Lagrangian drift studies using satellite-tracked surface drogues.

P. C. Smith

Bay of Fundy Studies

The possibility of tidal power development has increased interest in the Bay of Fundy. A numerical model originally developed in Ottawa for the Tidal Power Review Board was also used to further study the Bay. The current and water depth conditions, which are sufficient to mix stratified areas, can be parameterized in terms of the frictional dissipation and readily calculated from a numerical model. Calculations made were able to reproduce very well the observed boundaries between well mixed and stratified areas. The predicted changes in these boundaries due to the insertion of tidal power barrages were small although the reservoir areas, which would be well mixed without barriers, showed a strong tendency to stratify with them. These changes could affect the local climate and biological activity in the area.

D. A. Greenberg, C. J. R. Garrett (Dalhousie University), J. R. Keeley (MEDS)

Studies on Particulate Matter

The procedure in this work is to study the suspended particulate matter and related physical and biological factors in specific geographical areas in order to develop an understanding of the behaviour of particles- in the sea in general and to help solve specific practical problems of pollution, sediment transport, and sedimentation in the areas under study.

During the last two years the investigations of estuarine environments have continued. Work completed in the Miramichi and St. Lawrence estuaries has confirmed the importance of flocculation in the estuarine sedimentary regime and in the formation and maintenance of the turbidity maximum. In 1977 a major field program partly supported by the Regional Ocean Dumping Advisory Committee (RODAC) was carried out in the Saint John River estuary (NB) and the Bay of Fundy. This River is of interest because it is a major source of sediment in the productive waters of the Bay of Fundy and it is also the most industrialized and dredged harbour in the area. The estuarine circulation in association with a very large tidal range, and the presence of the reversing falls, make it very difficult to predict the effects of the massive harbour maintenance dredging and dumping.

Preliminary results show rapid dispersal of sediment away from the entrance of Saint John harbour. The area around the Black Point dump site has an anomalously high muddy sediment and trace metal loads, but its effect on the surrounding Bay is limited. Inside the estuary, concentrations of suspended sediment were lower than expected; extremely high tidal currents dampen the normal alternating settling and resuspension, which usually maintain turbidity maxima in estuaries. The residual water and associated sediment circulation in the Bay of Fundy is counterclockwise. Some sediment is lost to Minas Basin and Cobequid Bay, but the principal sediment sink is the muddy area west of Grand Manan Island.

The theoretical studies of particle behaviour have focussed on the effects of different settling processes on grain size spectra and settling rates. In studies and modelling of suspended particulate matter in the sea it is usually assumed that the particles, which include plankton and organic and inorganic detritus, have defined and conservative sizes and densities that govern their physical behaviour. Particulate matter in estuaries and coastal regions, however, shows a high degree of physical interaction between particles, which in most areas controls their size distribution spectra.

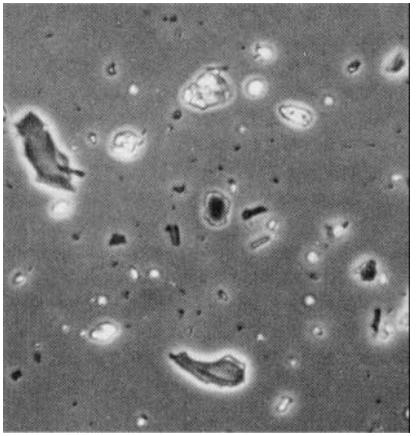
In laboratory experiments on artificial suspensions of various detrital minerals, the average settling rate due to flocculation varied directly with the particle concentrations, which led to an exponential decrease of the concentrations of all particle sizes with time. These results help to explain many aspects of particulate matter distribution in nature, such as the rapid decrease of suspended matter away from the continents, the rapid sediment fluxes of turbidity maxima in estuaries, and many features of marine sediment size distributions.

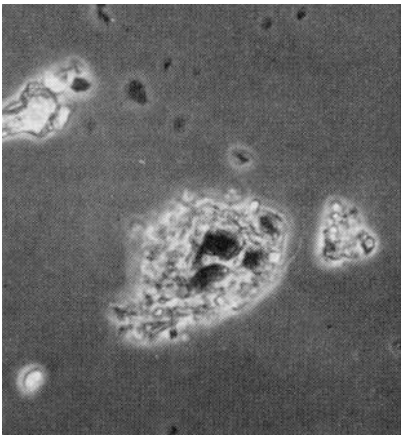
In regions with large amounts of living material, peaks in the particle spectra caused by plankton also show characteristics indicative of flocculation. This may indicate that the plankton standing stock is partly dependent on physical factors which control flocculation rates, such as turbulence, temperature, and total particle concentration.

K. Kranck

Strait of Canso Environmental Study

The Canso Marine Environment Workshop, sponsored by the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) was convened to consider all possible environmental effects of the Canso Causeway (completed in





Suspended particulate matter with abundant flocculated particles (left) and suspended particulate matter after ashing of organic matter and disaggregation of inorganic flocs (right). Scale: 1 centimetre = I micron.

1954). After the first session it was apparent that the most important fishery that had shown a decline related to this closure was the lobster fishery of Chedabucto Bay and the eastern Nova Scotia coast. It was also apparent that although transport of water southward through the strait before 1954 might have carried significant quantities of larvae into Chedabucto Bay, there were large uncertainties in the estimates of magnitude and duration of such flows.

Consequently a numerical model of flow through the Strait was developed. It was driven at both ends using sets of tide height constituents giving the best fit to data from all the appropriate nearby ports. The model was calibrated by adjustment of the friction parameter to give the best fit to a mid-strait slack-water time-series (1922-1926).

The results showed that if the long term height difference between the ends were zero, then only during spring tides would water be able to traverse the entire length of the Strait in one tidal cycle and thereby contribute to an exchange between St. Georges and Chedabucto bays. An analysis of all available tide height data, however, suggested that the mean level difference was of the order of six centimetres, for which the model predicted a predominance of southward flow (7000 cubic metres per second) with exchange occurring on nearly all tide cycles.

Using recent measurements of lobster larval densities in St. Georges Bay, Harding *et al.* have estimated that in a two month summer period the mean flow might move as many as ten million larvae southward. This quantity might fluctuate considerably as storms alter the larval density and the transport on time scales of order of ten days. Although little research has been done on larval dynamics in Chedabucto Bay, it is estimated that such a flow would constitute less than ten per cent of Chedabucto Bay larval production.

D. J. Lawrence, D. Greenberg

In another paper presented at the Canso Marine Environmental Workshop, the current patterns in Chedabucto Bay were analysed using data from an 18-day 5-mooring array from 1970. Tidal currents were small but consistent (5.3 +0.8 centimetres per second), dominated by the M_2 tide, and nearly rectilinear eastward. Temperature-salinity measurements confirmed the existence of seiche activity (two cycles per hour) although velocities were low. The most notable features were the abrupt changes in direction of the mean flow on at least three occasions and the existence of an overall mean counterclockwise gyre at all three depths. The direction changes tended to occur simultaneously but were otherwise largely unconnected, and correlation coefficients were insignificant horizontally and across the 20 metre interface and with the local geostrophic wind. The pre-causeway inflow from the Strait of Canso might be expected to add perhaps 6 centimetres per second to the gyre amplitude, thereby significantly reducing transit times in the southern portion of the bay from 12 to perhaps 4 days.

Construction of the causeway (1952-1954) drastically reduced the tidal currents within the Strait of Canso. Tidal amplitudes near the mouth are now of the order of ten centimetres per second and so are no longer dominant. Local winds can produce comparable amplitudes in the top ten metres. Another feature first noted in the 1969-1970 data was the presence of currents of comparable or stronger amplitude, with periods of three to five days. These take the form of internal waves and are believed to be related to meteorological forcing over the Scotian Shelf. Such flows, because of their long duration could have an important effect on the flushing times of pollutants in the Strait. To investigate further, analyses are being done on the data from a year long current meter survey done in the Strait by the Department of Public Works on behalf of the Department of Transport.

D. J. Lawrence

Data Analysis

The data analysis section continues to be the main Centre for the processing and archival of physical oceanographic data within the Institute. In addition to reducing data for our Division's field programs, we processed this past year physical data for AGC and MEL, Dalhousie, McGill, and Rimouski Universities, and most of the divisions within AOL.

A major accomplishment during this review period was the completion of a project to reprocess all our historical CTD profiler data to present standards and transfer them to the national archive in Ottawa.

Other projects that the section was involved in during 1978 include the analysis and preparation of a report for a long term temperature monitoring program for the St. Andrews Biological Station (NB) and the setting up of an ocean drifter receiving and archival system in conjunction with MEDS.

The data shop is also jointly involved with the instrument shop in a continuing data quality evaluation program for the Aanderaa current meters. An intercomparison study of the Aanderaa and VACM rotor type current meters and the General Oceanics tilting current meter is also in progress.

D. N. Gregory

Instrumentation

This section continued to support other groups within the Institute by maintaining current meters, CTD profilers, moorings, and other related oceanographic equipment. A program to calibrate our recording current meters has been established and errors in the pressure gauges, salinity cells, rotors, and magnetic compasses were found. The most serious problems were occasional errors of up to 50 degrees or more in direction caused by stray magnetic fields sometimes affecting the instruments It has been possible to eliminate the causes of these errors and in most cases to correct the bad data. New equipment has been purchased to enable routine calibration of most sensors and we hope to establish routine calibration procedures before the 1979 season.

A. J. Hartling

Other Activities

Oceanographic surveys for outside users. The Division continues to assume responsibility for an ice forecast cruise each November in the Gulf of St. Lawrence to collect data needed by the Atmospheric Environment Service as input to their ice forecast calculations.

Another Division responsibility in the past was a seasonal sampling of the Halifax Section (extending from Halifax to the southeast over the Scotian Shelf) in support of ICNAF. This sampling was carried out in 1977, but a careful review of the time series collected over the more than 20 years the Section was sampled showed that no further useful data would be obtained by continuing the section. Consequently, the program was terminated in 1978.

T. R. Foote, D. Dobson

Ocean dumping applications reviewed. Since proclamation of the Ocean Dumping Control Act in 1975, technical advice on oceanographic characteristics of dump sites has been required for processing applications for permits under the Act. In co-operation with other disciplines at BIO, we have reviewed the physical characteristics of dumping operations. Through 1977-1978, 285 applications were handled, largely for dredging of marine sediment. As well, research directly related to ocean dumping problems has been carried out through contracts. Five contract reports have appeared to date and others are pending. An investigation of the effects of Saint John (NB) harbour dredging was combined with a project headed by Dr. K. Kranck on the suspended sediment regime of the Bay of Fundy.

Seabed drifter program. Following a study made in 1977, a clearing house was created in 1978 to supply seabed drifters for the study of bottom currents, and to process data from the card returns. To date about 4000 drifters have been supplied at cost to users, mainly for dredging operations and returns from the majority of sites average over 20 per cent. As well, surface drifters were procured, and about 2000 were used in a project on the coastal shelf. Further developments of drifters are being carried out.

D. S. Bezanson

ToC

Hydrography

Even though the 1977-78 period was relatively tranquil for the Hydrography Division, it was nonetheless productive and some events worthy of mention took place, notably:

-the decentralization of the cartographic function to the Region, which has been underway for two years, continued and 19 positions have been transferred from Ottawa thus far;
-Loran-C calibrations went ahead rapidly and most effectively;
-work on BIONAV is shaping up well and the system is proving to be an asset to the CSS *Hudson's* navigational requirements; and
-the introduction of GOMADS (Graphical On-line Manipulation and Display System) was begun and when completed it will be part of a national hydrographic system.

The field surveys in general progressed quite favourably; however, the success of the charting program in the eastern arctic left a great deal to be desired. In 1977 the CSS *Baffin* was severely damaged while attempting to reach her area of survey in Victoria Strait; this retarded the work greatly, and in 1978 severe ice conditions throughout the arctic practically eliminated any success in new charting. A summary of the work done during the period by each of the five sections composing the Division follows.

R. C. Melanson

Charting Section

Field Charting. This Section is responsible for planning and conducting field surveys of navigable waters within the Atlantic Region for navigational charts and related publications. To carry out this function, seven field establishments from the Bay of Fundy to the eastern arctic were operated in both 1977 and 1978.

The main thrust was concentrated in the Gulf of St. Lawrence, Labrador Coast and Sea, Ungava Bay, and the arctic. In addition, the requirement for "fire-fighting" projects had diminished, and this allowed some concentration on new charting in the Bay of Fundy and along the south coast of Newfoundland. Even though the reporting period was highly productive, there were setbacks. In 1977 the *Baffin* was severely damaged by ice while attempting to navigate Victoria Strait, which eliminated any amount of accomplishment, and in 1978 this vessel's intended program for the Gulf of St. Lawrence had to be cancelled because of serious mechanical difficulties. However, the CCGS *Labrador* in 1977 enjoyed the most productive hydrographic season ever experienced by an icebreaker, and in 1978 the Labrador Sea was completed to the extent that a complete series of Natural Resource Maps may now be published.

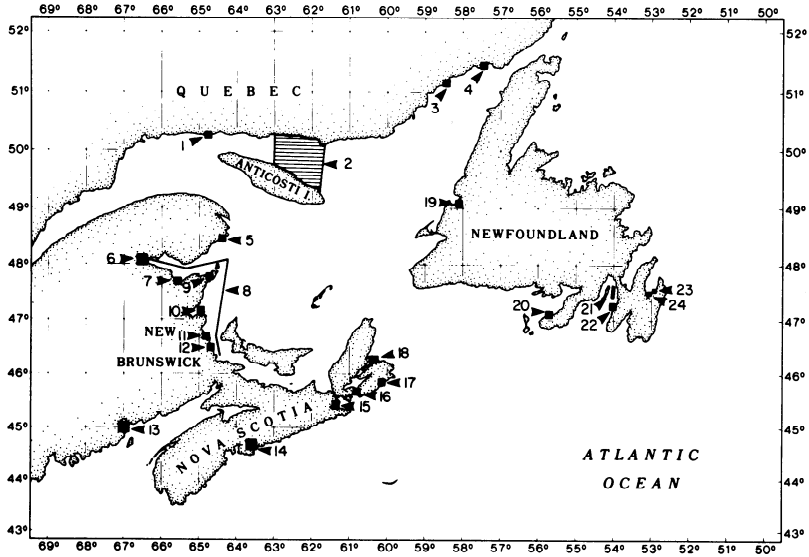
T. B. Smith

1977 field program

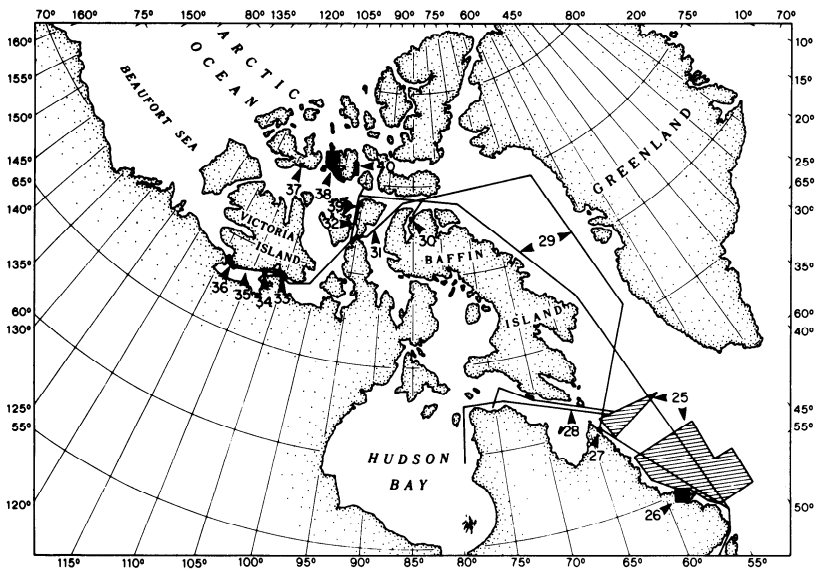
Establishment and dates	Reference number* and area	Type of survey
CSS Baffin (May 2 - Sept. 26)	2 - Gulf of St. Lawrence	Navigational charting, some magnetics
	27 - Nones Head, Labrador	Positioning and identifying off-lying islands
	29 - Strait of Belle Isle to Victoria Strait, return	Track sounding
	36 - Miles Island to Chantry Island	Corridor survey
	35 - Jenny Lind Islands to Cape Bexley	Track sounding
	34 - Byron Bay	Shoal examinations
	33 - Cape Alexander	Shoal examinations
Eastern Arctic Survey: (July 18 - Sept. 30) *(CCGS Labrador, CCGS John A. Macdonald, CCGS D'Iberville)*	38 - Cape Cockburne to Cameron Island	Route survey
	30 - Strathcona Sound	Harbour survey
	39 - Aston Inlet	Beaching site
	40 - Bateman Bay	Harbour survey
	37 - Bridport Inlet	Beaching site
	31 - Strathcona to Victoria Strait	Track sounding
	32 - Victoria Strait to Resolute	Track sounding
	28 - Hudson Strait and Hudson Bay	Track sounding
Charter Vessel I MV *Martin Karlsen* (June 28 - Oct. 17)	25 - Labrador Sea	Natural resource charting, gravity, bathymetry, and magnetics (Satnav/Loran-C for positioning)
	26 - Cape Harrison to Makkovik	Route survey
Charter Vessel II MV *Meta* (May 12 - Oct. 25)	5 - Grande Riviere, PQ	Harbour survey
	6 - Dalhousie, NB	Harbour survey
	Dalhousie to Campbellton, NB	Channel survey
	7 - Bathurst, NB	Post dredging
	9 - Shippegan Gully, NB	Predredging, range survey
	8 - Dalhousie to Richibucto, NB	Revisory survey
	10 - Miramichi, NB	Post dredging
	11 - Richibucto, NB	Range survey
	12 - Buctouche, NB	Harbour survey
Shore Party (May 2 - June 17)	16 - St. Peters Inlet, NS	Standard charting
Local surveys (May 1 - Sept. 30)	14 - Halifax Harbour, NS	Wharf survey
	1 - Riviere au Tonnerre, PQ	Engineering study
CSS Maxwell (May 2 - Oct. 28)	3 - St. Augustin, PQ	Standard charting
	4 - Old Fort Bay, PQ	Standard charting
	19 - Cornerbrook, Nfld.	Revisory survey
	20 - Grand Banks, Nfld.	Wharf survey
	21 - Placentia Bay, Nfld.	Check survey
	22 - Argentia, Nfld.	Wharf survey

23 - Holyrood, Nfld.	Channel survey
24 - Long Pond, Nfld.	Harbour survey
13 - Head Harbour Passage, NB	Standard charting

*Refer to figures following.



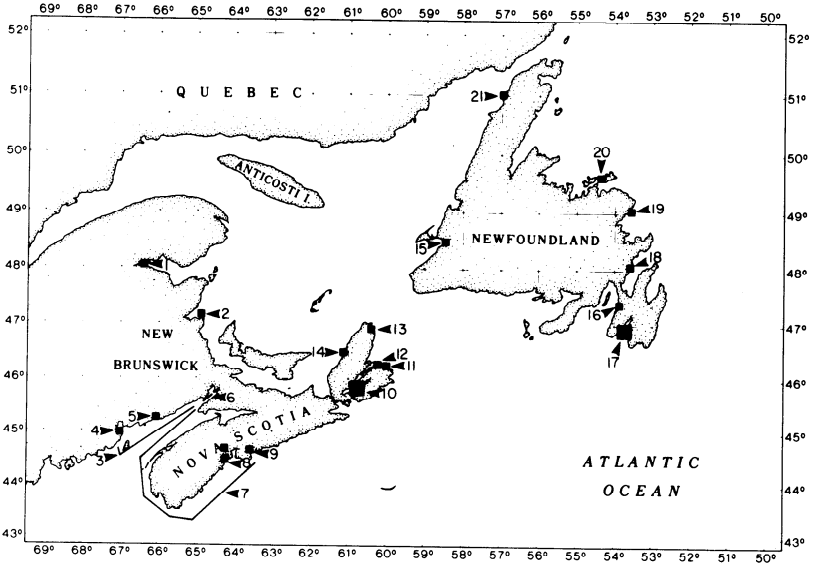
Above: Hydrographic survey operations in the Atlantic Provinces in 1977. (BIO 5107-1).
Below: Hydrographic survey operations in the eastern arctic in 1977. (BIO 5107-4)



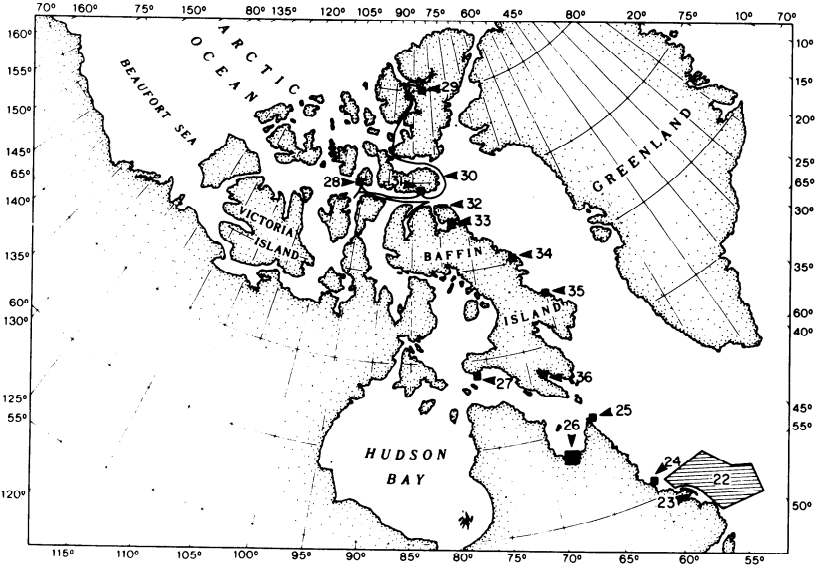
Establishment and dates	Reference number* and area	Type of survey
CSS Baffin (Julv 12 - Sept. 29)	21 - Brig Bay, Nfld.	Channel and shoal examination
	24 - Davis Inlet, Nfld.	Approach corridor
	25 - Labrador Reef, Nfld.	Shoal examination
	26 - Ungava Bay, PQ	Standard charting
Eastern Arctic Surveys (July 13 - Sept. 27)	27 - Cape Dorset, NWT	Standard charting
	28 - Resolute, NWT	Standard charting and navigational ranges
(CCGS John A. Macdonald,	29 - Slidre Fiord, NWT	Reconnaissance
CCGS d'lberville,	30 - Eastern Arctic, NWT	Tracks
CCGS Louis S. St. Laurent,	31 - Dundas Harbour, NWT	Harbour survey
CCGS Pierre Radisson)	32 - Bylot Island, NWT	A few tracks
	33 - Pond Inlet, NWT	Harbour survey
	34 - Clyde. NWT	Harbour survey
	35 - Kangeeak Point, NWT	Navaids
	36 - Pike Resor, Frobisher Bay, NWT	Navaids
Charter Vessel I MV *Martin Karlsen* (June 21 - Oct. 19)	22 - Labrador Sea	Natural resource charting, bathymetry, gravity, and magnetics (SatnavlLoran-C for positioning)
	23 - Cape Rouge to Iron-bound Island, Nfld.	Route survey
CSS Maxwell (May 1 - Oct. 27)	4 - Friar Roads and Head Harbour Passaoe to Petite Passage: NB	Standard charting
	8 - Mahone Bay. NS	Shoal examination
	16 - Argentia and Placentia, Nfld.	Horizontal control
	17 - St. Mary's Bay, Nfld.	Standard charting
	18 - Random Sound, Nfld.	Shoal examination
Charter Vessel II MV *Meta* (May 8 - Oct. 27)	3 - Grand Manan to 1 Sackville, NB	Revisory, navigational ranges and harbour
	7 - Sackville to St. Margaret's Bay, *NS*	Revisory, navigational ranges and harbour
Shore Party (May 1 - June 23)	10 - Bras d'Or Lakes, NS	
	(a) St. Peters Inlet	Standard charting
	(b) East Bay	Standard charting
	(c) Denys Basin	Reconnaissance
	(d) Little Bras d'Or	Check survey
Local Surveys (Jan. 1 - Dec. 31)	1 - Dalhousie, NB	Wharf survey
	2 - Miramichi, NB	Monitoring changes in channel south of "The Lump"
	5 - Saint John. NB	Navigational ranges
	6 - Chignecto Bay, NB	Reconnaissance
	9 - Halifax Harbour, *NS*	Chart revisions
	11 - New Waterford,- *NS*	Navigational ranges
	12 - Sydney, *NS*	Navigational ranges
	13 - Dingwall, NS	Wharf survey
	14 - Inverness, NS	Navigational ranges

15 - Stephenville Pond, Nfld.	Channel survey
19 - Greenspond, Nfld.	Navigational ranges
20 - Bacalhao Island and Change Island, Nfld.	Navigational ranges

*Refer to figures following.



Above: Hydrographic survey operations in the Atlantic Provinces in 1978. (BIO 5107-3).
Below: Hydrographic survey operations in the eastern arctic in 1978. (BIO 5107-2)



Cartography. This Section is responsible for the compilation and drafting of new and revised editions of navigational charts and the maintenance of a block of charts covering the waters adjacent to the Maritime Provinces, Newfoundland, and Ungava Bay, Quebec. The cartographers in this Section produce new charts in accordance with approved chart schemes and national standards. They also evaluate and incorporate all new data in the ongoing maintenance program, prepare assessments for stock requirements and the publication of pertinent information, and produce new editions and notice to mariners chart correction patches. This is to satisfy the requirements of Eastern Canada as determined by the National and Regional Hydrographic offices and the demands of marine transportation in general.

In September 1977 the first group, eight cartographers and one photo-mechanical technician, relocated from Ottawa to BIO to carry out the chart production mandate of the block of 138 charts adjacent to the Maritime Provinces. During the summer of 1978 the second block of charts (205) covering the waters of the province of Newfoundland and Ungava Bay was transferred. To carry out the production mandate, ten more cartographers were relocated.

From September 30, 1977 to December 31, 1978, four new editions of existing charts were published and seven additional new editions were more than half completed. Two new charts were almost completed and seven chart correction patches were published in the weekly Notices to Mariners publication.

Readers may obtain more detailed information regarding Cartographic projects in production by directing enquiries to: Chief of Chart Production - Atlantic Region, BIO, P.O. Box 1006, Dartmouth, NS B2Y 4A2.

R. F. J. *Gervais*

Cartographers at work. (BIO 5182-4)

Hydrographic Development

This Section investigates and implements instrumentation and techniques in support of hydrographic and cartographic activities. Two major ongoing programs are underway: automation of field surveys and implementation of GOMADS.

GOMADS will be utilized for both hydrographic and cartographic requirements. The system will permit digital data to be edited or modified and graphical documents to be digitized. A standard format for the exchange of digital data within the Canadian Hydrographic Service (CHS) has been established. Final plotting of chart data will be carried out on the Gerber 32 optical plotter in Ottawa.

A PDP-11/34 computer system has been installed and the editing software is being modified to work in conjunction with the various systems in use at BIO. Procurement of a digitizer table is underway. When fully operational, GOMADS will provide the Atlantic Region with a powerful interactive graphics tool.

A major thrust towards automation has resulted from the CSS Baffin's mid-life refit program. The following items have been procured to upgrade the ship's survey and data processing capabilities: two HP system 1000 computers; two ZETA 3651 plotters; two Tektronix 4051-1 graphics terminals; two HP 9815 programmable calculators; and two EG&G side scan sonars.

Efforts to obtain data logging, navigation, and sounding systems are underway. Specifications for a small launch navigation system have been prepared in co-operation with Central Region, CHS. These units will facilitate the running of straight survey lines when using range-range or hyperbolic positioning systems, Plans call for a major survey to be equipped for the 1979 season.

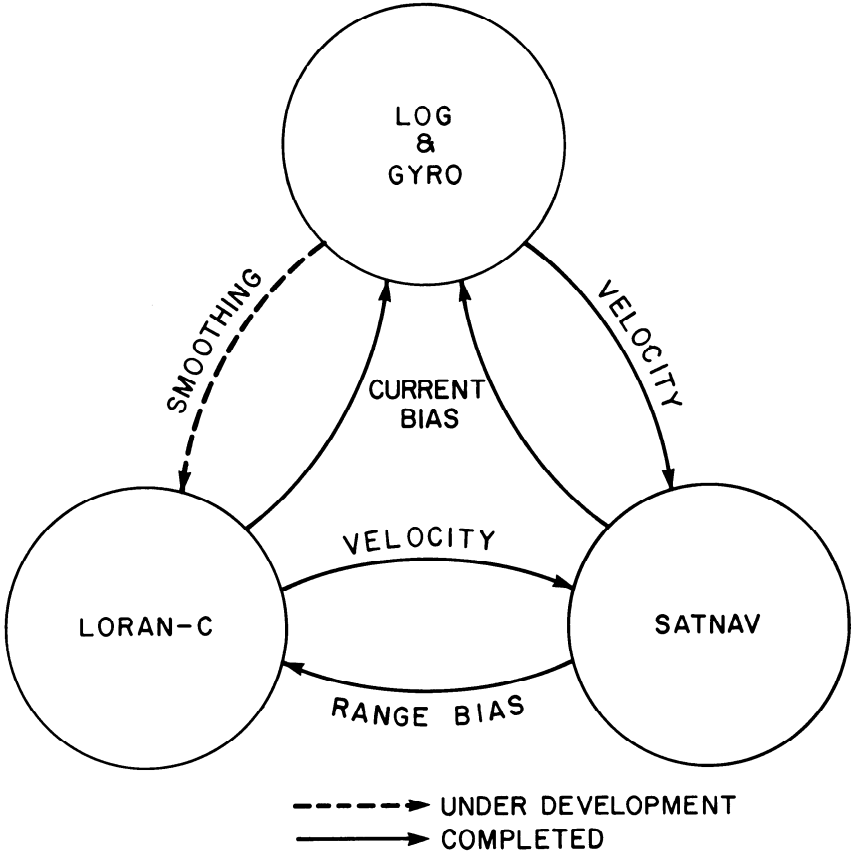
A new semi-automatic echogram scaler has been designed and interfaced to an HP 9815 programmable calculator. The scaler takes full advantage of calculator software capability to eliminate the need for high-precision analogue circuits. Tidal reductions and velocity corrections are handled by the software. Depth data from the sounding roll are recorded on miniature tape cartridges. These data can be transferred to an HP 2100 through an HPIB (Hewlett Packard Interface Buss) for subsequent incorporation into a digital bathymetric data base. Other calculator projects include the development of a prototype navigation unit designed to be used with Mini-Ranger III, a software package for cartographic applications, and a program tape duplication facility using HPIB.

R. G. Burke

Navigation Group

This Group, whose job is to improve and extend the Institute's capabilities in positioning at sea, is working on two main projects. One is to develop BIONAV, which is being done jointly by D. E. Wells of the Metrology Division and S. T. Grant of the Navigation Group (with microprocessor hardware and software developed by Systems Engineering, IF). The other is in contributing to Loran-C expansion in Atlantic Canada, through testing Loran-C performance and calibrating the lattice for accurate charting. At the same time, the Group takes on smaller, shorter term jobs as needs arise.

BIONAV. BIONAV development has consisted mainly of writing a set of computer programs to combine data in real time from existing navigation systems at BIO. After two years of development, including one manyear at sea, this set of programs is essentially complete, and will be installed on CSS *Hudson* for testing during the 1979 field season and on CSS *Parizeau* late in 1978; it will be used on LOREX in 1979.



A schematic representation of the BIONAV concept (see text). (BIO 5107-5)

The BIONAV concept is depicted in the accompanying figure. The Transit Satellite System (Satnav) forms the backbone of BIONAV with its 20 to 30 fixes per day, but it requires an accurate knowledge of the ship's velocity during the up to 18 minute satellite pass. The Loran-C gives continuous positioning information between Satnav fixes and smoothed velocities with respect to the ocean bottom, which, when compared with the log/gyro velocities with respect to the water, give measurements of the surface current. The log/gyro velocities, corrected for current bias, are very sensitive to short term ship motions and are therefore used in the Satnav fix calculations. When necessary, BIONAV will operate (with reduced effectiveness) using any one or any pair of these three subsystems.

The key objectives of BIONAV were determined from a users' survey to be reliability and simplicity of operation. It will also provide flexibility to input and output (i.e., it will be simple to add or delete new sensors, video displays, loggers, plotters, etc.); it will be more accurate than existing unintegrated components; and it will add new capabilities (i.e., real time tracking of a water mass).

The hardware required for BIONAV consists of a moving head disc and additional memory for the HP 2100 Satnav computer. Interfaces were added to the passive ranging Loran-C system and a microprocessor unit (MPU) specially built for BIONAV by Systems Engineering (IF). The MPU not only takes some of the computing and interfacing load off the main BIONAV computer but it also provides greater reliability since it can operate independently should the main computer fail.

BIONAV software consists of about 125 programs (15,000 lines of Fortran) that acquire and process the data from the various sensors and output the results to video displays, terminals, and data storage facilities. There are four main families of BIONAV programs (log/gyro, Satnav, Loran-C, and Operator), which have been developed in four stages (data acquisition, processing, logging, and communication between families).

Loran-C expansion. Passive ranging Loran-C has been the mainstay of our positioning on the Atlantic Ocean and Labrador Sea for several years, and we have periodically improved the navigation programs used with it. This year, geophysicists on CSS Hudson used the homing program to first map a small seabed feature about 300 metres wide, and then to return to take five samples across it.

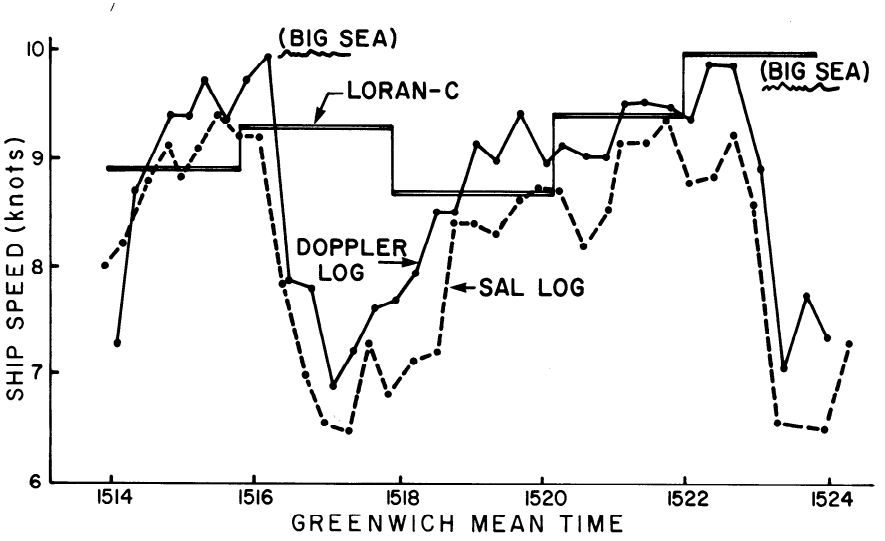
Standard three-station Loran-C has recently been extended over the Pacific Coast of Canada, and over the Bay of Fundy and Scotian Shelf on the Atlantic Coast. There are plans to expand coverage to the Grand Banks and the Coast of Labrador, in which case Loran-C would eventually replace the existing Loran-A and Decca.

Capitalizing on our Loran-C experience, we recently worked with the Canadian Coast Guard on a comprehensive test of the performance of the existing transmitters, in order to plan the optimum chain configuration for the future.

While the Canadian Coast Guard is responsible for providing navaids (navigational aids), the CHS is responsible for the accuracy of the navigational information on the chart, which includes navaid lattices. In 1977, the Navigation Group joined with the Pacific Region to calibrate the new Canadian West Coast Loran-C chain, using Satnav offshore and short-range miniranger radar transponders inshore. Satnav gave the expected 150 metre consistency in results, while the higher accuracy miniranger strikingly verified theoretical predictions of a 500 metre large anomaly in the reading that occurs when the Loran-C wave crosses the coast.

In 1978 we are doing a similar calibration on the Atlantic Coast and adding extensive readings on land by calibration van to further check propagation theory and to provide the value of land conductivity required to improve lattice predictions.

Fishermen suffer temporarily through any changeover in the navaid they use. To help alleviate this we have written a guide to Loran-C operation, stressing problems at the long ranges they will encounter, and we are advising on contracts to evaluate Loran-C receivers and to convert existing "hang-up" points in Loran-A or Decca co-ordinates to the new Loran-C co-ordinates.



A graphical depiction of how a big sea slows a ship down. On the homeward leg of a cruise, the CSS Dawson encountered five metre seas that caused her to pitch and corkscrew, and had scientific staff hanging on to rails. The Sal and Doppler logs recorded a 3.5 knot drop in speed but the Loran-C, due to its damping, produced the smoothed average speed shown in the graph. (BIO 5107-6)

One important aspect of our work for BIO is providing accurate ship's speed measurement, which is useful both in handling the ship on station and in navigation. We now have doppler speed logs working in all our ships, using a flush-mounted bow transducer when in ice, and an extending ram to get below the bubble layer along the hull in rough weather, when there is noise around. One interesting result from tests of a transducer in a blister in *Dawson's* forefoot was the way that a big sea will slow a 2000 ton ship by 3 knots once a minute (see figure).

The Navigation Group must always be aware of navigational problems and of new developments. One such problem is positioning in the arctic, where there are no fixed navaids, and a development that should help is the recent improvements in UHF positioning (based on the old "extended range Shoran") in systems such as "Marinav" and "Syledis". We have joined with Mobil Oil Canada Ltd., Marinav Ltd. (Ottawa), and the Canadian Coast Guard in recent demonstrations of these and we plan a thorough evaluation of UHF performance in the near future.

R. M. Eaton

Tidal Section

This Section is responsible for the tidal and tidal current work carried out by the CHS in the Atlantic Region.

The early part of 1977 saw the completion of our involvement in the Bay of Fundy - Gulf of Maine Tidal Regime Studies Project. Begun in 1976, and funded by the Tidal Power Review Board, the project was designed to acquire an understanding of how the tidal regime in the Bay of Fundy system would be altered by the presence of tidal barrages. Tidal Section staff measured and analysed the existing tidal regime in both the inshore 'and offshore areas. Excellent tidal data for a total of 1094 days were subsequently analysed and incorporated into the OAS numerical tidal model.

A project to transmit tidal data by acoustic means from a bottom mounted tide gauge was completed jointly with the Systems Engineering Group, IF. This Tidal Telemetry System was tested for a month in Bedford Basin, and yielded slightly better than a 96 per cent correct transmission of tidal data through the water. Production field use was scheduled aboard CSS *Baffin* in August 1977 but failed due to flooding of the instrument package.

Two offshore tide gauge moorings were completed in 1978, one in Ungava Bay, the other at the eastern edge of Hamilton Bank in the Labrador Sea. Both gave a complete data set, which is presently being analysed.

The joint management of the Atlantic Region permanent gauging network continued with gratifying results. For both 1977 and 1978 submersible recorders have been in place at five locations in the eastern arctic, yielding lengthy continuous records at locations ranging from Hudson Strait to Alert.

Tide gauges have been provided to support hydrographic surveys in the Atlantic Region. The program of providing current information started a number of years ago and continued during this review period. The major field establishments undertook shallow water current meter work as part of their surveys, ranging from the Bay of Fundy to the eastern arctic. This information is incorporated into the appropriate charts and sailing directions.

The Section, in an advisory role, has assisted the Government of Newfoundland in the establishment of vertical control along the west coast of the province in 1977, and along the northeast coast in 1978.

D. L. DeWotfe

Metrology

It is Metrology's function to investigate, evaluate, and apply new marine science and survey measuring techniques by:

(a) managing contracted research projects for BIO in which the development of new measuring techniques is important;
(b) operating specialized facilities such as the Instrument Development Shop, the Standards Laboratory, and the Technical Reference Library; and
(c) serving as a small centre of excellence on measuring techniques in the ocean for marine laboratories on the east coast of Canada and industry.

Metrology attempts to contract out all major development projects and minor development or construction projects for which an adequate specification can be written while maintaining its internal program at a level sufficient to allow it to collaborate with Canadian industry in many areas of ocean technology.

D. McKeown

Irving Whale

In June 1977, a third attempt to measure the oil remaining in the sunken oil barge *Irving Whale* was made. The method used was identical to that described in the previous Biennial Review; however, the Sea Rover vehicle had been improved by the addition of a gyro compass and more powerful drive motors. Also, improvements to the acoustic positioning system permitted a much more accurate definition of the vehicle position relative to the barge.

The method of detecting an oil-water interface using the change in attenuance of sound through oil and water proved to be usable and all eight tanks were sounded. However, the fenders on the outside of the barge complicated analysis of the results. These fenders produced an effect very much like that of the lip on the oil drum as described in the previous Review. Further investigation aimed at extending the method to other tank geometry and cargoes has been terminated because of lack of resources.

K. George, D. McKeown, S. Young, D. Harvey

Bottom Sampling

Drilling for bedrock cores has developed to the state where it is now considered an integral part of BIO offshore geological and geophysical surveys, the equipment being routinely operated by non-Metrology personnel. Modifications are continuing to improve reliability and ability to recover difficult-to-core material (such as young or badly fractured formations or glacial till overlying bedrock).

Metrology is assisting Dalhousie University (Halifax, NS) and AGC to extend drilling capability from the present 650 metres water depth to

1000 metres. A British company operating in Australian waters has recently used commercially produced versions of the drill with considerable success.

Since the purchase of an Institute of Geological Sciences (UK) designed vibracorer, several sediment sampling programs have been carried out with Metrology's assistance. The equipment, as received, was not suitable for operations from BIO ships so sever& modifications to the basic operating system were carried out. Work is still continuing to improve the reliability and ease of operation.

A miniature vibracorer "Portavibe" has been developed in co-operation with AGC for use through ice and has been reported in the Geological Survey of Canada "Report of Activities". The unit has seen limited service but will be used this year in a sampling program in the Bay of Fundy.

The normal method of locating a suitable seafloor site for drilling entails doing a seismic survey using a system such as the Huntec high resolution seismic system boomer. This identifies a general area, but there is a need to get more detailed information at the time the electric drill is being positioned in order to place the bedrock within reach of the 6.7-metre drill extension. A 200-joule mini-sparker mounted on the drill was first tried but problems associated with secondary emission of energy from the drill frame and pressure cases obscured the shallow seismic events of interest. To overcome this problem we propose to use a conventional shipboard source such as a broadband boomer, or in some cases an echo sounder, to generate the acoustic signal while retaining the receiving hydrophone on the drill frame to minimize the area of insonification and to improve the signal-to-noise ratio and thus record quality.

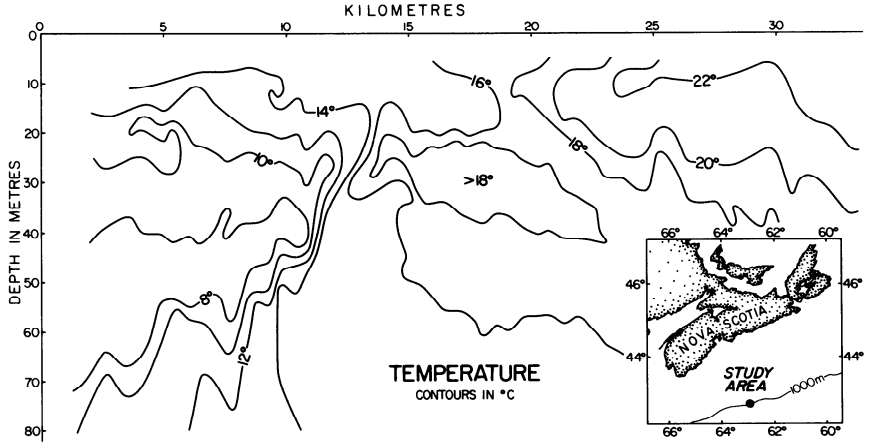
J. Brooke, G. Fowler, P. Kingston, W. Whiteway, R. Cassivi, D. Harvey, D. Knox

Physical Oceanographic Sensors

Routine recalibration of CTD systems has continued to be the main activity of the Standards Laboratory. This work is in support of all users of BIO CTD units including local universities. This routine work has brought to light discrepancies in conductivity measurement that are still under investigation and has pointed to the need for better pressure measurement when the CTD is used in the deep ocean. Collaboration on these problems continues with NRCC and Guildline Instruments, Ltd., Smiths Falls, Ontario.

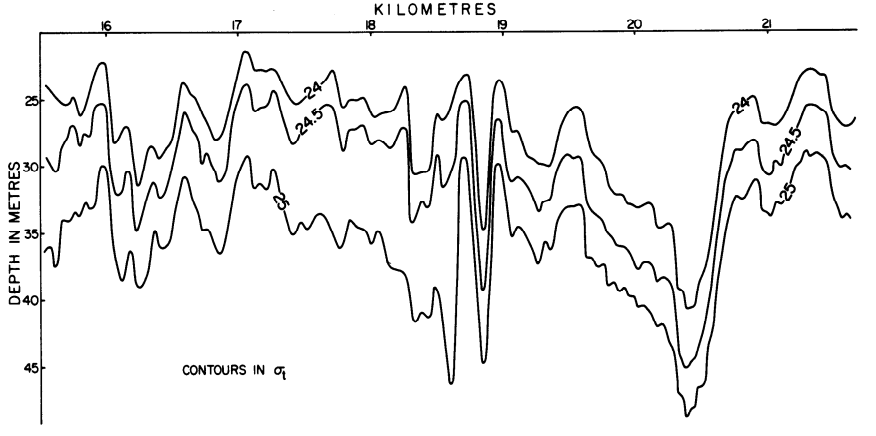
The development of computer software for data acquisition on the HP 2100 shipboard computers, using the disc-based Real Time Executive (RTE) system is now complete. The programs, which are versatile and have applications beyond CTD data acquisition (e.g., acoustic positioning data), are in routine use and final documentation is in preparation.

The CTD and Batfish variable depth towed body have continued to be used in conjunction with Coastal Oceanography's (AOL) Shelf Break Dynamics Program. As well as sections mapping the position of fronts, much information on internal waves was obtained. This information is still being analysed. However, examination of the records showed structures that appeared to be unresolved at the 600 metre to 1 kilometre cycle rate of the Batfish. An experimental cruise was therefore undertaken in August 1978 during which the horizontal cycle of the Batfish was reduced below 100



A typical section through a front between cool coastal water on the left and warm Gulf Stream water on the right. (BIO 5196-2)

metres by reducing the vertical excursion using computer control of the turning points and by increasing the vertical speed as far as was consistent with obtaining a reasonable length of tow before a mechanical breakdown occurred. With the improved horizontal resolution, almost all the features found appeared to be well resolved. Large amplitude internal wave trains were found, which indicate that the internal wave field is not homogenous. This finding agrees with the surface manifestations on satellite photographs of what are believed to be the same type of large amplitude internal wave trains. The detailed analysis of the data has only begun and will take considerable time to complete.



Large amplitude internal waves in the thermocline on the Scotian Shelf close to the shelf break: a variety of horizontal scales is shown. The location of these waves was immediately south of the front in the preceding figure. (BIO 5196- 1)

A further joint cruise took place in 1977 with Professor Kroebel and his Kiel University (Germany) group. Broad agreement was obtained between the Guildline CTD and the Kiel multisonde measurements of pressure, temperature, and conductivity; differences were well accounted for by small constant calibration offsets, in contrast to previous intercomparison cruises where the discrepancies were embarrassingly large. However, large discrepancies remain in light attenuance measurements Problems encountered in this work have led to an improved frame design for the multiparameter CTD and rosette sampler in which the interference of the frame with the water flow to the sensors has been reduced.

The majority of Institute CTD users wish to measure more than these three basic parameters. To meet this requirement, Metrology has begun to integrate various existing sensors into a system with provision for new sensors. The unit, known as a multiparameter CTD (MPCTD), is based on a Guildline Model 8705 digital CTD. The BIO Larsen light attenuance meter and a General Oceanics rosette water sampler have been integrated with the CTD on a framework that protects them during sea operations. The digital code used to transmit data to the surface has been altered to a biphase code and teletype format to provide better noise immunity, limited error detection, and availability of a computer-compatible data format. Systems Engineering (see IF) built a microprocessor-based shipboard control and display unit to compute salinity in real time and display this along with the conductivity, temperature, depth, light attenuation coefficient, and other parameters when more sensors are added. Future plans include the purchase and integration of an acoustic altimeter plus a bottom contact alarm, a dissolved oxygen sensor, a two-component current meter, and a two-way data command telemetry system on a single conductor cable.

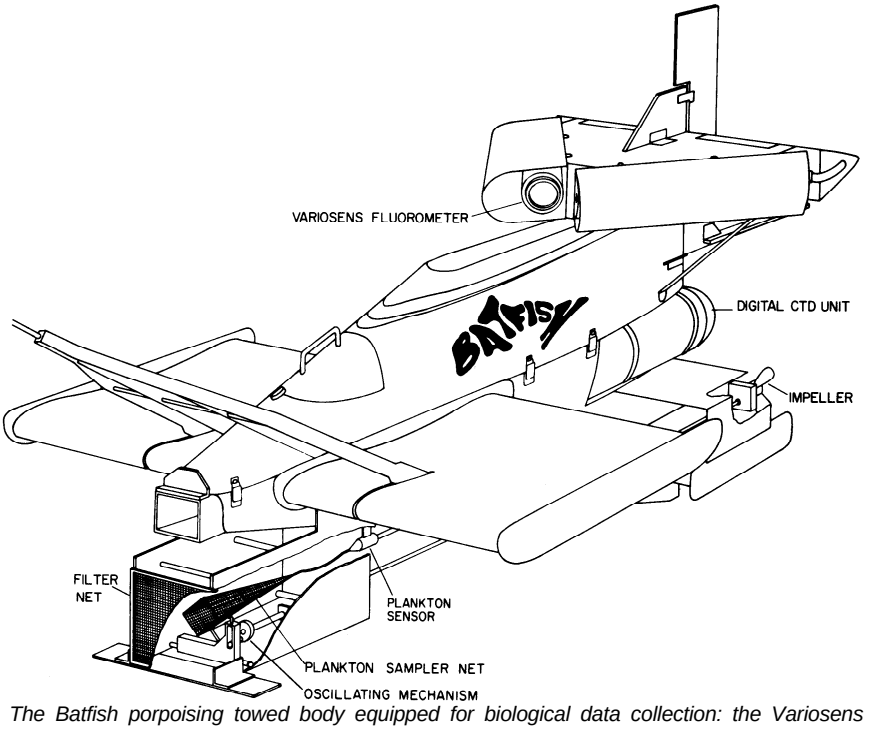
Between development phases, the unit has been extensively tested at sea on both engineering trial cruises and by scientists from Chemical and Coastal Oceanography (AOL), Biological Oceanography (MEL), Environmental Marine Geology (AGC), and McGill University (Montreal, PQ) on data production cruises. This close collaboration with users should enable us to provide a system suited to their needs.

A. Bennett, P. Thorburn, J. Betlem, M. Stepanczak, S. Young, E. Phillips, G. Dubois

Biological Oceanographic Sensors

The variability (both spatial and temporal) of phytoplankton and zooplankton in our oceans has generated the need for high resolution and rapid profiling of these organisms. Metrology has been involved in a program with Biological Oceanography (MEL), the NRCC, and Guildline Instruments, Ltd. in the development of such biological instrumentation and measurement methods. The program of chlorophyll *a* measurements with the Variosens fluorometer has undergone instrument sea trials, verification of data, and, more recently, direct involvement in specific MEL programs. One such collaborative effort with Biological Oceanography has resulted in an ecosystem study off Yarmouth, Nova Scotia, which showed anomalously high chlorophyll levels and evidence of local upwelling driven by tidal currents in the same area.

During the past two years, the program of *in situ* detection of zooplankton has undergone instrument sea trials in the laboratory and at sea. The

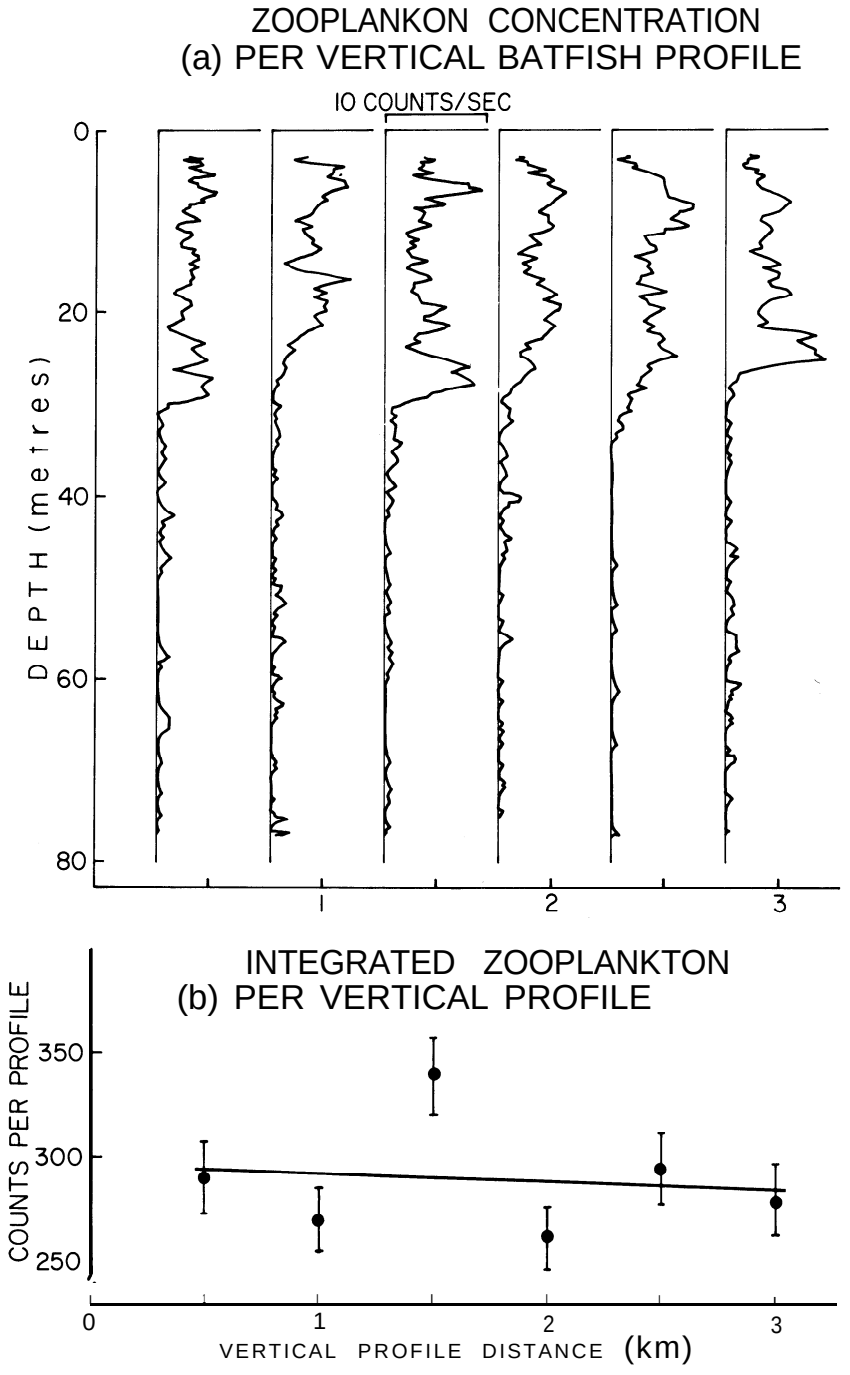


The Batfish porpoising towed body equipped for biological data collection: the Variosens fluorometer is used to measure in situ *chlorophyll* a, *which can be related to phytoplankton biomass concentration, and the undercarriage assembly consists of an electronic zooplankton counter and sampler net. (BIO 4923-2)*

zooplankton sensor was designed by Dr. Dauphinee of NRCC and prototype units were manufactured by Guildline Instruments Ltd. One aspect of development has been the design of a sampler net (see figure above) that would concentrate and feed zooplankton into the sensor and, above all, would not clog with algal matter during continuous towing. This problem was alleviated by oscillating the sampler net from side to side at a frequency of 5 hertz thus enabling a transverse flow of water through the side of the net and maintaining open mesh pores. The result allows continuous towing for periods of up to 6 hours. The major thrust of the program, however, has been the verification of our data by comparison of zooplankton catches with larger plankton nets (such as MEL's BIONESS) and calibration of the sensor enabling physical measurements of length and volume for individual zooplankters. A first-order calibration algorithm has been generated and has been tested on individual animals by comparing their dimensions obtained with the algorithm (using an *in situ* electronic measurement) against those dimensions obtained from microscope measurements. We obtained reasonable agreement with a ±20 per cent variation.

During the ongoing program of sea trials, the electronic zooplankton counter has also been involved in two specific biological programs with Biological Oceanography - one in the region of the Scotian Shelf break and the other in the coastal upwelling waters of Peru. Sample data from the Peru expedition are shown.

A. Herman, M. Mitchell, S. Young



Zooplankton concentration per vertical Batfish profile for six successive profiles. The highest concentrations consist mainly of copepods and are visible in the upper layers from 0 to 30 metres deep. The copepods migrated down during the day. (BIO 4923-9)

Air-Sea Instrumentation

The stable tower installed off Halifax Harbour in the summer of 1976 (see Biennial Review 1975-76) was used throughout the winter of 1976-77 for air-sea interaction studies (see Ocean Circulation, AOL) and as a wind speed and direction reference for the testing of the CODS's buoys, which were moored in the adjacent area. These programs continued until early January 1978 when a severe storm caused the loss of two CODS's buoys and toppled the stable tower. The tower and virtually all its mooring assembly were recovered and returned to BIO. The prime contractor, Whitman Benn and Associates, Ltd., Halifax, NS, is still investigating the matter. It is suspected that leakage of buoyancy tanks between regular inspection trips to the site may have caused the failure. There is also an indication that some broken shackles may have parted at 50 per cent of their rated load.

The MK8 thrust anemometer (see previous Biennial Review) was slightly modified to prevent freeze-up of rain around the thermistor enclosure. It was used in the field on the stable tower and survived vibration and cold-chamber tests in the laboratory at Hermes Electronics, Ltd., NS. All results indicate that this is a viable instrument for measuring turbulence, wind stress, and heat flux on stable platforms at sea and that it may have potential for manufacture in limited quantities.

In the past two years, Metrology has designed and constructed two prototype pressure-sensing buoys in conjunction with the Air-Sea Interaction Group of Ocean Circulation (AOL). The buoys are free floating and are equipped to measure atmospheric pressure fluctuations near the water surface, as well as the pitch, roll, vertical acceleration, and compass direction of the buoy itself. These data are transmitted via a digital telemetry system to a shipboard receiving unit where they are logged on a computer and/or a casette recorder. The telemetry system will accept 1 to 15 analog or digital sensor inputs and has 8 selectable sampling rates in the 0.5 to 64 hertz range. The receiving station provides analog outputs of all parameters for real-time monitoring purposes.

The prototype buoys were tested in Bedford Basin, then deployed in the JASIN experiment from the WHOI ship *Atlantis II* during July and August 1978 (see also Ocean Circulation, AOL).

A variant of the data telemetry system of the pressure sensing buoy was created for the Chemical Oceanography/Ocean Circulation (AOL) carbon dioxide flux experiment on Sable Island. Data from air-sea interaction sensors such as thrust anemometers and a "Barringer" carbon dioxide sensor are digitized and transmitted to a remote recording station either via a radio link or along a cable. This system can be adapted to future experiments of a similar nature but with different sensors simply by changing the interface card associated with each input.

J. Brooke, J.-G. Dessureault, P. Thorburn, D. Harvey, D. Knox

Mooring Program

A joint program between the Metrology and Ocean Circulation Divisions (AOL) has been established to study the performance of oceanographic mooring systems and evaluate possible inclusion of new materials and components.

Considerable attention has been placed on the evaluation of Kevlar, a new synthetic fibre, as a replacement for metallic mooring lines. Several experimental moorings have been set using the material and the results obtained have been incorporated in a paper presented at a conference. Problems have been encountered with unexplained strength losses after exposure to the marine environment but work on the material is continuing.

A computer modelling program for the design of moorings has been adapted from that in use at WHOI. A major segment of this activity has been the establishment of a library of physical and hydrodynamic characteristics for the equipment in use at BIO. Models of BIO subsurface floats have been towed in the tank at CCIW to determine both drag and stability characteristics. Although most units were found to be stable, some problem exists with the accurate determination of drag coefficients.

The mooring program has been expanded to include over the side handling of electromechanical cables, and emphasis is being placed on the development of a lightweight larger diameter metering block, the proper winch storage of cables, and the interaction of cables and attached instruments in non-static situations.

G. Fowler, J. Brooke, W. Whiteway, K. George, B. Nickerson

Marine Geodesy

BIONAV, BIO's integrated navigation system, which consists of a set of programs to run on computers already a part of BIO ships' navigation systems, was developed in co-operation with the Navigation Group of Hydrography Division (AOL), and is described under their section of this Review.

One of the main navigation aids available to the increasing marine traffic in the Canadian Arctic, including BIO ships, is the Transit satellite navigation system. It uses satellites in polar orbits, which causes problems in high latitude performance due to interference between different satellites and poorer ship-to-satellite geometry there. These problems can be overcome by using computer-controlled receivers and a novel method of computing the position fix. Convenient opportunities for testing these procedures has led to participation in two arctic sea-ice experiments, AIDJEX and LOREX. Careful analysis of data previously collected during AIDJEX indicates that the 75 metre positional accuracies achieved were limited by the equipment used. The Division has responsibility for navigation on LOREX during which three ice camps will drift across the North Pole in early 1979. Improved Transit receivers, similar to those on BIO ships, and BIONAV software will be used. The high-latitude performance of BIONAV is expected to benefit from the results of LOREX.

Sea-surface topography from satellite-borne radar altimeters provides both geodetic and oceanographic information. However, it is still an experimental tool. The goals of the Hudson Bay Experiment (HBE), co-ordinated by the Division and involving a number of Canadian and West German investigators, are: to use radar altimetry from the GEOS-3 satellite of NASA to compute the ocean geoid over Hudson Bay; to attempt to recover the tidal signal; and to investigate methods of improving satellite orbital accuracies by using local tracking data. Pre-processing is complete on the Doppler

tracking data obtained during the four month data acquisition period. Work will continue once the corresponding altimetry data have been received from NASA.

D. E. Wells

Acoustic Positioning

During the past two years, the Ocean Circulation Division (AOL) has constructed a set of vertical current meters to provide the Division 'with the facility to make measurements of small vertical currents. In March-April 1978 these, along with similar units from France, were deployed in the Labrador Sea (see Ocean Circulation, AOL). The Metrology Division created an acoustic positioning technique, which periodically positioned these units once their general location had been found by the French system. Subsequent to this, an experiment was conducted to determine the accuracy of this method. A proposal based on these experiences has been prepared that outlines the details of a more advanced system for positioning vertical current meters.

New survey methods for locating seafloor transponders have been examined at sea and an array used to provide high-resolution positioning for certain BIONAV trials. Planning is underway for further experiments with ocean bottom transponders next year in support of other programs of Ocean Circulation (AOL) and Environmental Marine Geology (AGC).

Since 1976, work has continued on the development of a short-baseline positioning system utilizing two hull-mounted transducers and one towed hydrophone. The electronics associated with measuring the hydrophone signals and calibrating the array have been built and tested. A microprocessor based range and bearing calculator/display has also been built that displays range and bearing in real time. Results indicate the short baseline system (SBS) as presently constructed will only give bearings to a range of 2000 metres and only when an acoustic transponder is used. The problems mainly stem from a poor signal-to-noise ratio, especially when the ship is holding station at which time bubbles from the propellers are pulled under the ship and across the transducers.

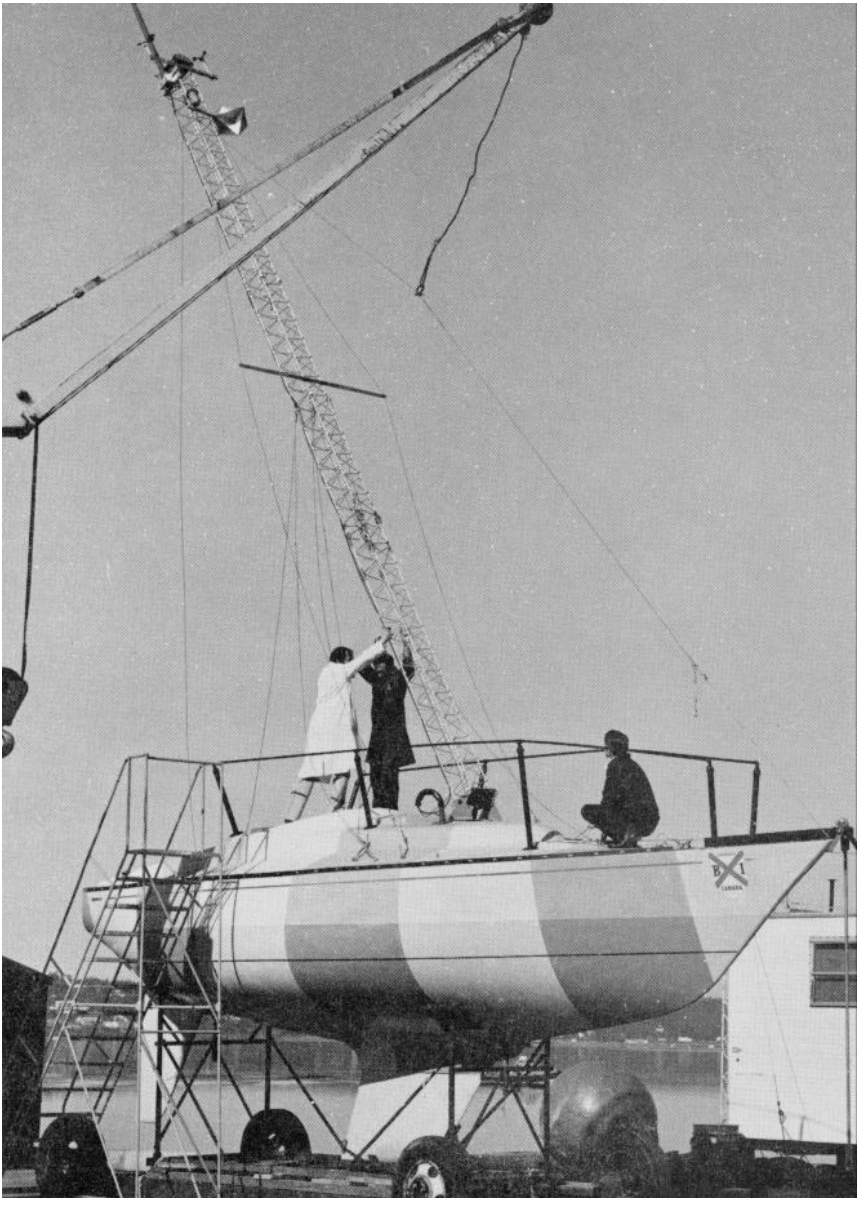
Support is also being provided to Huntec (70), Ltd., (Toronto, Ontario) in their program to develop an acoustic positioning system using transducers spaced a fraction of a wavelength apart.

D. Mc Keown, K. George, A. Atkinson, B. Harding

Contract Management

The Division continues to provide scientific contract management for the CODS program (with the assistance of Ocean Circulation, AOL) while Hermes Electronics, Ltd., is the contractor. Hermes moored a large fibreglass discus buoy on the Scotian Shelf, 160 kilometres south of Halifax, to record wind speed and direction, air pressure, and temperature for Coastal Oceanography (AOL). Except for a visit in March to change data tapes, the buoy remained on station from December 1976 to July 1977, producing data of excellent quality. The program is now concentrating on investigation of sensor reliability and analysis of buoy motion data. Eight large discus buoys with power generators have recently been sold to the Cubic Corporation of the United States for use by the United States Navy.

CODS has led Hermes to develop drifting buoys for the FGGE. These units telemeter air pressure and sea temperature via a satellite. Of 20 that were deployed in the North and South Atlantic Oceans, and the Pacific



The yacht hull used as an oceanographic buoy being prepared for tow to the experiment site. (BIO 4070-10)

and Tasman Seas, 17 gave continuous results in excess of their expected battery life. Several came ashore previous to battery depletion. Some were retrieved and placed back in the oceans and nine buoys were still transmitting after 450 days at sea. A further 78 drifting buoys are being manufactured for the FGGE.

The Division has also provided the Seabed Program of Huntec (70) Ltd. (see AGC) with ship time for engineering trials and professional and technical consultation and assistance. It participates extensively in this contract's management. While not directly managing other contracts within BIO, staff of the Division have acted as links between industry and Institute scientists. For example, we have been assisting the Marine Fish Division to specify and purchase a Batfish biological sensor system from Guildline Instruments, Ltd.

J. Brooke, D. McKeown

Experimental Yacht Buoy

Since the last Review, the experimental yacht hull buoy, the Division's contribution to the CODS program, was tested again in the open sea near the BIO stable tower. The modifications include a new mast, a new radar reflector, a new mooring (including nylon rope), and the addition of ballast.

To measure motion, three accelerometers were used with a vertical gyroscope or mounted on a long time-constant pendulum to measure the motion directly without having to correct for the rotation of the axis. The measurements include pitch, roll, heading, surge, sway, heave, mooring line tension and angle, water speed along the hull, wind speed, and direction. Although we were unable to record data during the most severe storm encountered, the yacht buoy survived, through winds of about 22 metres per second and waves to 15 metres height peak-to-peak, for several hours. The buoy motion and the mooring tension are being analysed (with the assistance of Ocean Circulation, AOL) to record the response of the yacht hull to wind and wave forcing. The results are compared with wave measurements obtained from a nearby Wave-Rider wave measuring buoy.

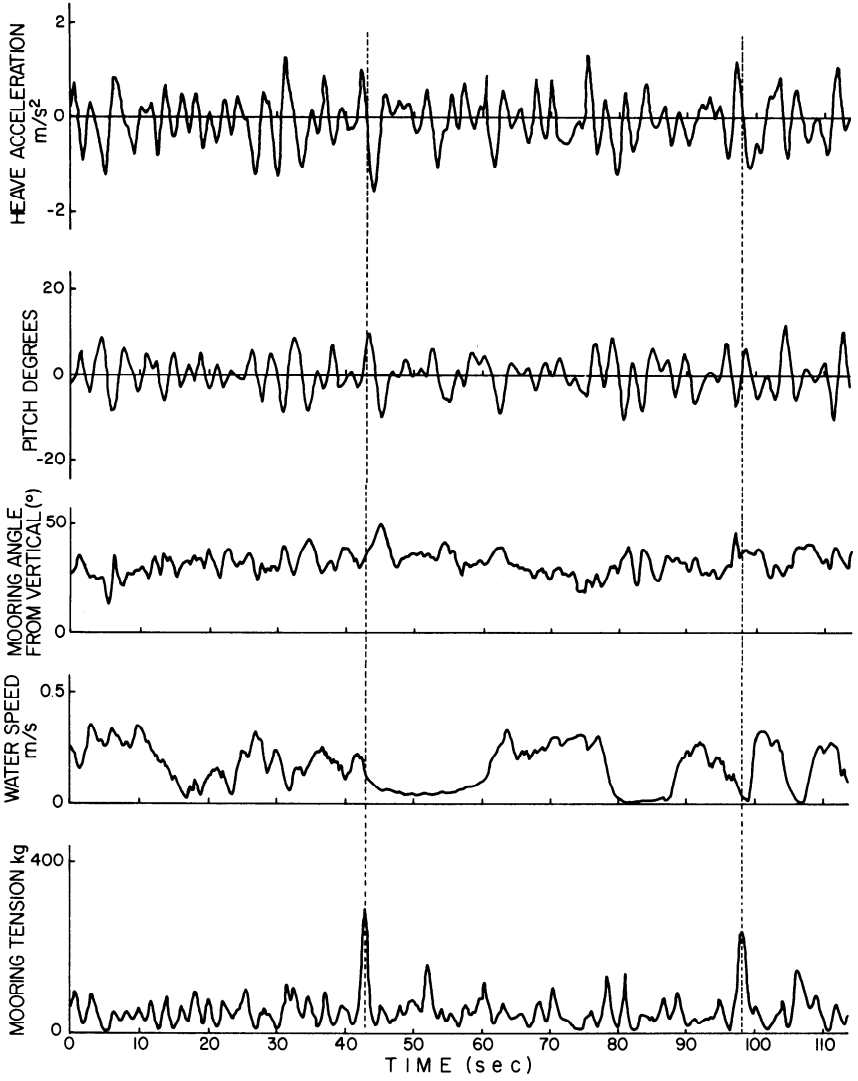
A more robust and durable anemometer unaffected by the motion of the mast is being designed, constructed, and tested. It will then be installed on the yacht buoy. It is planned to moor the buoy again over the winter of 1978 to test its endurance and to collect additional motion and meteorological data. Occasional high tension and large roll during the storm mentioned above and similar storms will also be investigated.

J.-G. Dessureault, J. Brooke, D. Knox, D. Harvey

Support

In common with many other units at the Institute, Metrology directly supports the programs of others. Of paramount importance is the Instrument Development Shop - a group of skilled instrument machinists and mechanical innovators who create, construct, and test a wide range of devices for Institute staff. They also manage contracts for outside machining services and give advice and assistance to Canadian industry whenever possible.

P. Kingston, D. Knox, G. Connolly, W. Hall, E. Moody



Sample recordings from the yacht buoy experiment. (BIO 4608-6)

ToC

Ocean Circulation

The Ocean Circulation Division tries to understand the physical processes in the ocean. These processes determine the distribution and transfer of momentum, heat, salt, and energy throughout the ocean depths over horizontal scales of several metres to thousands of kilometres and time scales of seconds to centuries. This work ultimately furthers our ability to predict the climatic response of the ocean and the ocean/atmosphere system or to predict the distribution and residence times of pollutants introduced into the world ocean. The individual projects pursued by our personnel fall into three main classes. Firstly, there are field experiments aimed at measuring properties of the velocity, temperature, and salinity fields over tens of hundreds of kilometres for a half a day to months. Over the last two years, examples of these types of projects are the Labrador Sea project and the low frequency eddy studies. Secondly, there are field experiments designed to measure the short spatial and time scales in the ocean and the atmospheric boundary layer above the ocean, which enable us to determine the turbulent fluxes of heat, momentum, etc., within the ocean or between the ocean and atmosphere and to relate these exchanges to the large-scale fields around. These experiments include the work on wind stress and heat flux, oceanic microstructure, and open sea wave-growth. Finally, there are a number of theoretical and numerical studies of physical oceanic processes, which are sometimes linked with the larger field programs (for example, the Labrador Sea numerical models) or else point the way for future field programs by exploring more fundamental aspects of general, time-dependent, baroclinic, geophysical, fluid dynamics.

The Division's programs are frequently pursued in co-operation with the other research divisions within AOL. International co-operation also continues, in particular with WHOI on low frequency eddy studies, with the Museum nationale d'histoire naturelle, Paris, on a deep convection study of the Labrador Sea, and with numerous European and American groups in JASIN.

Our personnel also serve on a number of national and international working groups, panels, and committees seeking to define programs, set standards, plan experiments, and determine where oceanographic resources should be deployed in the future. With the increasing pressure for exploitation of mineral and fisheries resources off our coasts, we are being asked more frequently by industry and other government agencies to provide advice, data, evaluations, and support to engineering designs, environmental impact studies, and fisheries management experiments.

R. A. Clarke

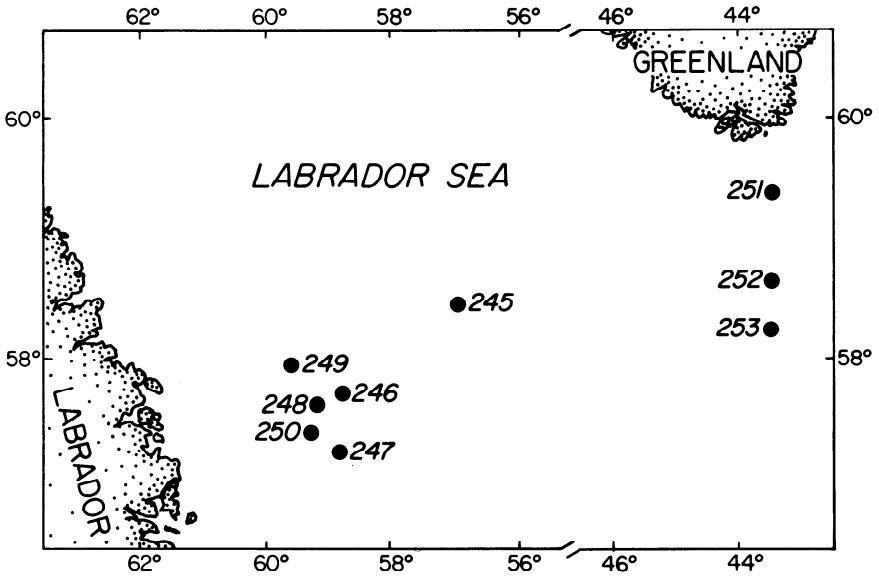
The Labrador Sea Project

This project began in 1976 and was continued with a large field program during 1977 and 1978. Its objectives are to obtain: (a) good data on the Labrador Current from moored current meter arrays and repeated CTD surveys, (b) estimates of the flow in and out of the Labrador Sea across 44°W that could be used as an open boundary condition on a numerical

model of the Sea, and (c) measurements of the formation of Labrador Sea water through deep convection during the winter.

The Labrador Current. The Labrador Current flows along the east coast of Newfoundland and transports cold and relatively fresh arctic water to the south. Oceanographers have long recognized the current's strong influence on the fisheries and climate of eastern Canada. The first and only major study prior to 1977 of the current was undertaken between 1928 and 1933 in what became known as the Marion and General Greene expeditions of the US Coast Guard. The results of this study have been for 50 years the main source of such information on the area; however, because of hydrocarbon exploration and the recently established 320 kilometre fishing zone, a new study using moored internally recording current meters as well as measurements from a ship became necessary. In October 1977, CSS *Hudson* placed five current meter moorings across the shelf and slope off Nain, Labrador, in water depths of 140 to 1500 metres. In addition, 125 stations arranged in 13 lines across the shelf and slope from Frobisher Bay to the Strait of Belle Isle were occupied. At each station, temperature, salinity, dissolved oxygen, nitrate, silicate, and phosphate were measured at various depths with the co-operation of Chemical Oceanography Division (AOL). In January and February 1978, two of the moorings placed in October were recovered and six new moorings were set across and along the slope. Another set of stations was occupied to map the offshore branch of the Labrador Current.

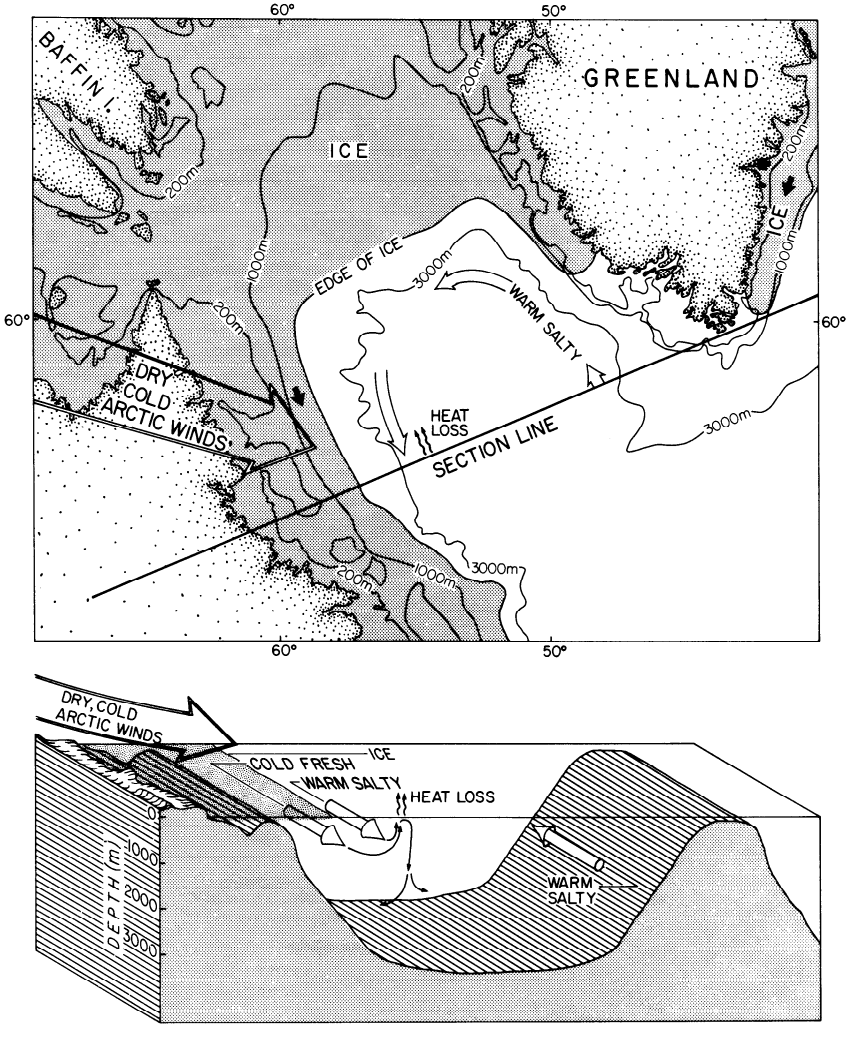
Hudson returned in July 1978 to recover the remaining moorings. Five of nine moorings had lost their upper buoyancy and instrumentation and two were lost completely, presumably due to encounters with icebergs with drafts deeper than 100 metres.



Current meter moorings laid during January and February 1978 on the continental slope off Nain, Labrador, and south of Cape Farewell, Green/and. Note that the longitudinal scale is broken between 46°W and 56°W. (BIO 5121)

Cape Farewell to Flemish Cap Section. Three current meter moorings were set at the IOOO-, 2000-, and 3000-metre isobaths along 43°3O'W just south of Cape Farewell for two months beginning in early February 1978. During this period, CTD stations were occupied along the current meter line, then south to Flemish Cap, and finally west along 47°W across Flemish Pass to the Newfoundland Grand Banks. These data sets will provide estimates of the flows of various water masses in and out of the Labrador Sea.

Deep convection study. In certain restricted areas of the world oceans, winter cooling increases the density of surface water, which then mixes with subsurface warm salty water, and then cools again to form an even



The area of the Labrador Sea where mixtures of cold, fresh, surface water and warm, salty, subsurface water are cooled by northwest winds to form Labrador Sea water. (BIO 5136)

denser water mass and so on until much of the water column is at the same density. Through this process a large volume of dense water can be formed that then spreads at depth under the lower density surface waters away from its area of formation and forms an intermediate or deep water mass. The ocean thus responds to climatic variations by forming larger or smaller amounts of new deep water depending on the severity of the winter, and heat is released to the atmosphere in the process.

One such area is the western side of the Labrador Sea, where mixing and cooling near the surface form Labrador Sea water, which then spreads across the western North Atlantic at depths of around 1500 metres. We first observed this process in the Labrador Sea in March 1976, then returned to study it more extensively during March 1978, joined by French scientists and Metrology and Chemical Oceanography (AOL) staff. Vertical current meters were deployed and tracked to measure the vertical motions taking place as the new denser water sank. The oceanographic environment in the region of deep convection was monitored using current meter moorings and CTD stations. Dissolved oxygen concentration and carbonate content of the water were also measured to learn something about the gaseous exchanges of the atmosphere with the ocean.

Though the weather in 1978 seemed more severe than in 1976, deep convection was much less active. This may be due to the longer periods in 1978 when winds accompanied by snow came from the southeast in contrast to the cold dry northwest winds encountered in 1976. The sea and freezing spray conditions this year made it difficult to carry out almost all phases of the operation and hampered both equipment and personnel.

Long-term moorings on the Labrador Shelf. A long-term mooring program was begun in the autumn of 1978 to obtain up to 10 years of data, which could be used to study the seasonal and yearly variations in the Labrador Current since these may affect the climate and fisheries of the area. Three near-bottom moorings were placed in the current in the vicinity of Hamilton Bank; two on the offshore slope and one in the inshore marginal trough. These will be replaced at yearly intervals.

R. A. Clarke, J. R. N. Lazier

Low Frequency Eddy Studies

During the past ten years oceanographers have learned that low frequency (periods of weeks to months) fluctuations in oceanic variables such as current and temperature occur throughout the world ocean We are exploring these features by maintaining long-term moorings in several areas of the western North Atlantic Ocean, particularly in the Gulf Stream System. The worldwide study of ocean eddies has revealed the great spatial variability of energy contained in these fluctuations, and in particular a relationship between eddy energy levels and strong current systems such as the Gulf Stream. One of the main goals of eddy studies is to explore the link between the time-varying fluctuations and the general circulation.

From December 1975 until May 1977, we kept three deep moorings in place in a zonal array near 55°W longitude in the vicinity of the Gulf Stream. A fourth mooring maintained by WHOI near our own as part of their effort in the joint US-USSR POLYMODE program was combined

with the three BIO moorings to give a variety of zonal separations of up to 90 kilometres. Strong eddying motions with overall time scales of about 40 days and speeds of up to 60 centimetres per second were observed, and these were well correlated over 50 kilometre separations. The eddying currents were much stronger than the mean flow at the 4000-metre depth of the experiment, but definite mean currents of a few centimetres per second were observed to flow westward in the direction opposite to the surface Gulf Stream.

In May 1977, the 50°W Moored Array Experiment was begun. It involves a triangle of three deep moorings, with 50 kilometre horizontal separations, located south of the axis of the mean Gulf Stream at 50°W. Data will be gathered for one year to allow an investigation of the propagation characteristics of eddies at the 4000-metre depth, and to gain the first stable estimates of eddy energy, Reynolds stress, and mean flow in this area, which remains one of the major unexplored regions of the subtropical North Atlantic gyre. In December 1978, improvements in mooring technology that have been achieved in our Division over the last few years, will allow a vertical extension of the Array up to at least the 1000-metre depth into the base of the main thermocline. The Gulf Stream Extension region where the 50°W Array is located is of considerable interest to oceanographers, and our past and continuing co-operation with colleagues at WHOI and elsewhere greatly broadens our perspectives.

R. Hendry, R. F. Reiniger

Conductivity of Standard Sea Water

For many years oceanographers have used the IAPSO Standard Seawater Service (often referred to as “Copenhagen water” until 1975, thereafter as “Wormley water”) as the standard for salinity determinations. Recently, the laboratory salinometer has attained sufficient precision in measuring the conductivity ratio to point out slight variations in the conductivity/chlorinity relationship of the Standard Seawater. The UNESCO/ICES/SCOR/IAPSO Joint Panel on Oceanographic Tables and Standards requested four laboratories, including AOL, to undertake precise determinations of the conductivity ratio of 26 batches of Standard Seawater. These measurements verified that the Standard Seawater has varied by as much as 0.008 part per thousand in salinity from the conductivity/chlorinity relationship but generally remains constant to within ±0.003 part per thousand. Measurements of conductivity ratio, pH, and silica concentration were made for two different batches by Metrology and Chemical Oceanography (AOL) at various times since the water was collected and sealed in glass ampoules. Initial results indicate that silicate concentration does increase with time but conductivity ratio and pH changes are more random.

C. K. Ross

Instrumentation

The technical group has continued to support the research programs of the Division through the development of new instruments and methods, and the modification, maintenance, and operation of existing ones.

During 1977, three vertical current meters were constructed to measure deep penetrative convection. These instruments, a modification of those

developed at WHOI, are neutrally buoyant floats that are tracked acoustically and internally record vertical speed, temperature, pressure, and time. They have been ballasted to sit at the desired depth, used successfully, and recovered seven times during the Labrador Sea Experiment.

Studies designed to improve our mooring technology continue. Over the last few years, methods of controlling the corrosion associated with our stainless steel wire moorings have been perfected so that long-term moorings can be set with some confidence. The behaviour of our moorings in strong currents is being studied in the hope that long moorings can be set to place current meters into the core of currents such as the Gulf Stream.

N. S. Oakey, R. F. Reiniger

Sea Surface Wind Stress and Heat Exchange

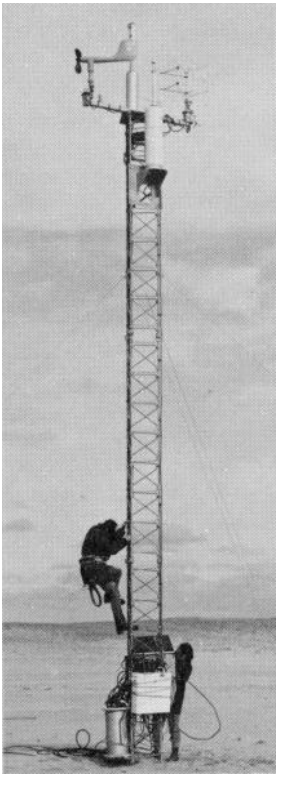
The atmosphere supplies momentum and heat to the ocean through exchanges across the sea surface. Within the atmospheric boundary layer momentum and heat are carried by turbulent fluctuations of wind and temperature. By measuring these fluctuations and averaging their products over suitable times (40 minutes), one obtains a direct measure of the wind stress and the heat flux. These measurements must be carried out from a very steady platform not large enough to affect the wind flow around it. For this reason, direct measurements of stress and heat flux by these techniques had not been made over the open sea for wind speeds greater than 15 metres per second.

Metrology (AOL) managed a contract for the installation and maintenance of a large stable platform 10 kilometres from shore near the approaches to Halifax Harbour. Using a BIO thrust anemometer, a thermistor and a wave staff, time series records of wind, air temperature, and wave height were obtained. A fast-response propeller anemometer and other sensors, operated by the Institute of Oceanography, University of British Columbia, obtained similar turbulence measurements, often simultaneously with ours. Data runs were obtained at wind speeds of up to 22 metres per second.

Wind stress twice as large and heat fluxes six times larger than those previously measured at sea were observed. Some of the wind stress data may have been degraded by the motion of the platform; however, the heat flux measurements are less sensitive to this problem. The ultimate goal of the wind stress measurements is to obtain a parameterization of wind stress in terms of the wind speed. This parameterization is usually given as τ (stress) = $C_D U^2$, where C_D is the drag coefficient and U is the wind speed. Earlier workers have suggested that instead of being constant, C_D may increase with increasing wind speed. Our preliminary results indicate that such an increase in drag coefficient does occur with increasing wind speed. On the other hand, the heat flux is a linear function of the product of the wind with the air-sea temperature difference over the range of our measurements.

With these data, values of the wind stress and heat flux have been obtained to sufficiently high wind speeds to include the large majority of the winds contributing to the mean monthly exchanges in most oceanic regions. Higher wind speeds, while not contributing significantly to the average

stress, may control catastrophic events such as storm surges and bottom water formation. It is hoped to extend these measurements to even higher wind speeds during a proposed future experiment with the Department



Measurements of air-sea exchange of CO_2 in the waters off Sable Island, NS, October, 1978. Top left (left to right): an aerovane anemometer, a CO_2 sensor, and a sonic anemometer. Top right: the ten-metre tower on the beach. Bottom: tower, generator hut, and data recording shelter. (BIO 5050-52-53, 58)

of Atmospheric Sciences, University of Washington, from an oil or gas platform in the North Sea.

S. D. Smith, R. J. Anderson, D. L. Hendsbee, F. W. Dobson

Air-Sea Exchange of Carbon Dioxide

In a joint project with Chemical Oceanography (AOL), we are measuring turbulent fluctuations of carbon dioxide concentration and wind, temperature, and humidity. By analysing these data, we are developing a method to determine the rates of transfer of carbon dioxide between the atmosphere and the ocean. Measurements were made at a tower on the beach of Sable Island during periods of onshore winds to study the exchange in an area relatively free of local sources of carbon dioxide.

S. D. Smith, R. J. Anderson, E. P. Jones (Chemical Oceanography)

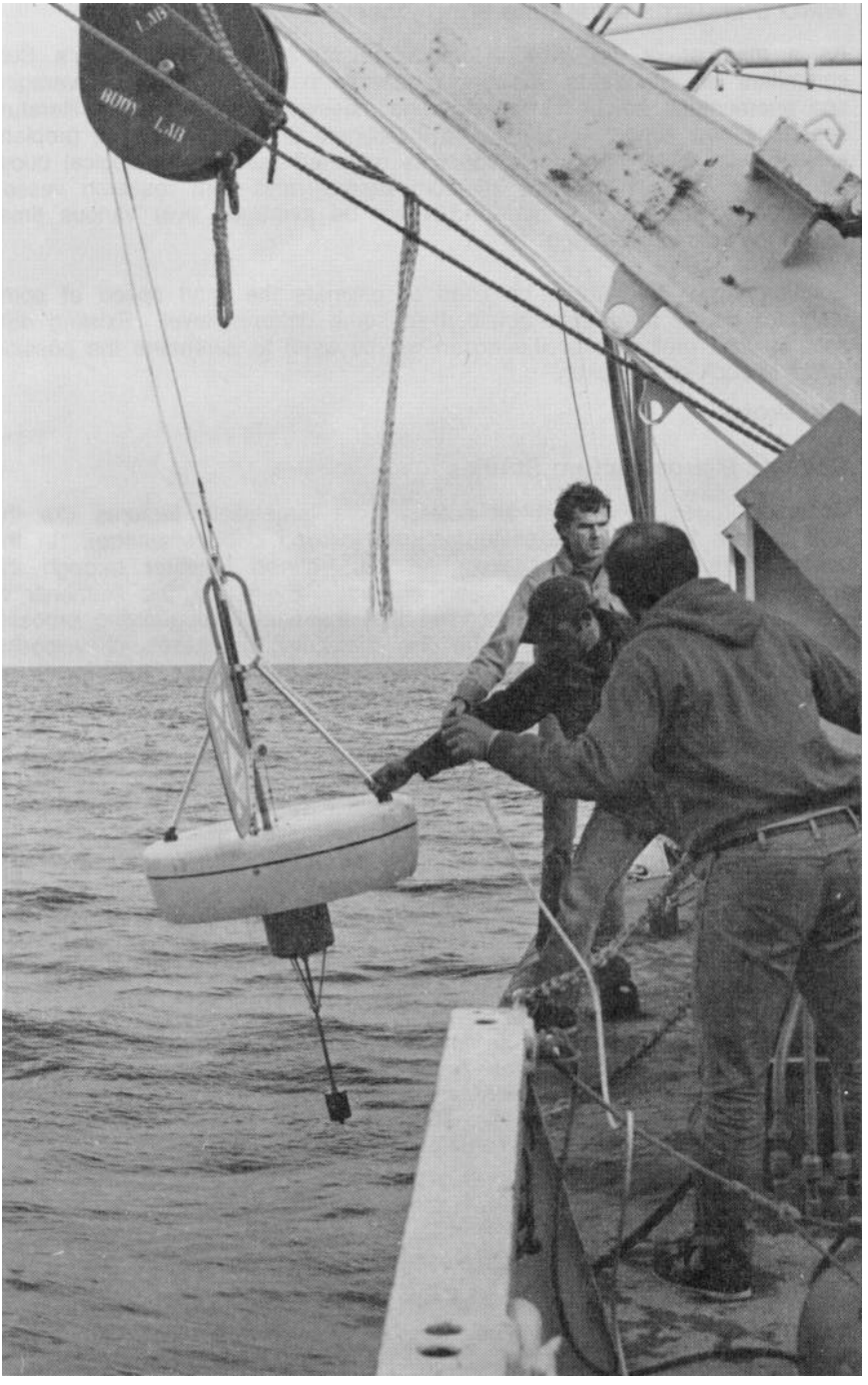
Wave Growth Studies

Research into the physical processes that underlie the growth of wind-driven sea waves has been focussed on the measurement of wave-induced fluctuations in air pressure. Begun in the early 1970s with measurements from small bottom-mounted towers in nearshore areas, the research has now been extended to include the open sea. There, the majority of the energy and momentum transfer from wind to water occurs, and the question of how the transfers take place (wave generation plays an important role, but no one knows how important) bears directly on our understanding of surface meteorology and the evolution of the upper layer of the ocean. Also, most recent wave prediction theories rely for their predictions on estimates of wave growth rates determined in nearshore experiments and, it is interesting to note, most of the proposed satellite sea surface "wind" measurements (SEASAT, for example) will in fact be wave measurements, converted to winds by inverting the available wave prediction schemes.

To measure wave growth rates in the open sea a small (1-2 metres diameter) surface-keyed pitch/roll buoy with a high-resolution air-pressure sensor has been developed and built by Paul Thorburn (Metrology). It is designed to be deployed for periods of 0.5 to 3 hours from a ship and to telemeter air pressure, true heave, pitch, roll, and compass direction data by radio link to onboard recording equipment. These data can then be converted into pitch/roll wave directional spectra and spectra of the energy and momentum inputs from the wind to the waves.

Two buoys were used at sea during JASIN 1978, on board R/V *Atlantis II* of WHOI. High-quality data in light winds, and low-quality data in winds up to 25 knots, have been recorded but not analysed. At the same time scientists from SIO and Stanford University measured the same wave field with a pitch/roll buoy of known characteristics and also a radar system as well as using measurements, when possible, from the NASA SEASAT-A satellite passes. Practical experience showed that various physical improvements are necessary before the buoys can be easily deployed from any ship and be expected to produce usable data.

F. W. Dobson



Pitch/roll buoy used *on the R/V* Atlantis-II *in the North Atlantic (300-400 kilometres west of the Hebrides) during JASIN 1978. (BIO 5097-20)*

WMO Standards for Marine Wind Observations

As a member of the WMO Commission on Marine Meteorology's Sub-committee on Standards, we are preparing standards for time averaging and anemometer height for making wind measurements at sea. A literature search is now almost complete. To investigate the time averaging problem, existing wind data intercomparison sets gathered from meteorological buoys off Halifax harbour (CODS's intercomparisons) and from research vessels and buoys during GATE and JASIN will be averaged over various times to find the optimum average.

Boundary-layer theory can be used to estimate the wind speed at some standard height from data obtained at some different level. Existing data sets of wind profiles over the ocean will be used to determine the possible errors in such an approach.

F. W. Dobson

Oceanic Microstructure Studies

Oceanic properties vary at all scales, from large-scale features like the Gulf Stream to very small-scale features (around one centimetre). In the ocean, water with different properties gets stirred together through the action of wind, waves, and ocean currents. Eventually the filaments of water become so closely intermingled that the final homogenizing process, called mixing, can occur through the molecular processes of viscosity, conductivity, and diffusion. The small-scale fluctuations that occur in this final stage of mixing are called microstructure.

Over the past two years our microstructure studies have been directed to making measurements within the surface layers of the ocean. We use a newly developed instrument, OCTUPROBE Ill (Oceanic Turbulence PROBE), to obtain vertical profiles of temperature and velocity fluctuations from the surface to as deep as 200 metres. By obtaining many profiles of the small-scale structure and at the same time measuring the larger scale structure using CTDs, current meters, and thermistor chains, we are attempting to piece together a picture of the processes putting energy into the mixed layer and causing it to deepen through mixing of entrained water at the bottom.

Recently, we participated in an international experiment, JASIN, designed to study the interaction between the atmosphere and the ocean by looking at as many scales of variability as possible in both. Octuprobe Ill was used to obtain the velocity microstructure in the mixed layer; this is a measure of the mechanical energy being dissipated into heat.

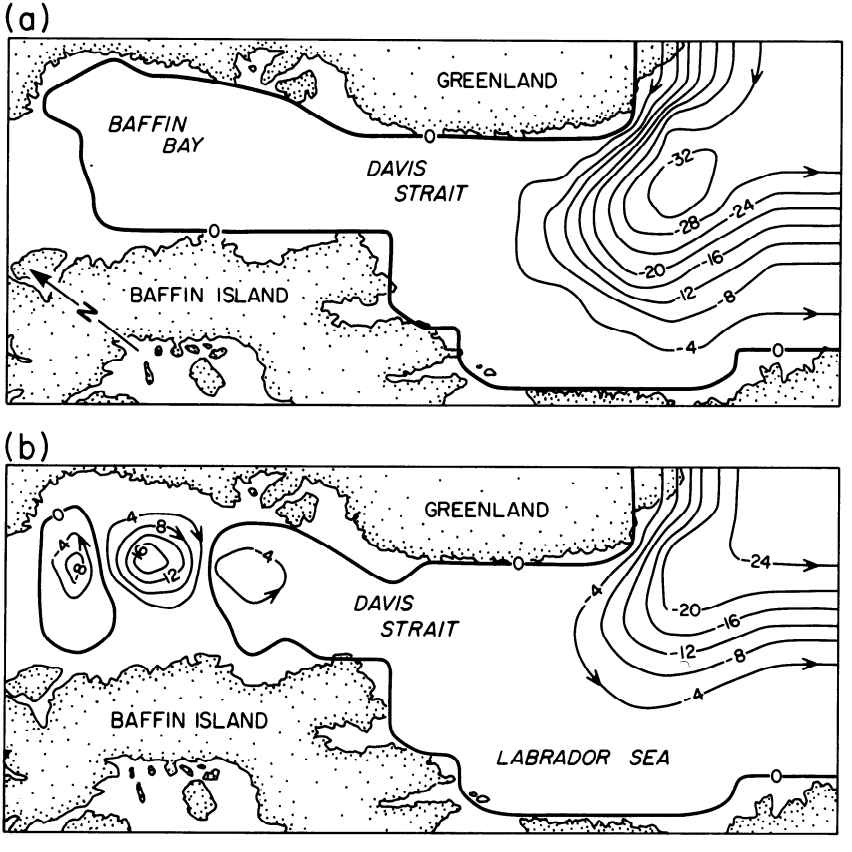
N. S. Oakey, J. A. Elliott

Numerical Studies of the Labrador Sea and Baffin Bay

Using a numerical model, we seek to describe the general circulation of the Labrador Sea and Baffin Bay and to determine the important factors that contribute to it. A numerical ocean model obtained from UCLA was adopted to run on the CDC 7600 at Dorval (PQ) and modified to refine the bottom topography and to include both bottom friction and the effect of storms of arbitrary strength and storm track. A co-ordinate transforma-

tion was also programmed so that the model can be used in an arbitrary orientation anywhere on the globe.

The program was then used to run barotropic (no variation with depth) models under various forcing conditions to test the effect of changing boundary conditions, bottom friction coefficients, and eddy viscosities. Two of these test cases are shown in the figures. In figure (a) an inflow is imposed around the southern tip of Greenland while in (b) a wind stress from the northwest decreasing from southeast to northwest is applied at the sea surface. Within the Labrador Sea, the large-scale barotropic circulation for both cases is similar because it is essentially determined by the topography. Although a wind stress distribution can generate a circulation pattern similar to that observed, the inflow south of Greenland is of immense importance in determining the overall mass transport. Hence one cannot expect reasonable results from the numerical model unless reasonably accurate transports across the eastern boundary are available.It should also be noted that in neither case does the flow from the Labrador Sea penetrate into Baffin Bay over the shallow water of Davis Strait. To obtain such flows, which observations indicate exist, one must consider a baroclinic (variation with depth) model.



Mass transport in sverdrups in the Labrador Sea and Baffin Bay. (BIO 5173)

The baroclinicity has been partially studied using a diagnostic baroclinic model. Here the density field is set to that observed. The model then computes the flows consistent with the density field in response to forcing at the sea surface and the boundaries. This model has been run on arbitrary data but it has not yet been run on real data. Since the data from some of the area are sparse and scattered in time and, since the density field changes with time, it is difficult to choose a density field that is representative of the sort of mean density field appropriate for such a diagnostic model.

When the work on the diagnostic model is complete, the model will be changed once more to allow the density field to be modified by the flow field (a prognostic baroclinic model) and then by using this ultimate model the actual physical processes occurring will be isolated and studied. At this stage smaller, finer, grid models embedded within the larger model may be developed to study the smaller scale processes that might be taking place. This has already been done at the barotropic model stage where the finer scale model of the Hamilton Bank area showed that the local topography tends to split the Labrador Current into an offshore and an inshore branch.

C. Quon, K. T. Tee

Three-dimensional Tidal Models

Tidal current models in shallow areas have usually used depth-averaged equations. In some cases, for example, computing fluxes of sediment and pollutant, the velocity profile must be known because the concentration of these materials varies with depth. The prediction of currents from multi-layered numerical models is very inefficient and complicated, and yields poor vertical resolution. We have developed simple models for computing both the first-order oscillating currents and the second-order residual currents, and we have investigated the dynamics involved. To determine the best form of the vertical eddy viscosity and to verify the model, three moorings with four current meters each were set for two months at the entrance to Chignecto Bay (NS) (with AGC). Future models will include various forcing mechanisms other than tides such as wind and density flow.

K. T. Tee

Circulation Models for Estuaries

There are two major difficulties in numerical modelling of estuarine circulations: the uncertainty in setting the vertical eddy viscosity coefficient and the open boundary problem, which involves the response at the estuary-ocean boundary to various forcing mechanisms such as wind and river run-off. In this study, we are developing a simple two-dimensional (channel) low-frequency estuary model that will be used to investigate the open boundary problem. We hope that by theoretical calculation and experimental observation, obtained in co-operation with scientists in Coastal Oceanography (AOL), the two major difficulties will eventually be solved and the circulation in stratified systems will be modelled properly. Our ultimate goal is to apply the models to some of the coastal basins, such as the Gulf of St. Lawrence.

K. T. Tee, T.H. Lim

Studies in Rotating and Stratified Fluids

In the ocean and atmosphere, baroclinic instability of sheared currents is an important mesoscale energy conversion mechanism. Recently we have been investigating numerically baroclinically unstable phenomena, which are well-defined and can be investigated in the laboratory. One such problem is the so-called symmetric baroclinic instability, which was reported to have been observed in a laboratory flow during the early 1970s; however, the result was controversial. I have simulated the system numerically, and I hope to be able to settle the arguments in the near future.

A closely-related problem is concerned with spatial oscillations in a non-uniformly heated rotating fluid, a problem recently studied analytically by others and that is related to the predicted existence of narrow sinking regions in the oceans. I have successfully confirmed the linear theory and extended the investigation into the high non-linear regime.

The problem of non-linear triad interaction of finite amplitude baroclinic annulus waves in a continuously stratified and sheared zonal current will be studied next. A mathematical algorithm has been formulated and published. It is hoped one will be able to study vascillation of baroclinic waves in much greater detail than ever before.

C. Quon

Continental Shelf Studies

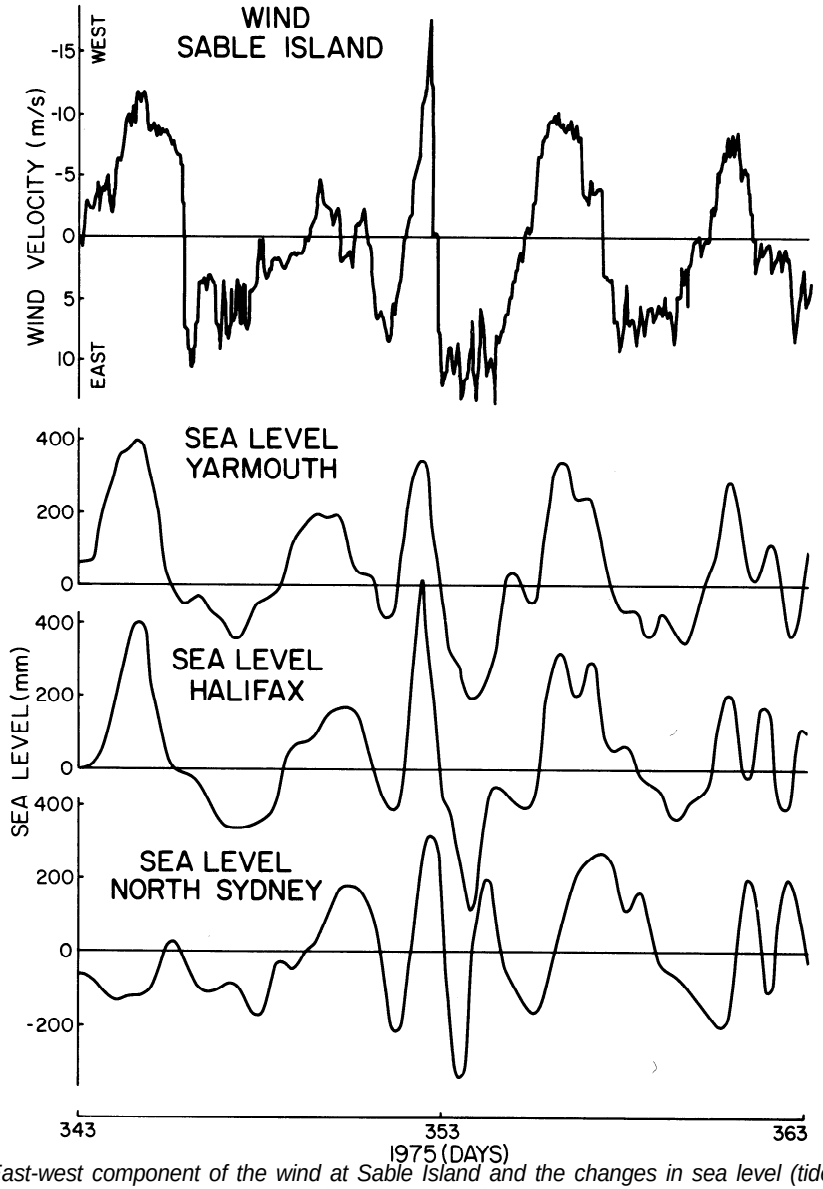
Previous analysis has established a link between coastal sea level and local weather on the synoptic time scale, in which a fairly simple, barotropic, frictional, response model explained the main features of the connection. As a circulation model for the shelf waters, however, the barotropic model is inadequate. The combination of variable topography and density stratification forms a highly variable pattern of currents. Theoretical studies were extended to consider baroclinic response to wind stress forcing with emphasis on the exchange of water at the Shelf edge to obtain estimates of offshore water intrusion on the Shelf particularly during strong wind events.

H. Sandstrom

Large-scale Oceanic Circulation and the Distribution of Properties

In this program we hope to gain some understanding of the processes that control the large-scale distributions in the oceans of potential vorticity and mass as well as heat, salt, and various chemical parameters. Work is continuing on two problems: the baroclinic instability of advective models for the main oceanic pycnocline and the possibility of using the large-scale distribution of potential vorticity to determine the absolute oceanic velocity field.

We know that advective models can describe many of the features of the main oceanic pycnocline and also that cross-isopycnal processes are relatively small. It is not known, however, what oceanic processes determine the functional relationship between the three conserved quan-



East-west component of the wind at Sable Island and the changes in sea level (tides removed) at Yarmouth, Halifax, and North Sydney (NS) in December 1975. (BIO 4501-4)

tities (mass, potential vorticity, and the Bernoulli Function) or indeed whether a unique relationship, as predicted by theory, exists over an ocean basin. The ocean may be near its most stable state - one in which there is a simple relationship between mass and potential vorticity alone. We have examined the stability of this system, and find that indeed the growth rates for linear perturbations are very small.

G. T. Needler

ToC

A.2

Marine Ecology Laboratory
Ocean and Aquatic Sciences, Atlantic
Department of Fisheries
and the Environment

Director - A. R. Longhurst

- **Biological Oceanography Division**
- **Environmental Quality Division**
- **Fisheries Oceanography Division**

ToC

Director's Remarks

The work of the Marine Ecology Laboratory (MEL) has continued through a period of organizational change during which its function of performing fundamental ecological research in support of resource management has been confirmed in the structure of the new Department of Fisheries and Oceans. MEL is organized as three research divisions (Biological Oceanography, Fisheries Oceanography, and Environmental Quality), which collaborate to perform its research projects.

After a decade-and-a-half of fundamental research at MEL it is time to evaluate what has been accomplished. During this period, the need by government to know about the functioning of marine ecosystems has become even more pressing than it was in 1965 when MEL was established: to the requirements for fisheries, originally the reason for establishing the laboratory, have in recent years been added new requirements associated with marine pollution and off shore oil drilling.

It has also come to be realized in the last ten years that marine resource management, both in Canada and elsewhere, was previously based on ecological assumptions of the simplest kind that neglected the real complexities of ecological relationships. It seems incredible to us now that we could apparently have ignored the possibility of food-chain accumulation of persistent chemicals when hard pesticides were first used, or that fisheries regulations could have been based simply on numerical population analysis of single fish species. Yet such was largely the case not much more than a decade ago, and was responsible for several notable failures in resource management. Because of the number of alternative pathways for the flow of energy, material, or information within and between organisms, and because it integrates biology with physics and chemistry, ecology presents the greatest intellectual challenge of any of the natural sciences. So great are its difficulties, indeed, that much of ecology has been based on the development of non-numerical concepts, which, because they are not predictive, can neither be verified nor falsified.

Nevertheless, ecological understanding is accruing much faster than sometimes appears to be the case, though there has been nothing in the last decade to compare with the unifying effect of plate tectonics theory on the earth sciences; because of the nature of ecology none should be expected, and the lack of obvious breakthroughs not permitted to obscure the reality of recent progress. This has not been achieved parochially, but by contributions from ecologists globally: scientists at MEL have played an important role in this process and the laboratory has achieved an enviable and international reputation over the last ten years for illuminating those areas of marine ecology judged to be critical to our understanding of ecosystem function and its management.

[1]The Department of Fisheries and the Environment was recently renamed the Department of Fisheries and Oceans. In this Review the old name has been retained since most of the work reported was done before the change.

MEL research projects have mainly concentrated on the biological and biochemical processes at the basis of the functioning of marine ecosystems. To cite just a few examples: MEL has contributed importantly to our understanding of the physiology of growth in fishes and the efficiency with which food is utilized, and to our understanding of the efficiency of capture and utilization of food particles by zooplankton; the physiology of the photosynthetic process in phytoplankton and its adaptation to light regimes has been studied, and our ability to predict timings and levels of primary production has been advanced. Special emphasis has also been placed at MEL on the structure of ecosystems and the relations between their component biota; studies of this topic have ranged from theoretical numerical ecosystem analysis, through consideration of ecosystems as simple particle size spectra, to the detailed study of exemplary marine ecosystems at sea.

Variability in fish stock abundance has been studied by MEL projects both on the macroscale, as represented by the response of populations of fish to distant events and trends in the physical environment, and in the microscale by analysis of reproductive strategies and larval survival mechanisms of individual fish stocks. Field studies have ranged from coastal embayments in Nova Scotia to stable open ocean situations, and currently include the study of a macrotidal embayment with a very modified estuarine ecosystem, the Bay of Fundy. Also ongoing is a collaborative multidisciplinary program in St. Georges Bay which is throwing much light on the mechanisms that control the productivity of coastal fisheries, especially those of the southern Gulf of St. Lawrence. In recent years, attention has been given to the effects of contamination on marine biota, especially with regard to the subtle, but critical effects on biotic populations of long-term, sublethal levels of contaminants, which would presently escape control by the regulatory agencies.

This work has been performed against a background of increasing demand for ecological information to support management policies, and a widening of resource management to include assessment of the impact of new technologies on the oceans, and of the performance of regulations designed to control that impact. MEL research projects concentrate on topics where ecological uncertainty constrains the development of more satisfactory management practices: for instance, in relation to fisheries, our work is specifically aimed towards a general solution of the major enigmas: why is year-class success and recruitment so variable from year-to-year, how do fish populations respond to long-term, and distant environmental changes, what controls the carrying capacity of any marine habitat, and how do multispecies fish populations respond to an artificial reduction in abundance of one of their component species?

The rapid evolution of management techniques now taking place in Canada and elsewhere in which the simplistic practices of the first few decades of regulation of ocean resources and amenities are gradually being replaced by more enlightened and ecologically sound ones is only possible now because of the advances made in marine ecology in the last 20 years, and the beginnings of quantification and prediction of what were previously simple and unverifiable concepts. The application of the new depth of understanding to management practice cannot, by the nature of things, be on a one-to-one, demand and supply basis and Canadian managers of ocean resources must look globally for their ecological input as well as closer to home, where the work of MEL has been an important factor during this formative period of applied ecology. It is no criticism of the progress of ecology to say that we are still far from arriving at a general synthesis.

Much of MEL's research is done in close collaboration on the one hand with the agencies having a more direct mandate in resource management, such as the Fisheries Management Branch and the Environmental Protection Service of DFE, and on the other hand with ecologists and oceanographers in universities both here and abroad. In addition MEL has also had an important input more directly to the management process at many levels: advice has been given in respect of the Ocean Dumping Act, the Fisheries Act, and the Environmental Contaminants Act; MEL responds regularly to calls for evaluation of Environmental Impact Statements, mostly concerning the impact of oil exploration in the Arctic; advice has been given in evaluating EAMES (Eastern Arctic Marine Environmental Studies) and the guidelines for an environmental impact study concerning a Fundy Tidal Power Barrage. Important support has been given to the Canadian International Development Agency by the MEL participation in the CIDA Peruvian fishery project during the CSS *Baffin* expedition in 1977, and the reception at BIO of numerous scientists from Instituto del Mar del Peru for collaborative research and training in 1978. MEL has also assisted IMARPE scientists in establishing an experimental facility in Callao and initiating critical physiological studies on anchoveta larvae.

An international symposium on "Recovery Potential of Oiled Marine Northern Environments" with 200 scientific participants was held in Halifax, as a result of MEL initiative, in 1977; the proceedings of this important meeting have already been published in full.

Finally, individual scientists have been very active in the international organizations, both in the regional bodies such as ICNAF and ICES, but also as participants and organizers of many scientific working groups sponsored by IOC, UNESCO, SCOR, NATO, and FAO.

More than in the other natural sciences, progress in ecology has suffered by the too-hasty hardening of hypotheses into dogmas, for this is easier than the stating of the set of critical questions required to test the hypothesis. Yet without such sets of questions further progress cannot be made: it is against this criterion that we plan our research in MEL, the progress of which during the last two years is briefly described in the following pages.

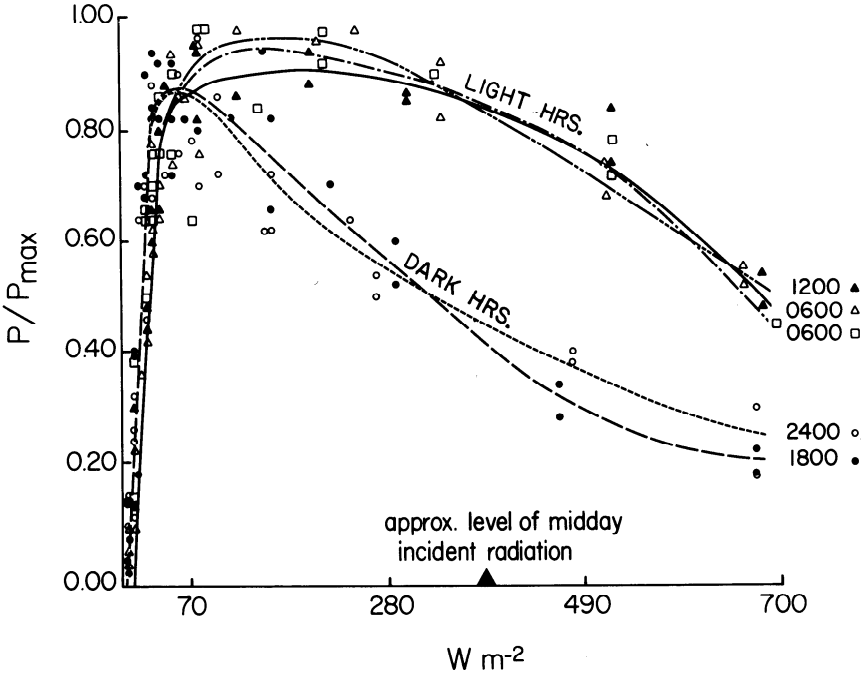
A. R. Longhurst
Director
Marine Ecology Laboratory

Biological Oceanography

To manage an industry without understanding each step in the manufacture of the product would lead to certain bankruptcy. By analogy, a long range management plan for renewable resources such as our commercial fisheries also requires a good understanding of how the biological system works at each step in the production process. The biological oceanography projects at MEL are designed to fill critical gaps in our information about the operation of oceanic ecosystems. For example, we are re-examining, on the basis of recently developed concepts, the dynamics of the photosynthetic process and the factors that govern the efficiency of the conversion of solar energy into organic material, at the same time that we are quantifying the mechanisms and rates of transfer of this energy and material to the rest of the food web. The efficiency of any production process, whether it yields fish or automobiles, relative to the input of raw materials, depends on the balance between heat (energy) losses and growth (or accumulated end product). Feedback processes required to keep any system functioning are major sources of heat loss and, hence, in nature could be at least as important as the iniqual quantity of material produced in a food chain in determining exploitable yields. As an example of one type of feedback operating in a natural production system, photosynthesis requires a continuous supply of nutrients, most of which in the sea is recycled by heat producing processes. While both micro-organisms, such as bacteria, and larger animals, such as zooplankton or benthos, break down some of the products of photosynthesis thereby releasing nutrient compounds, in the pelagic zone the relative importance of the different contributors and even their combined total rate is poorly known. Looking at another aspect of the general problem, efficiency of material transfer is also a function of transport time between producer and consumer, so it becomes vital to understand the relative distribution in space and time of the components of an ecosystem to be able to predict reaction times or feeding rates.

Ecology and Physiology of Phytoplankton

Photosynthesis - light experiments with natural phytoplankton assemblages. Previous work in MEL has determined that a hyperbolic tangent is the most consistently useful mathematical representation of the relationship between photosynthesis (carbon fixation) and light for natural phytoplankton populations. This 2-parameter (alpha is the initial slope and P_m is the maximum of the photosynthetic rate) model has been employed in field studies of the natural variation of the photosynthetic parameters on a number of temporal scales. Both parameters have been found to vary significantly with season and have also demonstrated a marked diurnal fluctuation. Initial results from coastal waters suggested that the seasonal fluctuations in the initial slope were most significantly related to previous light history while the maximum of the photosynthetic rate was related primarily to temperature fluctuations. Additional data have been collected over a much more extensive geographical area (tropical to arctic seas) and other environmental covariates (particularly inorganic micronutrients) are now under analysis.



Variations on a time scale of 24 hours in the shape of the curve relating photosynthesis and light for natural assemblages of phytoplankton off the coast of Peru. Curves from experiments (using artificial light) run in dark hours show a maximum but no plateau compared to those run during light hours. All curves are normalized to their maximum specific productions. (BIO 5171)

This experimental approach to primary production studies is expanding to consider the relationship between photosynthesis and light at intensities beyond saturation and commonly inhibitory to photosynthesis. Preliminary results have shown the incipient levels and degree of photo-inhibition vary significantly with regard to location, time of day, and composition of phytoplankton. Diatom populations from the Peruvian upwelling system, for example, are significantly inhibited when subjected to sea-surface light intensities (and to a greater extent during darkness) while the "red-tide" photosynthetic ciliate *Mesodinium rubrum* appears to be unaffected by intensities exceeding normal sea-surface levels. This work will continue with the objectives of **(1)** adding a mathematical description of the inhibition range of light intensities to the existing photosynthesis-light model and (2) investigating some biochemical consequences of exposure to high light intensities. The effects of the magnitude and duration of high light exposure on photosynthetic/respiratory enzymes and carbohydrate-protein pathways of organic synthesis in phytoplankton will be investigated initially.

Our ability to refine and improve our capabilities for modelling and prediction of photosynthetic production depends largely on our knowledge of natural variability, the environmental properties which account for that variability, and the mechanisms by which the environment regulates photosynthesis.

T. C. Platt, W. G. Harrison, B. D. Irwin

Size fractionation of phytoplankton production. In enriched coastal waters more than 70 per cent of both phytoplankton biomass and production is generally believed to be due to small flagellates and other nannoplankton (<20 microns) and the contribution of net-phytoplankton, containing a higher proportion of diatoms, is less significant, which implies that the nannoplankton biomass and production is subject to less temporal variation than those of bigger size classes. To examine this hypothesis critically, nearly 100 experiments were carried out on natural phytoplankton populations collected once a week from Bedford Basin (twice weekly during the spring bloom) and on 16 species of phytoplankton culture. Samples were physically fractionated by gentle filtration of water through sieves with pore sizes of 160, 100, 54, and 20 microns. Data were collected on the qualitative and quantitative abundance of phytoplankton in the different fractions and untreated water, their particle volume, chlorophyll-a content and photosynthetic uptake of carbon. To determine the diatom contribution to total photosynthesis, replicate sets of filtrates were spiked with germanic acid at 30 milligrams of germanium per litre: germanic acid is thought to be a specific inhibitor of diatom photosynthesis and carbon assimilation rates compared to controls without germanic acid. A few experiments were carried out using radioactive germanium (^{68}Ge) as a tracer to determine whether it was assimilated by other groups of phytoplankton algae. During 1978, 44 light saturation experiments were conducted on unfractionated and fractionated samples in Bedford Basin water to: firstly, determine variations in phytoplankton biomass in terms of cell numbers, photosynthetic pigments, particulate carbon, nitrogen, cellular fluorescence, and ATP (adenosine tri-

Phytoplankton size fractionation experiments in the cold room. (BIO 5183)

phosphate) and secondly to examine whether production per unit biomass showed any systematic variations among different size classes.

Fractionation of samples by filtration through Nitex sieves did not alter the production characteristics of phytoplankton. However, the percentage of photosynthesis inhibition by germanium was not constant, which suggests that germanic acid cannot be used as a quantitative inhibitor of photosynthesis in diatoms. Large seasonal variations occurred in the nannoplankton biomass and production in the Bedford Basin waters, and there was no consistent relationship between the biomass or production of the smaller (<20 microns) and larger size fractions of phytoplankton. During the 1977 spring phytoplankton bloom, which was of longer duration than usual, production was relatively higher at low biomass when compared to earlier spring blooms and the photosynthetic contribution of the <20 micron fraction was more than 50 per cent of the whole.

Subba Rao V. Durvasula

Physiological adaptation of phytoplankton. As part of a larger investigation of the dependence of phytoplankton photosynthetic rate on light and other environmental parameters, such as temperature and nutrient supply, a search has been undertaken for reliable indicators of metabolic activity of value in predicting primary production rates. The cellular concentrations and kinetic parameters of enzymes controlling the key steps of metabolic pathways would be expected to reflect the recent, routine, activity levels of those pathways and should not be sensitive to short-term environmental fluctuations. The photosynthetic enzymes ribulose bisphosphate carboxylase (RuBPCase) and phosphoenol pyruvate carboxylase (PEPCase) catalyze the fixation of carbon dioxide during photosynthesis and together probably limit the maximal photosynthetic rate *(P max).* As standard in vitro assay techniques were not suitable for our needs, it was necessary to develop an *in vivo* method for use with intact, permeabilized, phytoplankton cells Studies on the reaction kinetics and comparison with *in vitro* assays are in progress, but already the method looks promising. A strong positive correlation was observed between RuBPCase and PEPCase activities and *P max* during the 1978 spring bloom in Bedford Basin.

It is equally important in predicting primary production rates to understand factors affecting dark and light respiration. Maximal respiratory rates in phytoplankton cells are probably limited by enzymes in the electron transport system (ETS) at or near the level of cytochrome oxidase. Methods for measuring ETS activity (less cytochrome oxidase) and for cytochrome oxidase itself have been developed for use with phytoplankton, and are now being used in a seasonal study of phytoplankton respiration in Bedford Basin. Additional investigations on respiratory mechanisms of cultures are underway.

J. C. Smith

Nutrient dynamics of natural phytoplankton assemblages. Inorganic micronutrients (nitrogen, phosphorus, silicon, etc.) are essential for phytoplankton growth and at times, either singly or in combination, are found in such short supply as to limit photosynthetic production. Through the use of both radioactive and stable isotope tracer techniques, studies are underway

to examine the fluxes of nitrogen and phosphorus mediated by natural phytoplankton populations.

Regeneration of nitrogen and phosphorus from microplankton (zooplankton, phytoplankton, bacteria) is also under investigation. The ratio of ammonium to total (nitrate plus ammonium) assimilation will be used as an index of the relative contribution of regenerated nitrogen to phytoplankton production. In addition, isotope-dilution techniques have recently been developed and tested to directly measure the rate of regeneration of ammonium and orthophosphate *in situ.* These flux measurements will be used to quantify the supply rate of inorganic nutrients for maintaining observed photosynthetic production rates.

As a result of our studies of nitrogen metabolism and cellular composition of natural phytoplankton, a rapid, simple, fluorometric method for the analysis of phytoplankton nucleic acids (RNA, DNA) has been developed. Existing fluorometric techniques for the analysis of total protein are also being tested for application to our phytoplankton studies.

W. G. Harrison, B. D. Irwin, M. Hodgson

Zooplankton Physiology and Distribution

Feeding behaviour and nutrition of zooplankton. Over the 1977 to 1978 review period, a seasonal study of grazing by the neritic zooplankton community in Bedford Basin was completed, including a detailed investigation of carbon and nitrogen utilization by these animals during the 1977 spring bloom. Over the year, the rate of ingestion was positively correlated with increasing ambient food concentration and showed no tendency to become nonlinear even at the peak of the spring bloom. Not only does ingestion rate show a linear trend with increasing food concentration, but apparently filtration rate also tends to be higher when more food is available, although the results are somewhat confounded by seasonal temperature changes. There is good evidence from studies during a spring bloom that the Coulter Counter measures the volume of large phytoplankton differently than a microscopic examination and, moreover, the instrument gives data with a better correlation with -particulate carbon and nitrogen concentrations than can be obtained with volumes computed from the linear dimensions of cells. Although there seems to be some variation seasonally in the data, the ratio of carbon to Coulter Counter volume is linear and yields a slope of 87 micrograms of carbon per part per million (cubic millimetres per litre). Comparison of amount of carbon or nitrogen ingested in grazing experiments, calculated from the volume of particles removed using the C:ppm (and N:ppm) ratios, with net changes in particulate carbon and nitrogen would seem to give a simple method of determining assimilation rate. Using this method, no evidence of decreasing assimilation efficiency with increasing food ingestion was noted; in fact, for carbon the slope was positive. On the average about 60 per cent of the carbon in natural particulate matter ingested is utilized and the rate of nitrogen utilization is even higher.

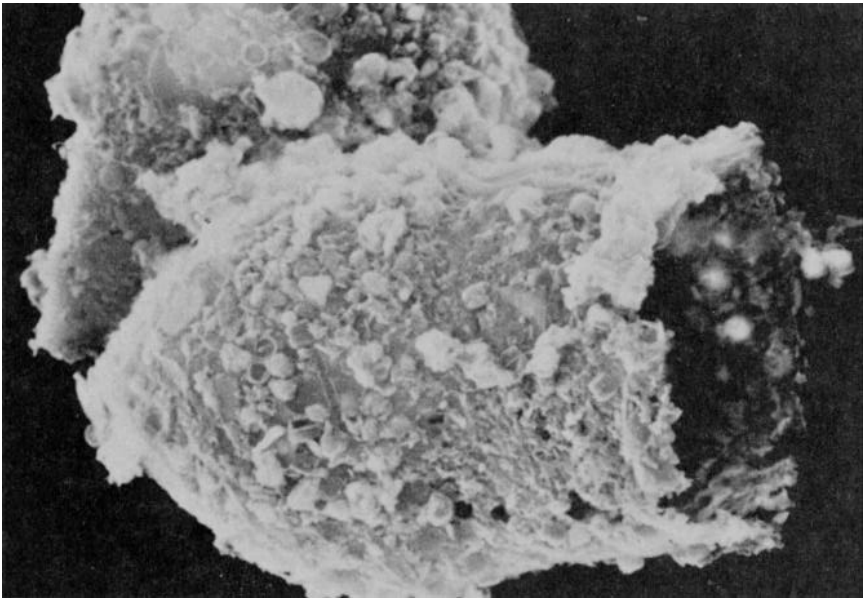
About 17 to 46 per cent of the daily phytoplankton production was grazed during the spring of 1977 with a gross growth efficiency for the zooplankton of around 13 per cent in terms-of carbon and 29 per cent in terms of nitrogen.

R. J. Conover

Digestive enzymes of zooplankton and their ability to &climate to a variable food supply. All the recently acquired feeding data support the hypothesis we recently put forward that zooplankton animals in nature acclimate to the quality and quantity of food available. Recent experiments have also shown that several common copepod species from Bedford Basin can be conditioned to select certain sizes of inert particles. Earlier it was shown that the digestive enzymes used to process different nutritional substrates were highly correlated with the abundance of such substrates in the particulate food of Bedford Basin zooplankton. Laboratory experiments support the idea that increased carbon in the diet can induce production of certain enzymes called carbohydratases. The responses to conditioning and the enzyme composition of different zooplankton species differ and suggest that resource partitioning among organisms occupying the same ecological niche may have some, perhaps subtle, behavioural and biochemical basis.

R. J. Conover, P. Mayzaud (Station Zoologique, Villefranche-sur-Mer, France), J. Skiver (Dalhousie University)

Ecology of microzooplankton in Bedford Basin. A study of the microzooplankton community in Bedford Basin is being carried out along two lines. A fixed station in the Basin has been visited weekly and samples for microzooplankton have been collected from 12 depths to define the patterns of abundance and the distribution of important species. So far, seven months of samples have been enumerated and a comprehensive species list has been prepared. The field sampling will continue until the end of 1978, thus providing almost 18 months of data on seasonal distribution patterns.



Tintinnopsis *species encrusted with diatoms about 60 microns long (magnified 1200 times).*

In addition, important species of ciliates, chiefly tintinnids, have been cultured in the laboratory to study their life histories and growth rates. So far, *Helicostomella subulata, Parafacella gigantea, Favella ehrenbergii,* and *Tintinnopsis beriodea* have been cultured for periods of 1 to 10 months. Cultures of *Helicostomella subulata* have been particularly useful in explaining the seasonal distribution of this species, which occurs in the Basin in late summer and fall but is totally absent in winter and spring. In fall, field populations of *Helicostomella* produce resting cysts that eventually sink to the bottom. In laboratory cultures, cysts are produced contemporaneously with those of the field population, even though the laboratory population is not subjected to the same environmental variations, which suggests that this phenomenon is part of the normal life cycle. Both laboratory produced cysts and field collected cysts have been observed to excyst at warmer temperatures after spending several months in simulated winter conditions. The cyst formation thus provides a mechanism for repopulation of the species in the inshore areas after unfavourable winter conditions.

M. A. Paranjape

Development of the Bedford Institute of Oceanography Net and Environment Sensing System (BIONESS)

A new concept has been used in the development of a second generation of the multi-net zooplankton and micronekton sampler. This has involved the use of rigid box-type construction, which made this sampler easier to handle, more compact, and in addition capable of being towed at a speed of three knots while still maintaining a vertical angle. The box frame allows us to mount a variety of sensors on the sampler including a CTD, pitch, roll, and yaw sensors, light meter, 35 millimetre camera, and strobe light, as well as the internal and external flow meter. In the future an oxygen probe and an *in situ* fluorometer will be added to the sampler. With this sampler it is possible during each tow to collect ten individual samples of a large size range of animals (from 300 microns up to fish size and squid up to 26 centimetres long) and at the same time obtain *in situ* measurements of temperature, salinity, and light. We are also able to photograph the animals in front of the net prior to their being caught. This latter observation is important in detecting possible net avoidance and animal aggregations. The light meter we developed has a sensitivity down to 4×10^{-12} watts per square centimetre, which allows us to measure the *in situ* light intensities that different groups of vertically migrating animals follow in their nocturnal migration to the upper layers of water.

D. D. Sameoto

The BIONESS and Acoustic Observations of Micronekton

As a result of the development of the BIONESS and the earlier multi-net sampler (described in the 1975-76 Biennial Review) it was possible to conduct quantitative and qualitative experiments on the type and abundance of euphausiids found in acoustic scattering layers off the coast of Gaspé (PQ). The large number of biological samples taken in the scattering layers simultaneously with voltage measurements of the acoustic backscattering demonstrated that it was possible to estimate accurately the numbers and biomass of euphausiid populations using a 120 kilohertz sounder. The correlations between the biological and acoustic sampler ranged as high as 0.765 for the biomass and 0.791 for numbers per cubic metre

of euphausiid. Photographs taken *in situ* of the euphausiids in the acoustic layers with the BIONESS demonstrated that the orientation of the euphausiids changed at different times of the day and night, which undoubtedly affected the target strength of the animals in the scattering layer. This is the first reported observable change in orientation with time of an acoustic scattering organism. This last finding has important implications for quantitative acoustic surveys, since the target strength of an animal is dependent on its orientation; laboratory studies of this problem have been initiated in the Dalhousie University (Halifax, NS) deep tank by P. Beamish as part of a general study of the acoustic properties of several pelagic invertebrates. In the past it has been generally assumed that the orientation of fish or other organisms was constant during a survey, but this may not be the case.

D. D. Sameoto

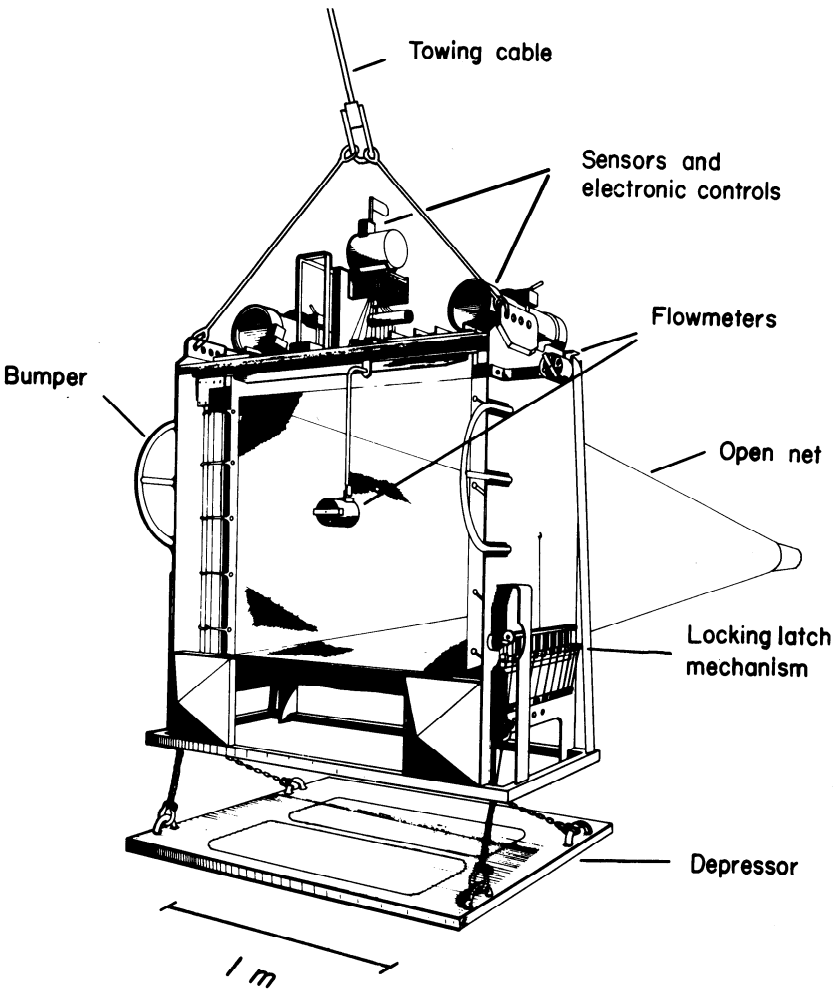


Diagram of the BIONESS as it would appear in the water when being towed (see text), (BIO 4834)

Nova Scotia Shelf Break Study

The techniques and equipment developed for the above study were applied to a study of the mesopelagic community of zooplankton and micronekton off the edge of the Nova Scotia shelf. The aim of this work is to determine the size and importance of this community to the primary and secondary production near the shelf edge. The interaction of the deep water and shelf zooplankton community is also being looked at. Preliminary results indicated that the mesopelagic community nightly migrates vertically up to the top 100 metres and, being primarily a predatory assemblage of animals, it feeds on zooplankton of shelf origin but that have been subsequently carried off the shelf over deep water by water movements. Therefore, the impact of these predators may be significant on the secondary production of areas adjacent to the Scotian shelf.

The sample collections of the BIONESS taken off the shelf contained large numbers of very young squid from 1 to 10 centimetres long, which provides evidence for the first time of an important nursery area for this increasingly important commercial species.

D. D. Sameoto

Other Biological Programs Using BIONESS

The BIONESS and the acoustic methods of measuring zooplankton were used in a study of the abundance and vertical and horizontal distribution of anchovy larvae and other icthyoplankton, zooplankton, and micronekton off the coast of Peru. The same systems were used in a study on Georges Bank (NS) of the distribution of zooplankton and a major predator, the chaetognaths, in the region of the major herring spawning grounds. The purpose of this work is to understand the physical and biological environment that the new hatch larvae encounter in the first days of life.

A study of the stomach contents of three species of euphausiids from the Gulf of St. Lawrence was completed that demonstrated a great deal of overlap in the types of organisms eaten, but significant differences in the time and depth at which the different species fed.

D. D. Sameoto

Biochemistry and Bioacoustics of Fish

Physiological adaptation in fish. Because of the expense and technological uncertainty about how best to simulate the natural environment, metabolic rates of fishes determined in the laboratory are usually unsuitable for predicting field rates. We are circumventing this problem by trying to understand how hematological characteristics and the activity of key enzymes now thought to control important metabolic pathways in fish may help to monitor the adaptive responses of fish to changes in their environment. Earlier it was shown that blood hemoglobin (Hb) concentration exhibited many of the properties of a metabolic indicator, but could not be related to body weight in a manner comparable to oxygen uptake. Subsequently, we have found that both blood viscosity (nu) and the affinity of hemoglobin for oxygen (P_{50}) are a function of weight in the American plaice. Also P_{50} of the hemoglobin in the fish is allosterically modified by red cell ATP levels Seasonal changes in P_{50} levels have also been observed and further work

on the relation between P_{50}, ATP concentration, and metabolic rate is currently in progress.

Previous studies on the enzymatic control of hepatic glycolysis and gluconeogenesis in the American plaice suggested that either the activity of cytochrome oxidase (CYTOX) or of some component of the electron transport system (ETS) prior to CYTOX might serve as a metabolic indicator. Accordingly, we have adapted earlier methods for ETS and CYTOX determination for use with fish. These methods are being employed to determine the relations between the hepatic activities of both ETS and CYTOX, body weight, metabolic rate, growth rate, ration level, and the levels of certain environmental parameters (solar radiation, temperature, salinity).

J. C. Smith, L. M. Dickie

Acoustics of small fish. As acoustic targets become smaller it becomes more difficult to make quantitative evaluations of numbers or biomass or to distinguish the size of individual targets. Recent studies off Newfoundland, and using the acoustic fish counting system in Bedford Basin, using capelin held in an acoustically transparent cage, suggest that the relationship between target strength and number is linear up to at least 750 fish per cubic metre. This work forms part of a co-operative study by FM and OAS under the aegis of the Trilab Acoustic Committee.

P. Beamish

Bioenergetic Models of Particle Size Distributions

Since the early 1970s the study of particle size distributions of organisms within marine ecosystems has been an important component of the MEL research program. A series of bioenergetic modelling studies has recently been carried out in an effort to interpret the results of these studies in terms of the flow of energy through the ecosystem. A good understanding of this bioenergetic flow could be a major step forward in our understanding of the production dynamics of fish populations and in the development of predictive models of commercial fisheries.

In the initial stages of this project a steady-state linear model of the equilibrium distribution of particle sizes was developed and found to agree fairly well with data on pelagic ecosystems. A dynamic version of this model was subsequently derived and its properties investigated. Under the assumptions implicit in the linear model the theory predicts that pulses of energy in the small particle range, such as algal blooms, propagate up the particle size distribution curve but do not become distributed over a wider range of particle sizes. It was recognized that the actual path of energy within the ecosystem is controlled in large part by feedback processes, such as reproduction (a reverse flow of energy from larger particles to smaller ones) and predation (a nonlinear flow from smaller particles to larger ones). In addition, spatial flows of energy were felt to be important, since primary production is confined to the euphotic zone but the pelagic region extends considerably deeper than this and there are important interchanges of energy with the benthos.

A general theory of energy flow that encompasses all of these considerations has been derived and is being used as a basis for bioenergetic

modelling studies. The earlier work on linear models can be interpreted as a special case, and by comparing the comprehensive model with the previous linear formulations the role of feedback in the system is beginning to be understood. In particular, it appears that predation can give rise to instabilities so that moderate variability in primary production can lead to massive changes in year-class strength in the fishery.

W. L. Silvert (Fisheries Oceanography), T. C. Platt

ToC

Environmental Quality

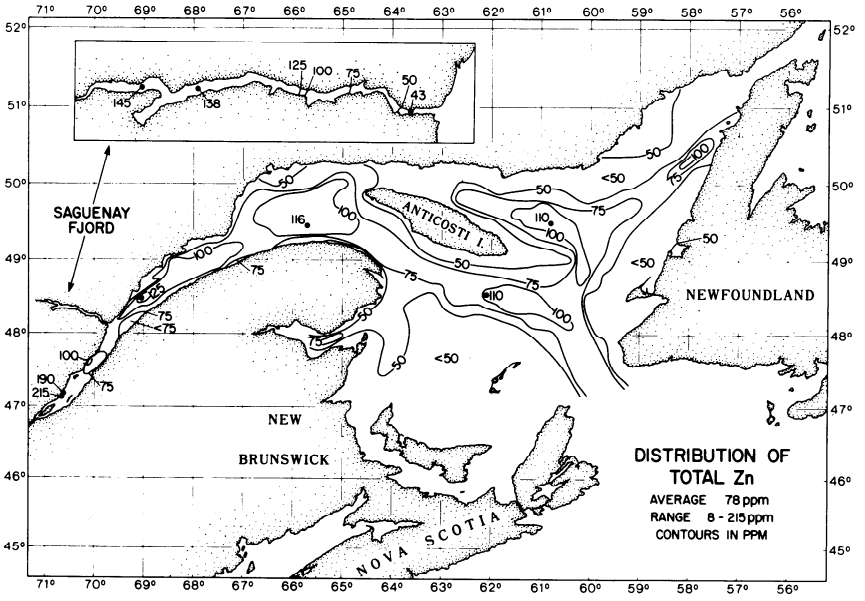
The purpose of the Environmental Quality program is to understand the impact of anthropogenic changes on marine ecosystems. The program contains research projects on ecosystem contamination and on the effects and implications to the ecosystems of large engineering works such as the proposed Bay of Fundy tidal power barrage and environmental disasters such as major oil spills. The projects include investigations of: the levels, the behaviour, and transfer of contaminants in estuarine, shelf, and ocean ecosystems, their availability, uptake, degradation, metabolism, and clearance by marine organisms, and their effect on marine life. They also include basic ecological studies of the Bay of Fundy as a whole and of areas where engineering works are proposed. These studies are continually being advanced by the development of new sampling and analytical techniques.

Ecosystem Contamination

Field and laboratory investigations of sublethal contaminants in the marine environment are directed toward determining and understanding the processes and factors that control their effects as well as the pathways by which the contaminants enter, remain within, or leave the ecosystems. Three groups of contaminants - *heavy metals, petroleum hydrocarbons,* and *organochlorine compounds* - in the sediments and their interactions with sediments and organisms have been studied in the field and laboratory.

Heavy metal contamination in the sediments of the Gulf of St. Lawrence. Biochemical studies of heavy metals in the sediments of the Gulf of St. Lawrence and the St. Lawrence estuary with its tributary the Saguenay fjord have been completed based on about 300 bottom grab and core samples. Forty variables were measured including grain size, organic carbon content, major elements (silicon, titanium, aluminum, calcium, potassium, iron, magnesium, manganese, sodium, and potassium), and heavy metals (mercury, zinc, lead, copper, cobalt, nickel, chromium, vanadium, beryllium, cadmium, and arsenic). From these data it has been possible to determine: (1) metal baseline levels; (2) heavy metal anomalies; (3) potential bio-availability of the metals; and (4) the carriers and pathways by which the metals have entered the sediments from natural and industrial sources.

Mercury is already a significant pollutant of the sediments, water, and biota of the Saguenay fjord as a result of industrial discharge from a single chloralkali plant. Zinc, lead, vanadium, and arsenic but not copper, cobalt, nickel, cadmium, and chromium accompany the mercury-rich industrial waste. Mercury (accompanied by small quantities of zinc, lead, and vanadium) has also escaped from the fjord and contaminated the fine-grained sediments of the lower St. Lawrence estuary where its bioavailable component presents a potential danger to the biota. In the upper St. Lawrence estuary zinc is a contaminant while copper, lead, and chromium are potential contaminants of the fine-grained sediments deposited beneath the turbidity maximum in the zone of resuspension at the mouth of the St. Lawrence River. The enrichment of the sediments by these industrially derived metals is related to their removal from solution in the turbidity maximum mostly by



Zinc concentrations increase with decreasing sediment grain size in the Gulf of St. Lawrence. Fine-grained sediments at the head of the St. Lawrence estuary and the Saguenay fjord are a sink and an enrichment zone for zinc supplied from industrial and natural sources. Zinc concentrations decrease seaward as man's influence decreases. (BIO 4513-5)

terrestrial organic matter and their subsequent transfer to the seafloor. Seaward, their concentrations decrease as the amount of dissolved and particulate matter from the' St. Lawrence River diminishes. In the open Gulf of St. Lawrence all heavy metals are at or near natural levels except in Chaleur Bay where anthropogenic inputs of mercury and cadmium have resulted in above background levels in the sediments.

Although the industrial contribution of lead, zinc, copper, chromium, and vanadium to the sediments throughout the region is small now, the quantities being introduced from industrial sources may lead in the future to an undesirable accumulation of metal contaminants in the sediments of the upper estuary (lead, zinc, 'chromium), lower estuary (zinc, lead, vanadium), and the Saguenay fjord (zinc, lead, arsenic). The studies have shown that in the case of mercury this has already occurred.

D. H. Loring, R. T. T. Rantala

Petroleum hydrocarbon pollution of sediments. Much of our work on behaviour of petroleum hydrocarbons in the environment was stimulated by the *Arrow* spill of Bunker C oil in Chedabucto Bay (NS) in 1970, and more recently by the *Amoco Cadiz* spill off the coast of France in 1978.

Petroleum hydrocarbon persistence in the marine environment varies with wave energy, self-cleaning being most rapid in high energy environments such as rocky shorelines, and slowest in salt marshes and soft-sediment environments such as lagoons and estuaries. In the latter, petroleum hydro-

carbons can be detected and measured up to 15 years following a spill. Alteration of the oil spilled in such environments, while initially a function of wave energy and other physical erosion factors, eventually becomes a function of photochemical and microbial degradation. Because of the differential degradation of straight-chain aliphatic hydrocarbons such 'weathering' of sediment-bound oils tends to result in a shift toward aromatically enriched oil residues. The latter are particularly tenacious and apparently resist continued microbial degradation to a considerable degree.

Studies of the *Arrow* spill have revealed hydrocarbon residues in all areas sampled during a full-scale detailed survey of the entire Bay, although these are not attributable to the Arrow oil spilled. Due to weathering, however, the composition of the oil has changed to a residue high in aromatics. Similar results have been obtained from, a study of oiled sediments in a salt marsh on the boundary between Quebec and New Brunswick, site of the 1974 Golden Robin spill.

J. H. Vandermeulen, T. P. Ahern, P. D. Keizer, J. Dale

Transfer of organic matter and contaminants within marine ecosystems. Studies of sedimentation to determine the flux of materials to the sea floor, levels of contaminants in sediments and benthic organisms, and transfer rates of dissolved substances between sediments and overlying water are being used to qualify the role that sediments and benthos play in cycling natural organic matter and contaminants.

Whether sediments and benthos are a source or a sink for materials will depend on the interaction between processes that affect the direction and rate of transfer. Both the nature of the substances involved and the physical characteristics of the water body affect the distribution pattern and transfer pathways. Relationships between the concentration and transport rates of substances may allow prediction of exchange rates; seasonal studies of suspended and sedimented particulate matter in Bedford Basin showed that 1 to 5 per cent of the suspended organic carbon and nitrogen settles each day. Aqueous phase hydrocarbons are adsorbed to this particulate material and input to sediments can be predicted on the basis of suspended concentration, at least for the study period.

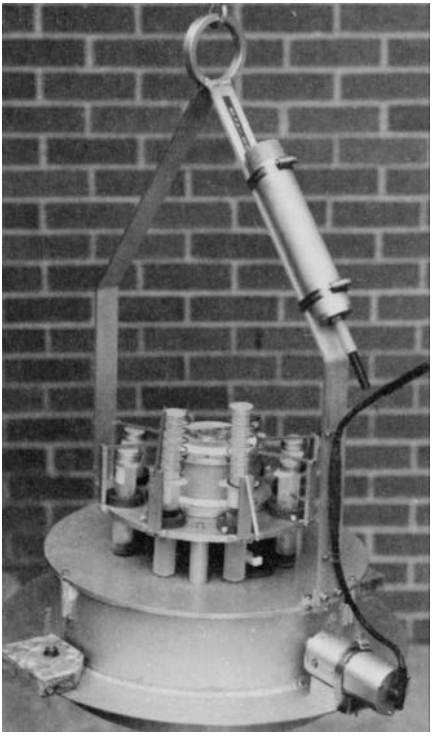
Particulate matter depositing in St. Georges Bay was collected in settling tubes exposed weekly during 1978. Concentrations of PCBs, and DDT and its metabolites will be determined in this material for comparison with levels in bottom sediments and benthos. These measurements will provide a baseline determination for these contaminants in a coastal marine environment not subject to direct input, where they must have originated largely from atmospheric fallout. Their presence in sediments, with measurements of rates of deposition, will quantify how rapidly such compounds can be transported from the atmosphere through a coastal ecosystem.

Compounds like petroleum and chlorinated hydrocarbons may return to the aqueous phase from sediments following biological metabolism or chemical diagenesis. It is necessary to measure the release of such material back into the water for any accurate quantification of such pathways. A device for collecting samples of water and particulate material suspended over undisturbed sediments was constructed to allow in situ measurement of the

flux of dissolved material between sediments and water. Serial samples taken by syringes from the benthic chambers, and at closely spaced distances above the bottom, may be used to calculate release of soluble compounds from bottom sediments. Measurements in St. Georges Bay and on the Scotian Shelf will show directly whether sediments in these areas are a source or a sink for dissolved materials. Similar studies are being applied to consider the role of intertidal sediments at the head of the Bay of Fundy in supplying organic matter to offshore waters.

B. T. Hargrave, G. Phillips, N. Prouse

Potential bioavailability of heavy metals in sediments. Total elemental concentrations are a poor means of assessing the carriers and pathways by which toxic heavy metals have entered the sediments, or in determining their potential availability to the biota. This is because part of the total amount of any element measured resides in solid particles and minerals and part has been incorporated into the sediments from solution. Chemical partition of the total element concentrations in their non-detrital (acid soluble) and detrital (acid insoluble) contributions allows deductions to be made about the carriers of the elements as well as their source and the pathways by which they have entered the marine environment. It also allows an evaluation to be made of the potential availability and danger of these elements to biota.



A benthic chamber with a clock-drive release mechanism. Spring loaded syringes are released and water samples collected above undisturbed sediments. (BIO 4771)

The detrital (acid insoluble) contribution is assumed to represent what is held in the lattice silicate minerals, discrete minerals, and secondary insoluble minerals and compounds. These minerals and compounds are usually transported as fine-grained clastic particles and deposited along with other material of comparable grain size and settling rates. Recent work in the Gulf of St. Lawrence has shown that 60 to 90 per cent of the total zinc, 80 to 90 per cent of the total copper, 74 to 85 per cent of the total lead, 76 to 92 per cent of the total cobalt, 77 to 88 per cent of the total nickel, 89 to 92 per cent of the total chromium, and 82 to 95 per cent of the total vanadium are held in the detrital fraction of the sediments and are assumed not to be readily available to the biota.

Small but biogeochemically significant heavy metal concentrations, however, do occur in the non-detrital fraction. This represents some proportion of the element that was initially leached from the source rocks or supplied in dissolved form from industrial sources. The elements have been incorporated into the sediments in a variety of ways such as precipitation, adsorption onto suspended particulate matter, or extraction by living and dead organisms. It is this fraction that is potentially the most easily available to the biota and constitutes the greatest danger if present in excessive quantities, particularly if the elements are of a form that can be selectively taken up by the biota. In this way, the non-detrital elemental concentrations provide an early warning system for detecting the build-up of available heavy metals in the sediments, long before excessive quantities can be detected in the aqueous environment. In the Gulf of St. Lawrence it was found that 8 to 39 per cent of the total zinc, 7 to 20 per cent of the total copper, 15 to 26 per cent of the total lead, 8 to 24 per cent of the total cobalt, 12 to 24 per cent of the total nickel, 2 to 11 per cent of the total chromium, and 5 to 18 per cent of the total vanadium are held in the non-detrital fraction. These concentrations are weakly held by fine-grained organic material, oxide grain coatings, ion exchange positions, and carbonates. Some of these amounts are derived from anthropogenic sources and all are potentially available to the biota.

D. H. Loring, R. T. T. Rantala

Availability and transfer dynamics of organochlorines within the marine ecosystem. The major organochlorine contaminants of marine ecosystems are DDT and its metabolites, and the polychlorinated biphenyls (PCBs). Very little is known, however, about the availability and transfer dynamics of organochlorines within the aquatic biosphere or the long-term effects of sublethal concentrations on biota and biological communities. It is desirable to predict the potential of these chemicals to concentrate in the biosphere, but a predictive model cannot be constructed until the rate-constants of uptake and clearance have been evaluated. We undertook to estimate these rate-constants in the laboratory using calanoid copepods as representative zooplankters. The results were described with a simple exponential model enabling us to calculate the amount of DDT that would be taken up from sea water by *Calanus* over time, knowing only the concentration of DDT in sea water. It was inferred that the uptake process was related to the exposed surface area of the organism, so a sensitive method was developed to measure the surface area of marine crustaceans. To evaluate the surface area uptake hypothesis, identical studies were performed with larger crustaceans, the euphausiids, that have approximately ten times the surface area of *Calanus.* The results were unexpected in that they showed both

uptake and clearance rate-constants to be essentially the same for copepods and euphausiids. However it was not at first appreciated that euphausiids swim three times as fast as *Calanus,* which means that the surface area exposed and available for uptake per milligram of dry weight per unit time is roughly the same in the two organisms, and this explains why the experimentally derived rate-constants are so nearly the same. This observation has enabled a more general predictive model for DDT accumulation by marine crustaceans to be constructed.

In attempting to model a toxic chemical in the biosphere it is of utmost importance to assess each organism's capacity to metabolize it. *Calanus,* experimentally contaminated with DDT, was monitored for a period of eight weeks but no metabolites of DDT (DDE, DDD, DDMU) at 6°C were observed. Field sampling was undertaken in 1976 and 1977 to measure organochlorine levels, seasonally, in a relatively uncontaminated marine food web. A special plankton size-fractioning apparatus (25-2000+ microns) was developed for this purpose. Samples taken during one year have now been analysed for PCBs and show no evidence for biomagnification over several trophic levels from phytoplankton to larval fish. In fact, it appears that PCB levels can be reliably predicted simply from the lipid content of the organism. This suggests that partitioning of PCB occurs between the sea water and the lipid of the plankters in nature.

However, the problem is not so simply solved. Feeding studies with copepods, using DDT-contaminated algae, show that they are about 90 per cent efficient in retaining DDT from their food. From a knowledge of the copepod life cycle, the food consumed at each stage, and the degree of contamination of their food, simple computations demonstrate that copepods could take up enough DDT through feeding to account for their present level of contamination as observed in nature. Our conclusion at present is that organochlorines are in a dynamic state of equilibrium with cell-membrane phospholipids of phytoplankton and that this equilibrium can be transmitted rapidly 'up' the food web by feeding.

Attempts are being made to measure DDT and its metabolites in the size-fractionated samples that have already been analysed for PCBs. Once done, dynamic modelling of DDT in marine plankton will be attempted using the known biology of the organisms and the DDT dynamics worked out in the laboratory.

Analyses will be carried out on several species of pelagic fish (herring, mackerel, gasperaux, smelts) to see whether they contain a constant weight of PCBs per unit weight of lipid from egg to juvenile to adult.

G. C. H. Harding, P. Vass

Sublethal Effects of Contaminants on Organisms

Work during 1977-78 has focussed on two topics: (1) the extent to which aquatic organisms can degrade and excrete known or expected environmental contaminants and (2) the effects of such contaminants on organisms.

Degradation of foreign compounds. Although the insecticide DDT has been used for over 30 years, (and has been recognized as an environmental contaminant for at least 25 years) we still know very little about how it is metabolized by aquatic organisms. A possible scheme for its degradation

was worked out for mammals some years ago; this postulated about a dozen steps in the change from DDT (a fat-soluble material readily stored in depot fat or organisms) to DDA (a water soluble and hence excretable degradation product). We have examined the extent to which this path can be followed in fish by studying the fate of ^{14}C-labelled 'intermediates' in DDT degradation. It was found that two of the steps postulated to be present in mammals, both involving the reduction of metabolites of DDT, do not occur in fish. Thus, in fish, this pathway of DDT degradation is blocked and this is at least a partial explanation of why DDT residues accumulate readily in fish and are not significantly excreted.

The fate of diphenyl ether in fish has also been examined. This is an industrial material widely used as a component of heat-transfer agents, and it has been reported as a trace environmental contaminant. It is probably accumulated and stored in fish, and so its degradation has been studied. It appears to be hydroxylated to the 4-hydroxy-derivative, which may be excreted via the bile on a conjugate.

A third potential contaminant that has been studied is n-octanohydroxamic acid. This material has been proposed for use as an ore flotation agent, and we found in previous studies that it was quite toxic to fish. Using ^{14}C-labelled material we have shown that this compound is taken up rapidly from water by fish: but is cleared quite rapidly when the fish is transferred to clean water. Clearance appeared to depend on the formation of an unidentified metabolite.

R. F. Addison, D. C. Darrow, D. E. Willis, M. F. Zinck

Enzyme induction systems. Most of the organic environmental contaminants in the Canadian Atlantic Region are present at relatively low levels, and do not exert any obvious acutely toxic effect. We do not know, however, whether they exert any sublethal effects, and some of our work has been directed at detecting these. The sublethal effect with which we have been most concerned is the induction (i.e., the stimulation of activity) of mixed function oxidase (MFO) enzymes. These enzymes are key components in the degradation of various foreign compounds, and their activity could not only illustrate sublethal effects of certain compounds in the organism, but might be refined to provide a sublethal bioassay.

It was found that the insecticide DDT and its metabolite DDE had no effect on the MFO system in fish. This finding was rather surprising, since both compounds are powerful MFO-inducers in mammals. However, PCBs and petroleum hydrocarbons are powerful inducers in fish, and petroleum may also induce MFO enzymes in molluscs. We have compared the induction of MFOs in fish by PCBs with the absence of induction by a PCB replacement, thus, demonstrating that the replacement may be more acceptable from one environmental point of view than the PCBs. Work on the refinement of the MFO induction as a sublethal bioassay towards PCBs and related compounds is continuing.

Also examined' was the mechanism of the toxicity of alkylhydroxamic acids (noted above as being proposed ore flotation agents, and under some conditions, potential environmental contaminants). It was shown that n-decanohydroxamic acid was acutely toxic to fish because it induced hypoxemia (low blood O_2 tension which effectively 'suffocated' the fish), through unidentified mechanisms.

R. F. Addison, D. C. Darrow, D. E. Willis, M. F. Zinck

Physiological responses of single organisms to petroleum hydrocarbons. Both laboratory and field studies have shown that soft-shell clams are particularly vulnerable to hydrocarbons persistent in the surrounding sediments, even up to seven years after initial exposure in the case of clams oiled by the *Arrow* Bunker C spill in 1972. Growth, shell deposition, carbon accumulation, and respiration as well as population structure and recruitment are markedly depressed, and are different from those in normal non-oiled populations.

This vulnerability of clam physiology and metabolism appears to differ in degree with the type of hydrocarbon to which they are exposed. In general, while fresh oils and oil products are extremely toxic initially, general physiological deterioration appears to persist in direct relation to the weathering character of the spilled oils.

Clams from oiled sediments continue to carry a large hydrocarbon load derived from spilled-oil sources in their tissues. This then can in turn become available for transmitting via yolk-fats to clam larvae, or via predation to predators such as fish. Part of the problem in clams seems to be due to their inability to metabolize petroleum hydrocarbons by the aryl hydrocarbon hydroxylase (AHH) system, which, in other organisms such as fish and man, is the main enzyme system for ridding the tissues of unwanted steroid-like aromatic hydrocarbons. Studies to date indicate the absence of such an AHH system in bivalves. This is reflected by their inability to rid tissues of accumulated hydrocarbons by normal depuration. Continuing studies in France at the site of the *Amoco Cadiz* spill are designed to investigate this depuration process in greater detail.

The ready availability of oil and of petroleum hydrocarbons to various fish including trout and the English flounder from sediments and water has been observed. Within a few days of exposure to oiled sediments, flounder show significant increases in tissue hydrocarbon concentrations in skin, muscle, and liver samples. Of particular interest, however, is the observation that, despite continued exposure to oiled sediments and despite continuous influx of petroleum hydrocarbons into the flounder, the flounder's tissue hydrocarbon loads decrease after an initial increase. After two months of continuous exposure to oil, tissue hydrocarbon concentrations had decreased to zero in skin and muscle samples with only the liver containing detectable amounts of hydrocarbons. The most persistent compounds in these tissues during the course of the 60-day experiment were the more highly complex substituted aromatics.

A parallel experiment with trout has shown that, over a similar time-course with continuous exposure to oil, induction of the aryl hydrocarbon hydroxylase (AHH) system occurred within 24 hours after exposure. Enhanced levels of the AHH activity were observed for in excess of two weeks during the experiment. A similar behaviour of the AHH system was observed in a second experiment using flounder. It appears then that in fish the physiological potential exists for active enzymatic depuration of the tissues by rapid and continuous enzymatic alteration of the hydrocarbons. This may also account for the extraordinary survival of mullet taken from severely oiled waters in north Brittany, France, four weeks after the *Amoco Cadiz* grounding.

J. H. Vandermeulen, T. P. Ahern

Potential alteration of predator-prey relationship by marine contaminants. Recent studies have focussed on the potential of marine contaminants to alter predator-prey relationships in the marine environment. Using experimental model food chains consisting of unicellular flagellate algae and copepods, it was demonstrated that even small (0.1 part per million) concentrations of a range of chemicals including heavy metals, petroleum hydrocarbons, and chlorinated hydrocarbons can significantly alter the grazing efficiency of a copepod on an algae prey population. Over a 24 hour period, the grazing efficiency of the predator was increased 10 to 25 per cent in the presence of from 0.1 to 0.5 part per million of hydrocarbons. Subsequent studies have shown that the increase in grazing efficiency by the predator, the copepod, was due to a decrease in swimming ability on the part of the prey, the algae. Studies over a 48 hour period have shown that such increased grazing efficiency due to contamination persists at the 0.1 part per million hydrocarbon level.

J. H. Vandermeulen, P. T. Ahern

Bay of Fundy Project

The purpose of the Bay of Fundy project is to investigate the properties and dynamics of the marine ecosystem in the upper reaches of the Bay of Fundy and to assess how they are influenced by the high tidal energy and suspended sediment concentrations characteristic of the region. After interpretation, the data obtained will become part of the Fundy Tidal Power Environmental Impact Assessment exercise to help predict, in both qualitative and quantitative terms, the ecological effects of barrage construction - for example, changes brought about as the result of reduced seawater

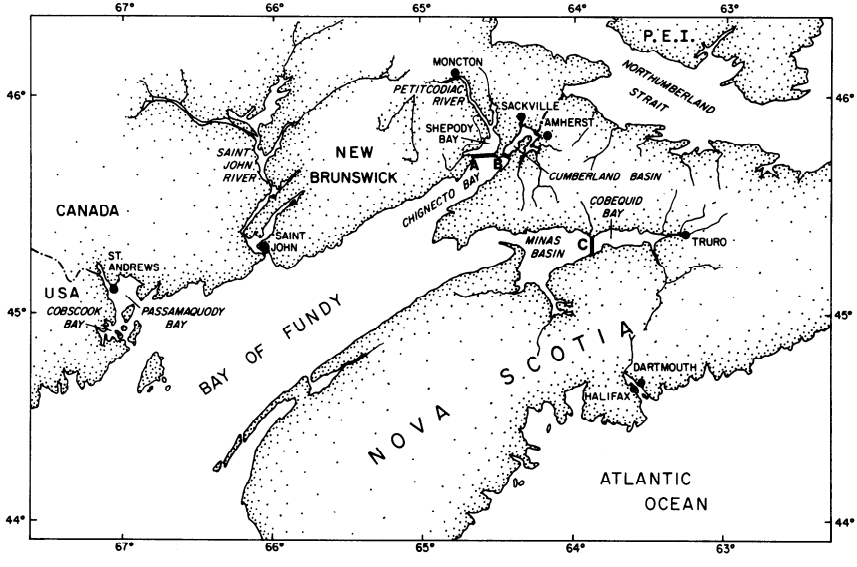


Chart of the Bay of Fundy indicating sites of potential tidal power development (A, B, and C). As a result of recent studies, site IB is the preferred site for further study and possible development. (BIO 4848)

exchange across the barrage site and reduction in intertidal areas and tidal energy behind the barrage. If a tidal power project is ultimately undertaken, the results can also be used to help measure the *actual* changes brought about by barrage construction and judge the accuracy of our prediction.

At the outset emphasis is being placed on conducting ecological surveys to complete the descriptive knowledge of the region. In time, emphasis will shift to studying ecosystem dynamics with the goal of constructing accurate carbon (or energy) budgets for specific geographic sites; for example, important intertidal regions or the entire proposed tidal basin. The results could also be used to construct ecosystem stimulation models. Prime attention is being focussed on the Cumberland Basin region, the preferred tidal development site, but data are also being collected from the Bay of Fundy area as a whole. Because of the dependence on so many environmental factors, this program is being conducted in close co-operation with other government agencies and universities engaged in Fundy research (for example, the Atlantic Geoscience Centre, Canadian Wildlife Service, St. Andrews Biological Station, and Acadia University). The accomplishments to date are summarized in the following text.

Descriptive ecology of benthic macrofauna. Several hundred grab samples have been collected from the Bay of Fundy and Chignecto Bay during the summer of 1978. In addition intertidal samples have been collected every other week at seven locations around Shepody Bay and Cumberland Basin between May and October 1978. Major taxa, numbers, and biomass of benthic animals will be determined. Detailed growth and mortality studies of key organisms have been conducted at two of the intertidal locations

D. L. Peer

Sediment chemistry. The inorganic fraction of 100 grab samples collected during August 1977 has been analysed for major elements and trace metals. Concentrations are generally similar to those found in the Gulf of St. Lawrence; however, variations attributable to sediment texture and geographic location are apparent. Local anomalies occur around a dredge spoil dumping site near Saint John and the dispersal pattern of some artificially-introduced metals may be useful to help predict the dispersal of other sedimentary materials.

Plant pigments and organic content have been measured in sediment samples collected from the Bay of Fundy and Chignecto Bay. These data will be compared to similar measurements of suspended matter in the water column and used to test the hypothesis that the biomass of benthic macrofauna is controlled by the flux of organic matter to the bottom and not by the amount accumulated in sediments.

D H. Loring, B. T. Hargrave

Water column chemistry. During 1977 and 1978 several thousand water samples were collected along the axis of the Bay of Fundy at 14 tidal cycle stations in Chignecto Bay and the mouths of Shepody Bay and Cumberland Basin. The following variables were measured at three or more depths: major elements and trace metals, chlorophyll and phaeopigments,

particulate organic carbon and nitrogen, dissolved organic carbon, and several dissolved inorganic nutrients. Concurrent measurements of suspended sediment, attenuance, and physical oceanographic parameters were made by the Atlantic Geoscience Centre. Zooplankton collections were also made with the assistance of Acadia University.

D. H. Loring, P. D. Keizer, D. C. Gordon, J. Dale

Epibenthic primary production and community respiration. Seasonal variation in epibenthic primary production, community respiration, plant pigment and sediment organic matter concentrations, macrofauna, and *Spartina* biomass have been measured along an intertidal transect at Anthony Park, Cobequid Bay, NS, between May 1977 and October 1978. In addition to providing production and respiration data, these field observations will help differentiate the physical and biological processes that affect the flux of elements across the sediment surface and they will be used to determine how much organic matter accumulates or is transported from intertidal areas in the upper regions of the Bay of Fundy. Similar monthly measurements have been made along a transect at Peck's Cove, Cumberland Basin, beginning in May 1978.

B. T. Hargrave, D. C. Gordon, G. Phillips, N. Prouse, P. D. Keizer, J. Dale

The remains of Bunker C oil from the 1970 Arrow *oil spill still coat some of the shoreline of Chedabucto Bay, NS, and surroundings. Continuous analysis of such residual stranded oil provides information on natural weathering and rates of self-cleaning by wave action and evaporation, as here at Black Duck Cove. (BIO 3934-41)*

Symposium on the Recovery of an Oiled Environment

One question central to scientific concerns over the impact of oil spills and oil contamination has been the problem of environmental recovery following a spill. Although recovery apparently does occur, both the pattern as well as the processes of recovery are not understood. Spills all appear to be unique; that is, each spill appears to behave differently and spills differ in their impact. Some factors that can affect spill impact as well as the subsequent recovery of the environment include temperature, oil type and degree of weathering, meteorological and oceanic conditions, coastline type (geomorphology), and the kinds of biota present.

To examine this question of recovery potential, over 160 scientists and workers in this field met in Halifax, NS, in October 1977 to discuss just how much oil an environment can tolerate, what the recovery patterns might be, and what the weak links or fragile components are in the sequence of recovery steps following a spill.

The 1969 West Falmouth spill and the 1970 *Arrow* spill served as focal points for discussion, with the program consisting of some 40 papers presented by the world's top scientists in this field. The three and a half day meeting consisted of three consecutive sessions, going from chemical and physical aspects of oil weathering, to physiological effects of spilled oil, and finishing with a session on long-term community changes attributable to oiling. Throughout the symposium the emphasis was on long-term follow-up studies, with strong emphasis on documented field work as distinct from simulated laboratory studies. The proceedings of the symposium were published in a special issue of the *Journal of the Fisheries Research Board* of Canada (volume 35, number 5, 1978).

J. H. Vandermeulen, D. C. Gordon, Jr.

Fisheries Oceanography

It is in the Fisheries Oceanography Division that the most direct link between ecological science and resource management occurs. Relevance, in the long rather than in the short term, is the criterion by which we evaluate our research, which is concerned mainly with the structure of marine ecosystems. There is a clear need to develop an understanding of the nature of the relationship between ecosystem structure and the physical environment. More importantly, it is necessary to be aware of the implications of this relationship to marine fish production. The projects cover a wide field of both theoretical and practical studies, and although our approaches are often empirical (in common with much of ecology) they are nevertheless directed towards well-defined goals.

The work in theoretical ecology forms an essential complement to the laboratory and field studies, even though we have to be highly selective in' our choice of projects: because of the complexity of ecological systems there are only certain aspects that, from our present state of knowledge, will yield to theoretical attack. It will be clear from the project descriptions that follow that there is no single path leading to the understanding of ecosystem structure, and the route we must take in order to relate this to efficient management is by no means obvious. However, among other things, our projects do reflect changing perceptions regarding the kind of information required by resource managers. The recent re-emphasis of theoretical studies and our new work on the interaction between ecology and fishery economics are good examples of the way in which our research responds to new concerns.

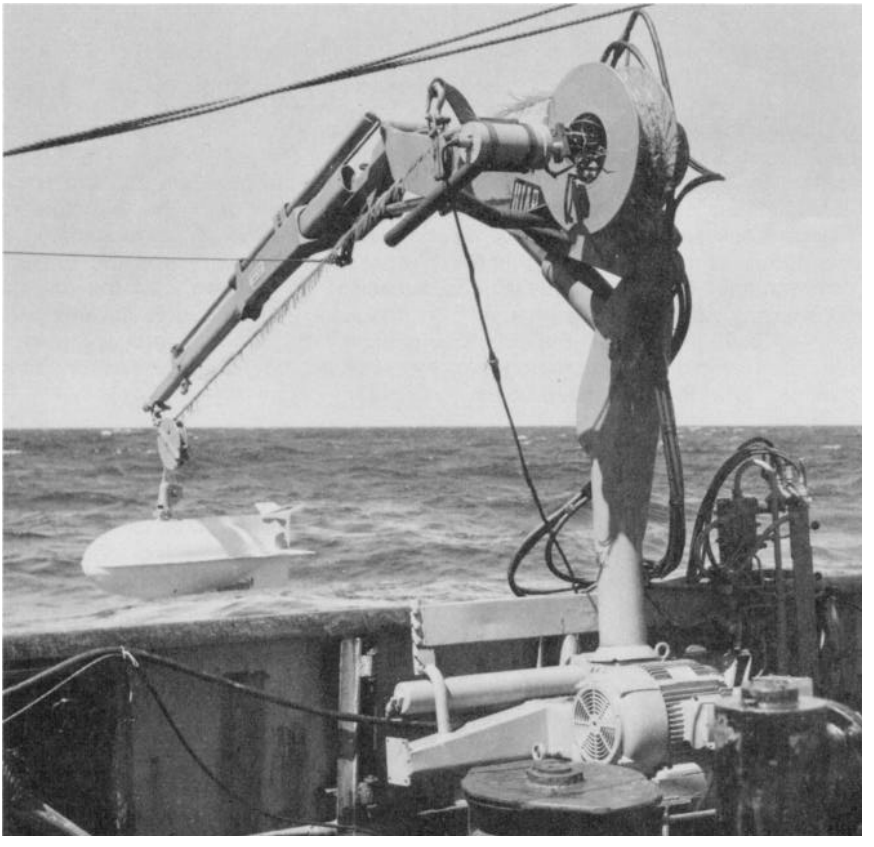
R. W. Sheldon

Population Dynamics and Ecological Theory

Hydro-acoustic assessment of fish stocks. Data on fish stocks are both difficult to acquire and essential for sound management. Traditionally, population parameters have been estimated from data on catch per unit effort and from analyses of the age composition of the catch. Although such fishery-dependent methods have provided apparently sufficient information for the purposes of fishery management they are clearly subject to biases beyond scientific control. In developing acoustic methods of stock assessment we hope to avoid these biases and provide estimates of stock size that are not dependent on the existence of a fishery.

Over the last several years, we have developed a system based on a Simrad EK-50 scientific echo sounder and a Honeywell 316 minicomputer. The transducer is in a body that can be towed at depths of up to 50 metres. This reduces spurious noise and adds to the versatility of the system. Data are recorded onto nine track magnetic tape and onto teletype for later processing. In addition to this, initial estimates of fish stock are processed and printed out during the actual survey.

Recent developments have included a 12-bit analogue to digital conversion system. This has improved the resolution, and the measurement of the



A hydraulic crane is used to raise and lower the towed body that contains the transducer used for hydro-acoustic assessment of fish stocks. (BIO 2535-19)

amplitude of the return echo to give an improved estimate of the size of the fish. Digital, time-varied gain has also been introduced to minimize errors due to the sound spreading and absorption. A dual beam 50 kilohertz transducer has also been employed to reduce the uncertainty in determining the size of sound scatters; a small fish near the middle of a single sound beam or a large fish near its edge may give similar echoes. The new transducer minimizes this effect by transmitting a narrow beam (6" between 3 decibel points) and receiving on both a broad (24") and a narrow beam.

Computer programs have been developed to permit simultaneous echo counting and echo integrating, which means that it is possible to distinguish between echoes received from groups of small fish, or single large fish, and to recognize single fish beneath schools of fish. It is also possible to investigate the structure of fish schools.

Because of the need for more detailed data analysis and interpretation, a second phase of development has now been initiated. The computer is being replaced by a microprocessor system and the echo interrupt sample

rate is being increased from 600 to 100 microseconds. With this redesign only a minimum of processed data will be available during a survey, sufficient only to check the proper functioning of the equipment. The bulk of the data analysis will be performed on shore-based computers; this disadvantage will be far outweighed by the much greater reliability of the microprocessor system.

Effective data analysis depends not only on the efficiency of the data collecting system but also on its deployment, and considerable effort is being directed to survey design. Methods are also being developed to enable the essentially two-dimensional information collected by the acoustic system to be interpreted as the three dimensional distribution of fish in the sea.

R. Shotton, R. G. Dowd

A holding system for shellfish experimental work. In 1974 attempts were made to use a simple wooden raft for shellstock production experiments being conducted at St. Margaret's Bay, NS. The system was not able to withstand winter ice conditions. Subsequently, trials have been made with a much more substantial steel submersible raft devised by the Fisheries and Marine Service, Halifax Laboratory, for holding salmonids in local embayments. Following some design modifications the raft was

The submersible raft used for shellfish production experiments. (BIO 4740-24)

deployed in April 1977 and was successfully maintained over a winter. Subsurface positioning of the raft during winter and retrieval during ice-free periods allowed successful monitoring of shellfish production studies throughout the first winter of use.

K. R. Freeman, L. M. Dickie

Studies on blue mussels. Analysis of mussel growth and mortality is continuing. The first results demonstrated substantial differences in net productivity of a single source stock reared in two areas. The explanation of the difference is complicated by evidence that there exists a variety of growth types within the source stock, and by variability in mortality patterns. However, in the main, the mortality rate did not appear to act differentially on the growth types.

It seems likely that the differences in growth rates within the source stock have a genetic basis. The reasons for mortality differences in different areas are harder to evaluate. The experimental field holdings have therefore been extended to give indices of mortality between source stocks. Mussels from St. Margaret's Bay, NS, Bedford Basin, NS, and Ellerslie, PEI, have been set out in each of the three growing areas. Preliminary results confirm that within a given area there are both growth and mortality differences among stocks from different areas, in addition to differences between areas. It appears that if both growth and mortality patterns are utilized, the blue mussel is a promising indicator of environmental quality. However, any such assessment may have to take account of genetic factors.

To further examine the basis for production differences, a number of tests have been undertaken in co-operation with scientists in other institutes. We are initiating tests (in co-operation with Dalhousie University) of the productivity of progeny of the first reciprocal transfer experiments. Fast and slow growing survivors from the various source stocks have been crossed and are being reared to a size where their production in the source of environments can be compared. A preliminary analysis of isoenzymes at the LAP (leucine aminopeptidase) site was undertaken by Dr. R. Koehn, State University of New York, Stony Brook, on specimens supplied from the three source areas. An extension of this work is planned in co-operation with Dalhousie University. At the same time a number of comparative studies of mussel physiology of the different source stocks is being undertaken by our associates.

K. R. Freeman, L. M. Dickie

Soft shell clam studies. Trays of different-sized soft shell clams *(Mya arenaria)* from an area near Halifax were suspended in Bedford Basin and St. Margaret's Bay, NS, to compare resources in this organism with previous results for the blue mussel. This experiment, which has been underway for only one year, has so far shown no major differences in either growth or mortality rates in the two transplanted areas. However, since the differences in production shown by mussels were greater during the second holding season than the first, this experiment will continue for at least another year.

K. R. Freeman, L. M. Dickie

Pesticide accumulation in seals. Adult male grey seals accumulate pesticide residues in their bodies. In general, the older the seal the higher the pesticide concentration. However, no cumulative increase was found in females. The reason for this is that the female seals use their fat reserves to produce milk. The pesticide residues are transferred from the fat to the milk and finally to the seal pup.

P. F. Brodie, R. F. Addison

Stock differentiation in whale populations. Evidence has been found from studies of energetics and functional morphology that different whale stocks can be recognized from measurements of body size. Among other things, there is a change of average body size in the northwest Atlantic whales that correlates with latitude. This is inversely related to the length of the feeding season; the shorter the feeding season the larger the average whale.

P. F. Brodie

The distribution of whales as an indicator of areas of high biological production. Information from logbooks of the whaling station at Blandford, NS, showed a distinct geographical pattern to whale kills. The whales occurred only in certain areas and remained concentrated in these areas in spite of the fact that some were removed by the catcher vessels. Once baleen whales find good feeding grounds they are not easily frightened away either by hunting or by ship traffic.

The whales occurred most frequently on the edges of the banks and at the break at the edge of the continental shelf. These are areas where large concentrations of zooplankton occur and where high levels of biological productivity are maintained. It is not surprising that baleen whales are used by commercial fishermen to locate fish schools, particularly herring.

W. H. Sutcliffe, Jr., P. F. Brodie.

The feeding strategy of whales and the concentration of food organisms. All successful predators are biased in the sense that they do not sample the environment randomly in order to find their food. They look for anomalous concentrations or clumps of prey organisms, and they stay with these until either their demands are satisfied or the prey are so reduced that it is energetically unprofitable to continue feeding. Seabirds, seals, whales, and fishermen follow this strategy.

Oceanographers take great pains to avoid bias in sampling, with the result that models of food chain dynamics describe average situations. They are undoubtedly useful in describing general conditions such as “annual production” or “total fish catch” but a rigid application of such models to short-term specific predator-prey interactions leads to obvious anomalies.

Using realistic estimates of swimming speed, mouth cross section, filtering efficiency, and duration of feeding of fin whales, it was possible to calculate that in the immediate feeding area the density of euphausiids must be at least 100 times greater than the average concentrations found on the Scotian Shelf. If this were not so then it would not be possible to account for the amounts of food actually found in the stomachs of fin whales. By selective deployment of net samples and sonar observations, euphausiid densities of the correct order of magnitude have been discovered.

P. F. Brodie, D. D. Sameoto (Biological Oceanography), R. W. Sheldon

Bioenergetics and recruitment of pelagic fish. Prediction of recruitment is a fundamental problem facing fisheries managers. This important topic is being examined from both a practical and theoretical point of view using the principles of natural selection and bioenergetics.

A recent study has shown that, according to hydrodynamics theory and the size composition of particles in marine food chains, there are at least two basic species-specific swimming speeds of importance to pelagic fish: (1) the optimal sustained speed, which maximizes the distance travelled for unit energy expenditure, and (2) the optimal foraging speed, which maximizes the rate of flow of surplus energy.

Using sockeye salmon data we have shown that optimal sustained and foraging speeds are proportional to the body length raised to the 0.4 power. By analogy, if pelagic fish in general tend to move at either the optimum sustained or foraging speed, their ration and growth rate relative to the body weight should be proportional to a power that varies between 0.7 to 0.8. These predictions are consistent with field growth measurements for several pelagic species.

From a practical standpoint, this theory of optimal foraging speed is currently being used to test the hypothesis that species-specific differences in the partitioning of energy into growth and reproduction play an important role in the stock-recruitment process.

D. M. Ware

Ecosystem structure. One of our major efforts in recent years has been to focus attention on the importance of the relative sizes of organisms in fish producing systems. Observations of biomass relative to size, and of predator-prey size relationships, led to the formulation of a theoretical ecosystem structure that could be described simply in terms of the standing stocks and sizes of predator and prey, and the growth efficiency of their interaction. In practice, this means that given the size and standing stock of plankton the standing stock of fish can be estimated, or vice versa. Given the growth rate of either fish or plankton, the production can be estimated.

We have used this theory of ecosystem structure to estimate the potential fish production in three areas. Two of these, the Gulf of Maine and the North Sea, support both demersal and pelagic fisheries; the other, the Peruvian anchovy fishery, is wholly pelagic. Estimates of average fish catch agreed very well with the data for actual fish landings. Further studies using this concept of ecosystem structure are now being made (both at MEL and elsewhere) on the North Atlantic fisheries. A recent report from the U.S. National Marine Fisheries Service indicates that the ability to estimate biomass is good but production estimates may be high by a factor or two. To a large extent this uncertainty is due to lack of information on size-dependent growth rates (see below).

R. W. Sheldon, W. H. Sutcliffe, Jr.

Variation of growth rate in relation to size; phytoplankton studies. An important aspect of the study of the size of organisms in relation to ecosystem structure is the determination of size-dependent growth rates In its general form this is simply a variant of the well known “metabolic law” which states that the rate of living processes varies inversely with the size of the organism. However, reliable data on size-dependent growth rates are not available. Phytoplankton were chosen for the experimental program simply because their generation times are short, typically of the order of a day or so, and experimental procedures can therefore proceed rapidly.

Current methods for measuring growth rates of natural populations were found to be unreliable; variations of an order of magnitude are common. Methods were therefore devised, based on particle counting techniques, that would give reliable estimates of growth rate. Experiments have been made in Bedford Basin and St. Georges Bay, NS, and off Peru. Much of the data have yet to be processed but preliminary results suggest that growth rate depends mainly on the size of the organism concerned and the environmental temperature. For very small organisms day-length is also a factor to be considered. The object of these studies is to establish a precise relationship between growth rate and size. With this done, the production at any size, including fish, can be estimated from measurements of standing stock.

R. W. *Sheldon*

Dynamic response of ecosystems. To complement the practical work described above, theoretical studies of ecosystem structure were undertaken. Most models of ecosystems, assume either a static or steady state environment. However, ecosystems are constantly subjected to external perturbations, and the sensitivity of a system to such interference is critical in determining or predicting the observed behaviour. By means of a new mathematical technique it is now possible to predict the amplitude of the response of an ecosystem to a perturbing influence. It is also possible to identify the type of external variability that is most likely to have an effect on stability.

W. L. Silvert

Community structure of exploited populations. Structural changes of fish communities, associated with major alterations of species, have been found in some instances to show abrupt, discontinuous behaviour. These discontinuities are associated with critical values of system productivity and fishery exploitation. Similar effects have been found to occur within species and are a potential contributor to the variance of the community size spectrum. Analysis has shown that much of the variance depends on the interaction of prey availability with fishery exploitation.

The above studies suggest the feasibility of general methods for determining the critical interactions of basic production parameters with fishing effort. Related work, that is not yet complete, began in 1978 on models of fish growth and reproduction and on the problem of identifying interacting species complexes.

S. R. Kerr

Niche theory and fish production systems. In its modern form, the ecological niche has been defined by G. E. Hutchinson of Yale University as a multi-dimensional array of ecological factors that affect the survival of an organism. As originally conceived and conventionally applied, the Hutchinsonian niche is firmly rooted in the competitive exclusion principle. These conceptual roots have made the quantitative description of the niche difficult, and the theory has limited predictive capacity.

An attempt has been made to redefine the concept in directly observable terms. The factor analysis approach taken by F. E. J. Fry of the University of Toronto provides both theory and measurement techniques that can be used to analyse the Hutchinsonian niche. Fusion of the Fry-Hutchinson

concepts leads to a metabolic niche definition that has the advantages of generality and precisely defined boundaries. It can also be applied to a quantitative description of the niche. For all organisms, measurements can be expressed in terms of metabolic capacity. As such, the metabolic niche has applications to analysis of growth and reproduction of individual fish populations. Equally, it can be applied to the study and prediction of population interactions.

S. R. Kerr

Optimal life history strategies of fish. Within the general theoretical framework described in the above studies it has been possible to investigate what one could describe as the life-strategy of fish. It is now becoming clear that because of ecological constraints there exists an optimal life history for any species of fish under certain environmental conditions.

The principle of natural selection implies that each species is optimally suited for its ecological role. In the past the problem has been that the ecological role has not been easy to define. But with the development of a theory of size structure for ecosystems this is now less difficult. It is of practical value in modelling the life histories of fish and in predicting likely responses to environmental change. One very useful application of this approach has been to further the understanding of the optimal foraging behaviour of fish under different levels of food availability. The same general approach can be used to explain why some fish virtually cease to grow at first maturity, and put all their energy into reproduction, while others continue to grow throughout life.

D. M. Ware, W. L. Silvert

Effect of fishing mortality on population stability. It is commonly believed that fishing pressure tends to destabilize populations. One way this can occur is by shortening the mean reproductive life span. However, theoretical studies suggest that increased mortality can also supress some of the natural causes of variability so that for some populations intrinsic variability may be decreased under moderate exploitation. This means that it is possible in some cases for population size to increase when a naturally unstable population is subjected to a low level of fishing.

W. L. Silvert

Interpretation of catch statistics in a multlspecies fishery. In many Canadian fisheries it is necessary to rely on commercial catch statistics to provide some of the data used in the assessment of fish populations. When more than one species is being taken, the analysis is complicated by the necessity to determine the allocation of effort between them. Where fishermen effectively distribute their effort so as to maximize net income, models of the distribution of catch per unit effort show that many of the procedures that have commonly been used in the past give strongly biased estimates of trends in abundance. In particular, catch per unit effort may fail to reveal even a drastic decline in a stock when fishermen are free to switch to other species.

W. L. Silvert, L. M. Dickie

Fishery regulation systems. Declaration of the 320 kilometre exclusive fisheries jurisdiction provided opportunities for development in Canadian fisheries. Reviews of the resulting needs for administrative initiatives have been undertaken by the writer and associates in the Fisheries Management Branch and in universities. There are important avenues in the economic and social as well as the biological-physical sciences that need to be considered for application.

An important landmark in the review process was the 1978 conference on Economic Rationalization of Fisheries, held at Powell River, BC. This comprehensive review made it clear that while fish stock recoveries under extended jurisdiction are consistent with expectations, economic results are variable and depend on interaction of sound organization in industry with technological change. In Canadian fisheries, while rapid economic recovery is confounded with both real price rises and increasing difficulties with the quality of data reported, there is little doubt that the short-term rise in prosperity verifies theoretical expectations that rent dissipation in the fisheries of the past has been very high indeed. In situations where social organization has effectively limited new access to the fishery, this rent recovery is appearing as large producer surpluses. But there are indications that in most cases the customary management measures and social organization have not effectively eliminated competition for the resource base, so that the newly emerging benefits are being lost again in increasingly excessive technology.

The signs of increased prosperity have created new pressures on systems for allocating access to the resource, resulting in marked incentives for participants to circumvent the rules. The rising costs of enforcement and decreasing quality of statistical reporting lend a sense of urgency to the development of more appropriate administrative responses. Recent management experiments show that limited forms of self-policing are both practicable and widely accepted as necessary. Such strategies would also directly serve the objective of employing some of the benefits of administrative services to offset their costs.

The rapid rates of recovery in some fisheries have exceeded expectations. They may reflect real long-term abundance changes or short-term availability effects, but management information systems developed under the old international control regime are not well suited to distinguishing between the two causes. With the shift to national jurisdiction, and the consequent partial elimination of competition for the resources, more precise methods are needed, only some of which have been successfully initiated. Better forecasts of catch rates are required in framing fishing plans and calculating "excess" production available for foreign bid. While fishery prediction has always been an important aspect of biological and physical oceanographic programs, the new jurisdictional setting provides much improved forms for the necessary joint research and management studies.

L. M. Dickie

Ecological Studies of Recruitment and Year Class Success

Structure and dynamics of the southern Gulf of St. Lawrence herring stocks. It was believed that in the southern Gulf of St. Lawrence there were two stocks of herring. One spawned in the spring and the other in

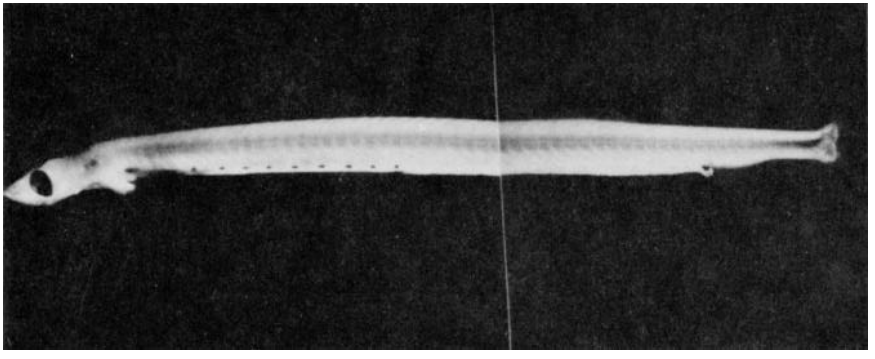
the autumn. Recent studies have shown that both the spring and autumn stocks consist of two separate spawning groups. Each of these groups can also be shown to separate into two or more runs. Therefore, instead of the previous concept of a single level of organization of the herrings stocks, it now seems that at least three levels of organization are present. This work was initially based on historical data on landing trends and spawning times and on recent measurements of the seasonal size distribution of the herring larvae. Following this we were able to show that a group of newly hatched larvae appears shortly after the arrival of each of the four parental spawning groups.

The population structure of the herring stocks that we believe exists is supported by length-frequency data. Since the spawning groups grow at different rates, the back-calculated length distribution at the size at which the first growth ring is formed on the scales ought to show four distinct modes. This, in fact, is what we found, and the match between the expected and observed distributions was very close. This not only confirms that the herring form distinct spawning groups but also indicates that in the southern Gulf of St. Lawrence the herring spawn at the same time as their parents and that four separate stocks are represented.

We have found that the spawning group frequencies have shifted in recent years and this shift is associated with changes in the abundance of the Atlantic mackerel. Our data suggest that the integrity of the herring spawning groups is probably maintained by a process of disruptive selection induced by cyclic variation in mackerel abundance. Taken together, all the evidence suggests that the spawning group, rather than the spring and autumn stock, may be the logical unit of management for the inshore herring fisheries.

D. M. Ware, B. L. Henricksen

Georges Bank larval herring study. An understanding of and an ability to predict the biological and environmental factors that determine good or poor year classes would greatly enhance current herring management practices. A multi-ship experiment was proposed by ICNAF for the autumn of 1978. The principal objective was to identify and follow a patch of herring larvae and to monitor its structure at short time intervals (hours or days).

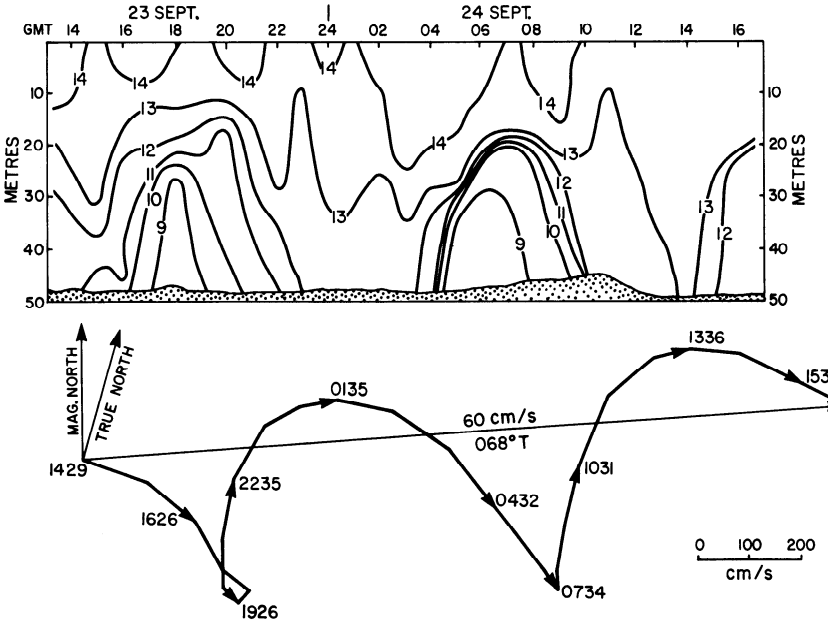


A composite photo of a herring larva, about three months o/d and 21 millimetres long.

MEL undertook the necessary physical oceanographic measurements and, accordingly, a one week survey was made along the northern edge of Georges Bank in September 1977 to gain preliminary information on the oceanographic structure of the area in autumn.

A 25-hour anchor station was occupied in an area where beds of herring eggs had been reported in the past. A time-depth temperature plot (see figure) showed a semi-diurnal variation in the temperature structure. Temperature at the bottom changed from less than 9°C to more than 13°C within a 6 hour period. A progressive current vector plot showed that there was a north-south tidal component advecting a subsurface cold front back and forth across the station. There was also a strong residual current of 60 centimetres per second at the surface that diminished rapidly with depth. There was no reduction with depth of the tidal current. It seems that the beds of herring eggs may be subjected to strong temperature fluctuations and that vertical variation in residual currents may be more important than the tide in dispersing the larvae laterally.

R. W. Trites



Semi-diurnal variations in temperature (upper diagram) and a progressive vector plot of currents at ten metres' depth (lower diagram) at an anchor station on Georges Bank, September 23-24, 1977 (see text). (BIO 5092)

Mackerel reproductive ecology. Intensive ichthyoplankton survey data indicate that the mean date of peak spawning of Atlantic mackerel *(Scomber scombrus)* in the southern Gulf of St. Lawrence is July 1 ± week. This coincides with the maximum biomass of the summer plankton. Mackerel eggs average 1.3 millimetres in diameter at the beginning of the spawning

season in June, and decrease steadily to 1.1 millimetres by mid-August. There is a corresponding trend in the mean particle size of the plankton, which reach a minimum length in mid-summer and a maximum in winter. This recurring size cycle was as important as the seasonal change in plankton biomass in determining the abundance of suitable food organisms for newly hatched larvae. Thus, the timing of spawning and the progressive decrease in egg size during the spawning season will tend to ensure that the parent stock produces larvae of a suitable size, and at the correct time, and that they encounter an abundant supply of appropriately sized food organisms.

D. M. Ware

Behaviour of first-feeding anchoveta larvae. Preliminary experiments concerning the development and feeding behaviour of anchoveta *(Engraulis ringens)* larvae were conducted at a shore station in northern Peru during the CIDA project in November 1977. The significance of the results of these experiments is being considered in relation to similar, but very much more extensive, studies of the western anchovy *(Engraulis mordax),* performed in California. We found that the Peruvian larvae were an average of 2.8 millimetres long at hatching, and that the yolk-sac stage lasted 2.75 days at the ambient water temperature (18°C). There was a high degree of variation in the quantity of yolk of wild-caught larvae presumably due, in part, to normal variations in egg size. This may be an indication that individuals had been developing under different environmental conditions.

The larvae began feeding 1.35 days after the disappearance of the yolk, at which time they averaged 4 millimetres in length. From a variety of natural plankton offered, they selected copepod naupulii and copepodites, and three genera of phytoplankton; *Actinocyclus, Gymnodinhrb,* and *Coscinodiscus.* During the 4 to 6 millimetre stage, 68 per cent of the larval diet (by volume) consisted of zooplankton and 32 per cent of phytoplankton, and for both types the captured food particles averaged 60 microns in diameter.

D. M. Ware, T. C. Lambert, J. McRuer

Residual currents off southwestern Nova Scotia and their possible effect on lobster recruitment. The production and supply of lobster larvae is being investigated by the Biological Station, St. Andrews, NB, and physical oceanographic data from drifter returns in the area of this investigation are being processed by the Marine Ecology Laboratory. The study relies mainly on existing data although five releases of drift bottles, drift cards, and seabed drifters were made in the summers of 1977 and 1978.

The project is not complete but enough information is now available to show that surface current patterns change significantly during the year. For most of the year there is a simple westward and southwestward flow over the western part of the Scotian Shelf, a northwesterly flow over the eastern part of Browns Bank, and a northerly flow into the Bay of Fundy. However, from June to September there is a change in the pattern: the southwestward flow over the Scotian Shelf diminishes and moves offshore, and water from Browns Bank moves towards Cape Sable and along the Nova Scotian coast. In most years this flow does not extend beyond Shelburne but it may extend to Mahone Bay (NS). Some of the water moving towards Cape Sable also

enters the Bay of Fundy. The transit time between Browns Bank and Cape Sable is about 30 to 40 days. If one assumes that lobster larvae are released on Browns Bank and on the continental shelf to the southeast then it is highly probable that they are transported inshore from these regions. In common with many inshore regions, considerably year-to-year oceanographic variability will occur.

R. W. Trites

Physical oceanographic studies in the Strait of Canso. Lobster landings have declined by an order of magnitude in Chedabucto Bay since the mid-1930s. The beginning of this decline corresponds in time with the building of the Canso Causeway and the cutting off of the flow through the Strait of Canso. Based on work done during the construction phase of the causeway, the mean volume transport was estimated to be 7000 cubic metres per second to the southeast into Chedabucto Bay; the transport was due to a higher mean sea level in the Gulf of St. Lawrence than in Chedabucto Bay. Elimination of the transport through the Strait is estimated to have reduced primary production by 15 per cent in Chedabucto Bay through loss of nutrient entrainment by estuarine flow. No changes are estimated to have occurred in the flushing rate or in the temperature-salinity characteristics of the water in St. Georges Bay (northwest of the causeway); however the mean circulation may have been altered.

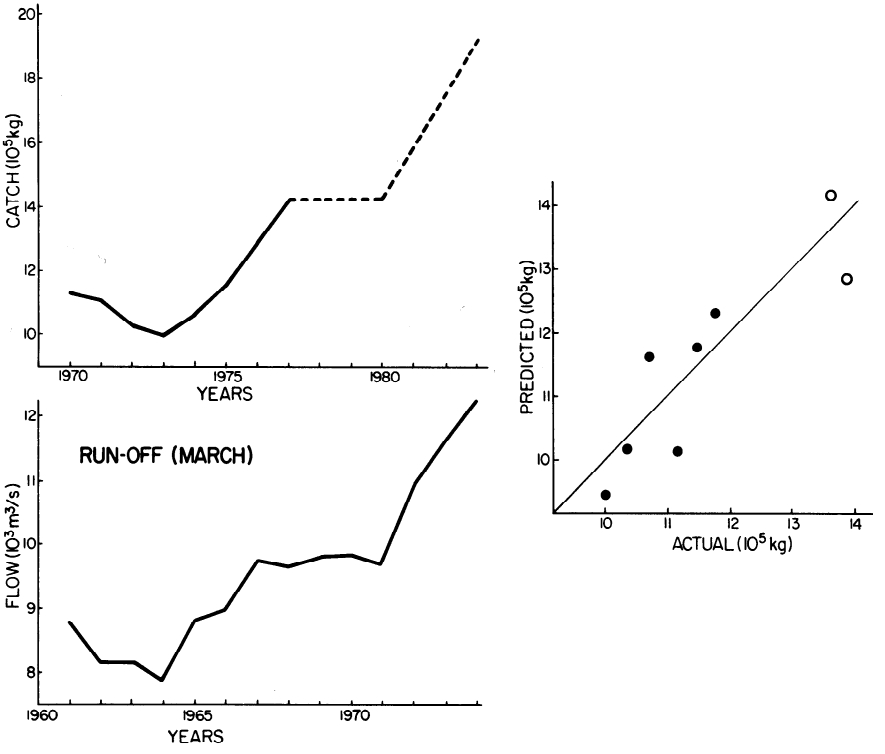
K. F. Drinkwater

Environmental Control of Fish Population Abundance

The relationship between St. Lawrence River run-off and fish catch. For the past several years studies have been made relating the discharge of the St. Lawrence River to fish catches in the Gulf of St. Lawrence. Positive correlations between river flow and fish catch were discovered but these were significant only if the fish catches were lagged several years relative to the run-off data. The lag varied with species and corresponded to the average age at capture. This suggested that run-off affected larval or juvenile survival. The economic importance of these observations is that the useful river run-off occurs several years before the fish catch responds, and therefore it may be possible to forecast fish catches for this area many years ahead, assuming that environmental relationships do not change.

Several species are being studied. The clearest picture has been obtained for the Quebec lobster catch; here, the significant lag between catch and discharge is nine years. In the 1975/76 Biennial Review we presented diagrams to show the relationship between run-off and lobster catch for the catch statistics of 1939 to 1968. The correlation between these data sets, with a nine year lag, was very high. Predictions of catch were then made for 1968 to 1974 (see figure). The average difference between the predicted and actual catches was five per cent and the maximum was less than ten per cent. However, it should be noted that the data were smoothed by three-year running means in order to study trends.

We now have data for two more years (see figure) and they do not differ significantly from earlier results. We now consider that we have sufficient information, both from the data base and from the 1968 to 1976 forecasts, to use river discharge to forecast Quebec lobster catch for the years 1979 to 1984 (see figure). Obviously, we suggest caution in interpreting this



Graphs showing the relationship between river run-off and lobster catch (see text). The solid curve (upper left) represents the lobster catch (see right-hand figure) and the broken curve represents the forecasted lobster catch (1978-1984). Actual and predicted catch (7 969-7978) are shown in the right-hand figure (see text). Solid circles represent data given in the previous Biennial Review; the open circles include 1977/78 data. (BIO 5102-1)

forecast. First, this is a forecast (i.e., it indicates a trend), not a prediction, and it is only as good as the data on which it is based. Second, the river discharge in recent years has been anomalously high, so that some of the forecasts are outside the range of the data base, and we have no means of knowing that the correlation will hold at such high levels. However, if the future correlation of river discharge with lobster catch follows the past trend, and providing that no new environmental or social changes occur, then Quebec's lobster catch should increase significantly in the next few years.

W. H. Sutcliffe, Jr.

The relationship between fish catch and temperature in the Gulf of Maine. A study, using correlation analysis, of coastal sea temperatures showed that the effects of the St. Lawrence River discharge extended through the Gulf of St. Lawrence, along the Scotian Shelf, and into the Gulf of Maine. In the same way that fish catch in the Gulf of St. Lawrence correlates with discharge, the catches of 10 out of 17 species (80 per cent of the commercial catch) in the Gulf of Maine correlated with temperature.

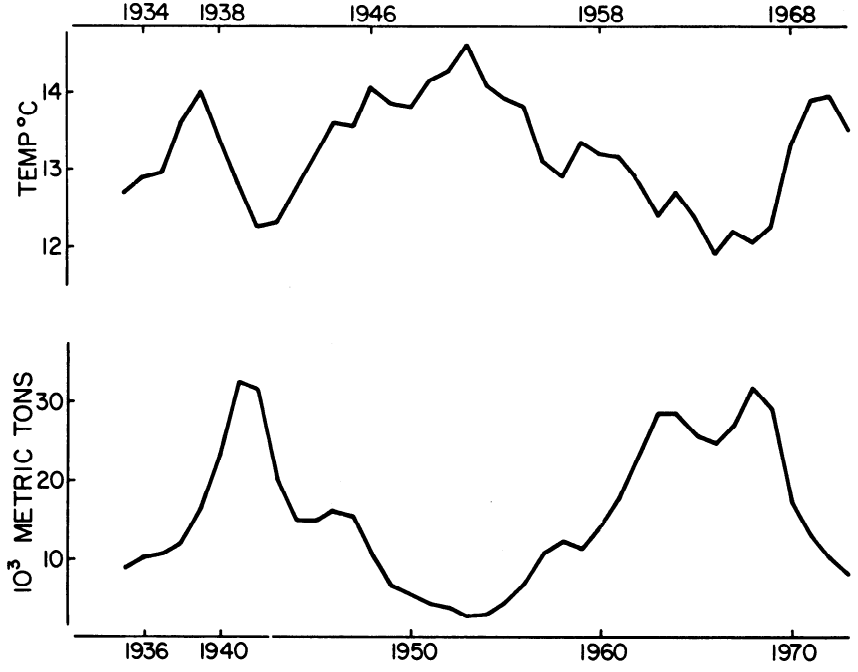
Hindcasting of fish catch was attempted by taking the first half of a 40-year data series and predicting the second half. Correlations improved if fishing effort was included; however, environmentally imposed patterns accounted for at least 50 per cent of the catch fluctuations. The predictions for the second half of the data record were particularly good for cod, haddock, yellowtail flounder, and menhaden.

W. H. Sutcliffe, Jr.

Freshwater discharge from Hudson Bay. The studies of the St. Lawrence River discharge and its effect on the coastal fisheries have provoked speculation that this might not be a phenomenon peculiar to the St. Lawrence. Recent work in Coastal Oceanography (AOL) has shown that very large quantities of fresh water are discharged seasonally from Hudson Bay and affect the Labrador Current in important ways; these effects extend at least as far south as the Grand Banks. This has aroused interest in the effects of seasonal nutrient additions to the surface layer off Labrador. Studies are underway in MEL to gain some knowledge of the structure and functioning of this system and to assess the possible effects on subsequent fishery production of the Labrador Shelf.

W. F. Sutcliffe, Jr., R. H. Loucks, K. F. Drinkwater

A fish population model with environmental input. The relationship between ocean temperatures, fish catches, and fishing effort was investigated in a simple model. Two fish populations were considered - yellowtail



Relationship between fish catch (yellowtail flounder, southern New England) and summer temperature in the Gulf of Maine. (BIO 3681)

flounder of southern New England and cod of ICNAF sub-area 5 (Gulf of Maine - Georges Bank). It is suggested that variation in ocean climate triggers corresponding fluctuations in fish-stock recruitment and subsequent abundance and catch. Two pathways between abundance and catch are recognized: (1) direct influence, where catch may be simply proportional to abundance and (2) responsive effort, where in some cases at least fishermen have adjusted their fishing effort to increased or decreased abundance. Where fishermen react to changing abundance, a combination of fish catch and fishing effort correlates with ocean climate.

The role of the environmental modifications in the simulation model turns out to be significant and sometimes the effect is very subtle. In yellowtail flounder, where reliance on recruitment is great, the effect of the environment upon the catch is direct. In cod, the effects of variation of recruitment are buffered by the presence of more year-classes. But the fishery is prosecuted by a perceptive fishing industry with results that are similar to that of a natural predator-prey system. This means that because of the responsive effort of the industry the effect of environment upon the catch is amplified but the effect of fish abundance on the subsequent catch is stabilized.

W. H. Sutcliffe, Jr., R. Loucks (Louck's Oceanology)

Water transport on the Scotian Shelf. Our demonstration of the effects of the St. Lawrence River discharge on oceanographic conditions in the Scotian Shelf and the Gulf of Maine, and on fish catch has resulted in a need for further oceanographic studies of the Scotian Shelf. To obtain a better estimate of the flow along the shelf as well as its seasonal distribution, monthly longshore geostrophic transports were calculated using data from a standard transect southeast of Halifax. Data had been collected since 1950 approximately once per season. The net longshore transport over the shelf is 350 cubic metres per second to the southwest varying from a high of 6×10^5 cubic metres per second in winter to 1.5×10^5 cubic metres per second in summer. Flow over the inshore third of the shelf accounts for 75 per cent of the calculated net transport. Comparison of monthly geostrophic transports through Cabot Strait and the Halifax transect suggests the latter to be an extension of the outflow from the Gulf of St. Lawrence, a result consistent with water mass analysis. The Halifax transect geostrophic transports have been used by other investigators as input into two separate box model studies, one of the Gulf of Maine and one of the Scotian Shelf. Aliasing (energy in frequency bands lower than the sampling frequency) is a problem with the Halifax transect data, which prevents it from being used to estimate year-to-year variability.

K. F. Drinkwater, B. D. Petrie (AOL), W. H. Sutcliffe, Jr.

Drifter data base. Since the early 1920s drift bottles have been released from time to time off the Canadian Atlantic coast to study surface current patterns. Since the early 1960s, seabed drifters have also been released in large numbers. While the bulk of the releases have been made by Canadian authorities, appreciable numbers have been released by United States agencies as well. The data, in general, were scattered among several laboratories, and in each case, were only partially computerized. For the continental shelf area extending from Cape Cod to the Grand Banks and including the Gulf of St. Lawrence, more than one quarter of a million drifter releases have been made to date. The bulk of these releases

together with recovery data have been assembled into one data base, and are now available through the Marine Environmental Data Service, Ottawa, for the interested user.

R. W. Trites

Studies of continuous plankton records. Biological oceanographic data in time-series form are usually not abundant and usually do not extend very far into the past. Through the generosity and co-operation of scientists at the Institute for Marine Environmental Research, Plymouth, England, we have gained access to Continuous Plankton Recorder survey data from eastern Canadian waters. These surveys were made along three commercial shipping routes, mostly across the continental shelf, and they extend over a ten year period. Tracks were sampled at least once each month and the data include most of the net zooplankton and the larger phytoplankton species, effectively at 16 kilometre intervals along each track. The data, supplied on magnetic tape, have been transferred to disc storage and can now be drawn upon with the help of specially designed computer programs. These data have enabled several time-dependent projects in plankton energy to be undertaken: the first of these concerns the plankton calendar related to the important coastal upwelling that occurs off southwest Nova Scotia each fall.

W. H. Sutcliffe, Jr., R. O. Fournier (Dalhousie University)

Ecological Studies of Inshore Fisheries - St. Georges Bay, NS

Studies in St. Georges Bay were initiated some years ago by Fisheries Oceanography. At the start, only a relatively small effort was involved and the work was concerned mainly with the life history and ecology of larval fish and the effect on these of the physical oceanographic regime. Three years ago the work was expanded considerably and began to assume the form of an ecosystem study with the general objective of giving further insight into the structure and potential production of inshore fisheries. Much of the work is reported elsewhere in this review and includes studies by Environmental Quality and Biological Oceanography of MEL as well as by the Institute of Oceanography, Dalhousie University. During 1978 two research students from Dalhousie University worked in the Bay on problems involving capelin and flatfish. In 1979 there are plans to encourage work by staff and students of St. Francis Xavier University, Antigonish, NS.

The decision to expand our ecological studies was based largely on the preliminary physical oceanographic results. The early studies had established the presence of a clockwise gyre in the Bay. This indicated that, at least during the summer, the Bay formed a partially closed system. Time series observations could therefore be made with the reasonable assurance that the same populations, at least of the smaller organisms, would be successively sampled. The generation mechanism of this gyre has been investigated by means of a barotropic numerical model. This model was forced by an external alongshore current setting to the east across the mouth of the Bay. Drift bottle recoveries and current measurements by ourselves and others had suggested the existence of such an easterly flow past the Bay. The model was able to produce a clockwise gyre with current velocities that were in good agreement with observation. The generation, size and intensity of the gyre depended on low values of bottom friction relative to horizontal friction. This is satisfied by the fact that, in the

summer, the Bay is strongly stratified, and this reflects itself in the baroclinic component of the velocity structure. The clockwise gyre decreases in magnitude over the upper 20 metres. Close to the bottom (30 metres) a consistent outflow is present. Investigations on a two layer system are now in progress. This will explain the outflow near the bottom and will determine if the barotropic numerical model contained the essential physics.

Associated with the clockwise gyre is a lens of warm water in the middle of the Bay that is surrounded by cooler water. This temperature structure can be modified by wind-generated water transport and by fluctuations in the intensity of the gyre. A towed thermistor chain and submersible pumps are being used to investigate the relationship between chlorophyll-a and temperature fields. Limited data collection was conducted during 1978 and an expanded field program is planned for 1979.

We are attempting to quantify the relationships between primary and secondary production and the growth of larval fish. Passive sedimentation of organic matter from the surface to the bottom is being studied in conjunction with active transfer (by zooplankton) of organic matter from the lower water layers towards the surface. The oceanographic structure is being related to particle distributions, phytoplankton and zooplankton biomass, and the distribution of fish and lobster larvae. Initial studies of the distribution of demersal fish and their relationship to the nature of the bottom are underway.

K. F. Drinkwater, G. C. H. Harding, B. T. Hargrave, W. P. Vass, T. C. Lambert, J. McRuer, S. Pearre (Dalhousie University), N. J. Prouse, R. W. Sheldon, R. W. Trites, D. M. Ware, W. G. Harrison, B. D. Petrie (AOL)

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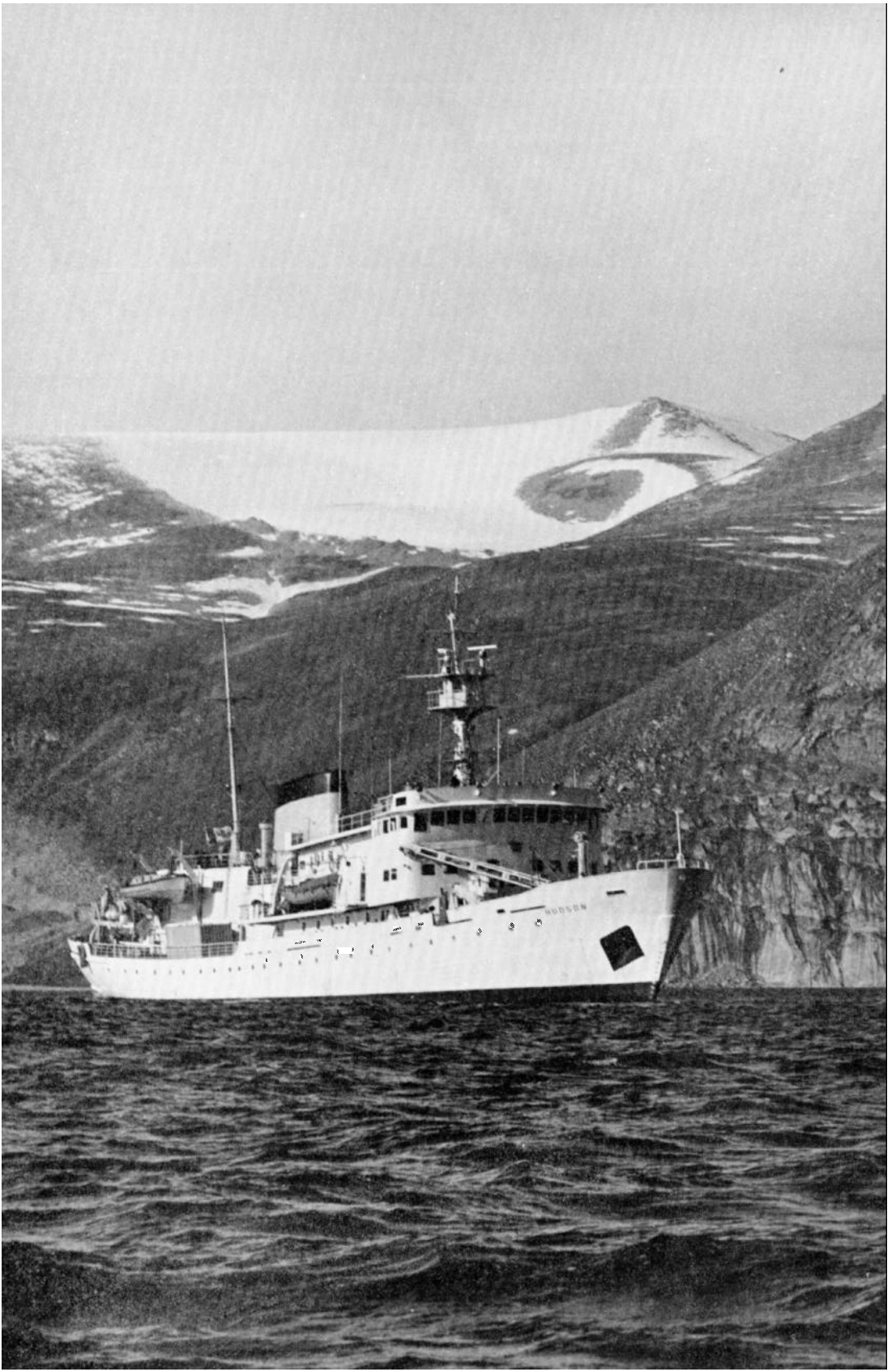
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Manager's Remarks

The two years covered by this review have seen continued restraint in Canadian government spending and this has had a substantial impact on the work of Institute Facilities. The immediate result of the reductions in funding and staff has been felt throughout the Institute - ship time has been reduced and support to scientists and hydrographers has decreased, whereas the demand for both has increased. This has forced the research and survey staff to modify their work in a variety of ways. Inspection of the ships schedules (see Section F) quickly reveals that, today, many scientific cruises on BIO ships involve more than one research project. Interestingly enough, the benefits of cross-fertilization from the intimate contact and co-operation of scientists from various disciplines may well exceed the disadvantages of the reduced time available to each scientist for data collection. The Government's restraint measures have also stirred controversy at the Institute. In recent years, Treasury Board has insisted more strongly that the total indirect and overhead costs to each project carried out should be precisely identified, preferably by charging the user for all services with which he is supplied. The benefits of directly charging each user for, say, ship-time, engineering design, drafting, editing, or electronic technician support are not clear to management at BIO. It is frequently claimed that direct charges reduce waste, but such a claim is difficult to support with 'hard' facts. Nonetheless, management at BIO does feel that a broadly spread knowledge of the full cost of the support is effective in reducing waste. Staff who are providing the support, as well as those requesting that support, will attempt to minimize costs and maximize benefits. Accordingly. Institute Facilities has initiated a cost assessment system to assign the total costs of its activities to the various users. The system is relatively simple but reasonably accurate. It does not involve the extensive work force a precise accounting system would, and it is used as a management tool rather than a financial system such as would be necessary were cost recovery involved. This approach was judged appropriate by the Departmental Special Task Force appointed to make recommendations on interdepartmental cost recovery. Its report recommended against cost recovery but emphasized that cost assessment was desirable, and it proposed our system as the model for the rest of the Department.

Restraint, it seems, will continue. Consequently, a major goal of all parts of Institute Facilities in the coming years will be to increase the output of support while holding constant, or reducing, the costs of that support.

R. L. Gilbert
Manager
Institute Facilities

Institute Facilities Division Reports

What is IF? What does it do?

Institute Facilities is the lead service organization of the Institute. It is a central pool of technical resources and expertise drawn on by all groups to support their research and survey work, to repair and upgrade buildings and offices, to edit and publish reports, and much more. IF is organized into five main divisions whose mandates and services are briefly outlined below.

Ships Division. Within the financial and manyear limitations imposed upon it, this largest of IF divisions operates the BIO fleet of ships, charter vessels, launches, and small craft so that as many needs as possible of the users from BIO and outside organizations are satisfied. The Division is composed of the fleet whose basic features are outlined in the statistics table below and of a shore-based administration section that is responsible for the economical and efficient operation of the fleet. Support to the users aboard ship includes day to day maintenance of equipment such as air compressors and handling of 'over-the-side' scientific equipment. Staff of the Division also supply, maintain, and operate launches, small boats, and similar craft for use in detached, shore-based, field parties and for use from the ships themselves. General control of the ship berthing facilities and adjacent areas as well as operation of launch and engine repair facilities are a responsibility of Ships Division.

Statistics on BIO research and survey fleet

Vessel	Year built	Overall length (metres)	Tonnage (tonnes)	Complement	
				ships	scientific
CSS Baffin	1956	87.0	4963	64	30
CSS Dawson	1967	64.5	2007	31	13
CSS Hudson	1963	90.4	4870	62	25
CSS Maxwell	1961	35.0	279	14	7
MV Martin Karlsen	1952	64.9	2428	18	15
MV *Meta*	1954	44.6	545	9	8
MV *Navicula*	1968	19.8	104	3	-
MV *Sigma-T*	1963	14.6	42	2	I

Note: *Martin Karlsen* and *Meta* are on charter for four and six months respectively: *Navicula* and *Sigma-T* are on day work only.

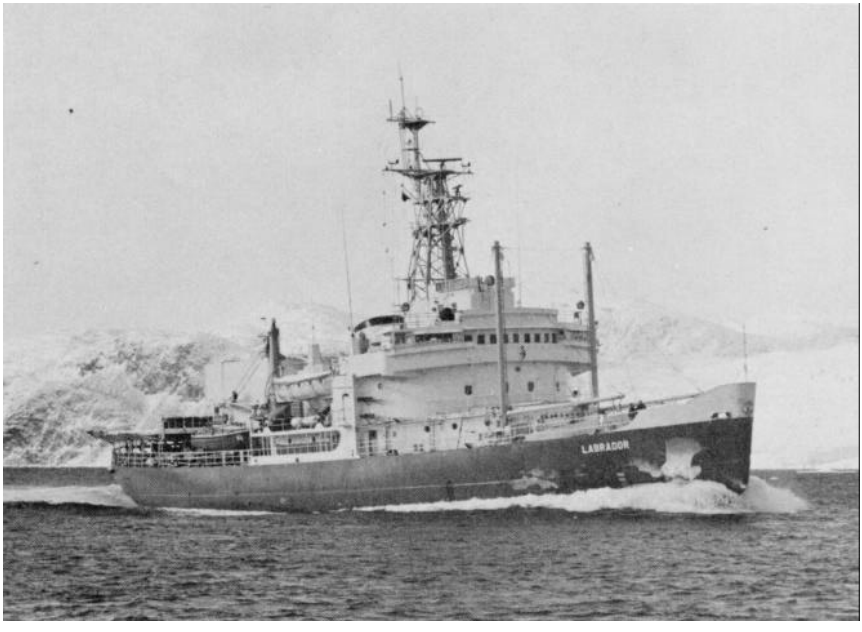
The CSS Hudson *is a diesel-electric driven ship designed as a combined oceanographic research and hydrographic survey vessel. (BIO 4926-C-7)*

The CSS Dawson *is a diesel-driven ship designed and used for oceanographic work in offshore as well as coastal waters. (BIO 3394-6)*

The CSS Baffin *is a diesel-driven ship designed primarily for hydrographic survey work in arctic waters. (BIO 2874-29)*

The CSS Maxwell *is a diesel-driven ship designed for hydrographic work in nearshore and coastal waters. (BIO 2637-2)*

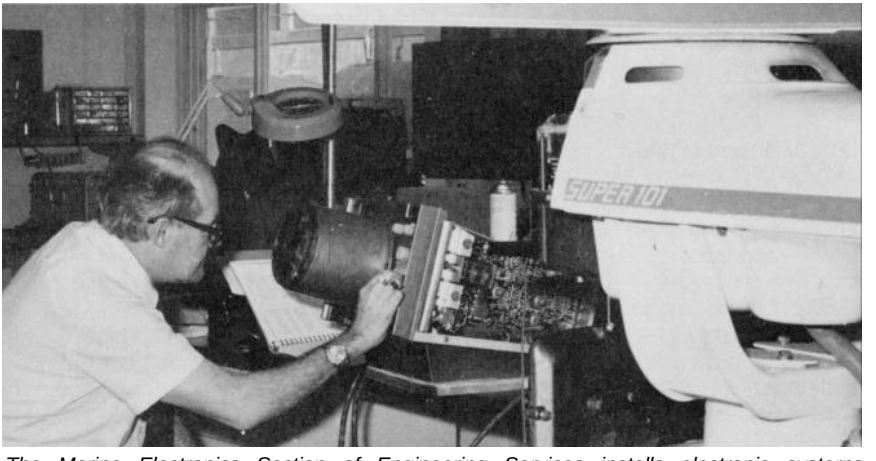
The MV Martin Karlsen *is a charter vessel used mainly for hydrographic-geophysical surveys. (BIO 4994-4)*



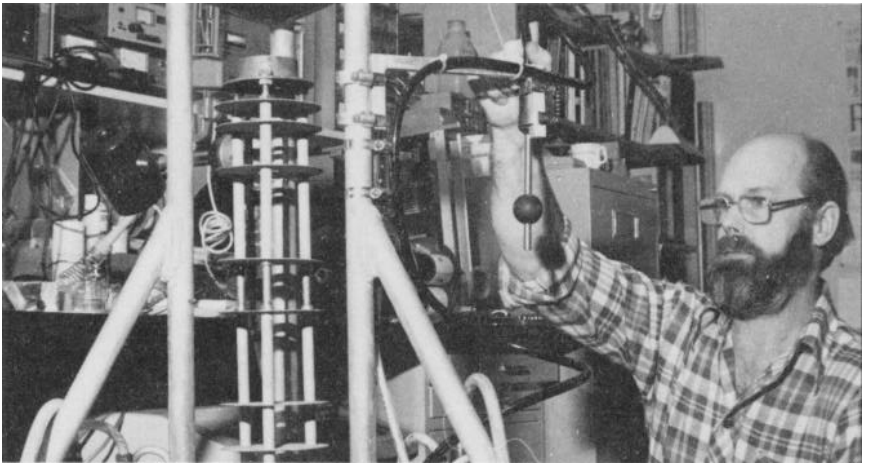
The icebreaker CCGS Labrador, *owned by the Ministry of Transport, is a diesel-electric driven ship occasionally used for hydrographic work in the eastern arctic. (BIO 2711 - A-6)*

Engineering Services. Electronic engineering, mechanical engineering, and building services are provided to scientists and hydrographers by this division. The primary function of the Marine Electronics Section is to provide technical support to electronic equipment while at sea. In the past, these services have been in support of ships' electronic systems, hydrographic survey systems, and certain scientific equipment used by more than one division (e.g., precision echo sounding recorders, shipboard general purpose computers, shipboard dedicated computers). In order to thoroughly familiarize themselves with all types of equipment, technicians undergo cross-training programs - i.e., the sonar technicians learn to service computers, tellurometers, Hi-fix systems, etc. Technicians act, in turn, as instructors in their own specialties and as students in others; the teaching program is based upon the detailed annual overhaul of some of the seagoing equipment. Other major duties include installing equipment onboard ship in preparation for each cruise, drawing up specifications for commercial contracts to repair and overhaul electronic equipment, and project management (including quality control) on commercial contracts for DFE electronic equipment, both for OAS and for Fisheries Management. The above duties account for about 80 per cent of the working year; the balance of the time is occupied in overhaul, repairs, and servicing of electronic equipment at the Institute. First preference is given to equipment that cannot be effectively serviced by commercial contract, either by reason of time constraints or because of technical complexity.

The Mechanical Workshops provide facilities for the installation of electromechanical equipment on ships, as required for each cruise, for the overhaul



The Marine Electronics Section of Engineering Services installs electronic systerns onboard departmental ships and maintains them during cruises. Staff repair and calibrate most of BIO's large collection of electronic equipment including satnav and Loran-C navigation systems, echo sounding systems, some 1200 pieces of test equipment, many minicomputer systems and their associated peripheral equipment, and microwave equipment such as radars, transponders, etc. They also design and maintain various computer interfaces and coupling devices to match instruments to data acquisition systems. Above, a technician services a small launch radar. (BIO 5786-5)

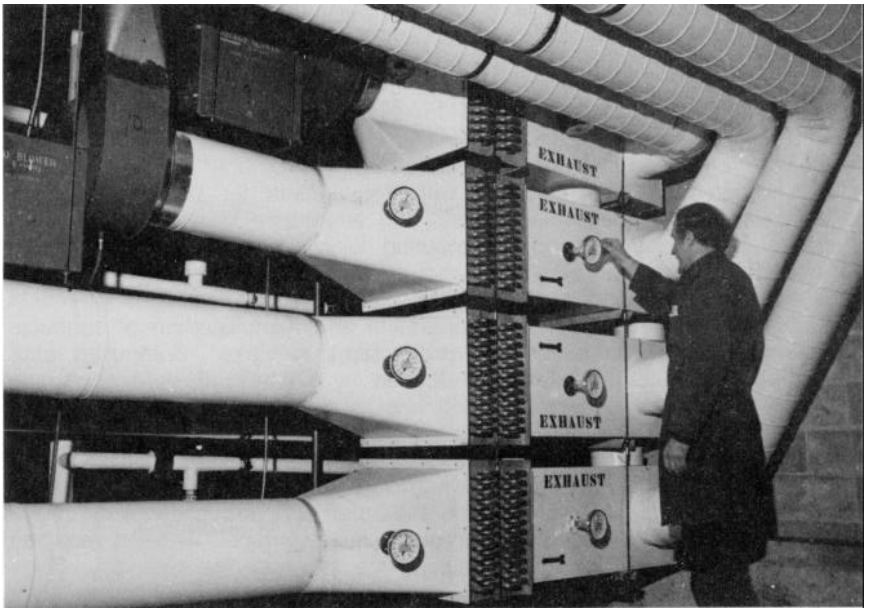


Systems Engineering is the group that develops new mechanical, electromechanical, and electronic equipment for use by the scientific and survey staff. Here, a technologist bench-tests the moored instrument package prior to its deployment (see text). (BIO 5185-1)

and repair of specialized mechanical equipment, and for the construction of some special mechanical components for the research and survey program. In each case, work is done in-house only when it is clearly cost-effective; this usually implies that the equipment concerned is specialized, of one-off design, and that the drawings or specifications required would render contracting the work outside very costly. Institute policy calls for as much work as possible to be done by commercial contract, and this particularly applies to repetitive items.

Systems Engineering provides design support to hydrographic and scientific staff of the Institute. The support involves designing equipment to meet the specific needs described by the scientist in order to better achieve the results he is seeking. Systems Engineering provides the engineering expertise necessary in any design, and, subsequently, provides the engineering capability in contract specification and management (if the project is built by contract) or internal project management (in cases where contracting out is uneconomic). The work will at times involve straightforward design, and at times will become a design or development project. The majority of projects are completed within a few weeks or months. A major function of the group is to act as a source of engineering expertise, on an advisory basis, to staff at the Institute.

The operations of the Buildings and Grounds at the Institute is a responsibility of Engineering Services. This includes routine maintenance, and emergency repairs of heating, plumbing, and electrical systems, and general building maintenance. Much of the work is carried out by contractors, while some is carried out by in-house staff. When other duties permit, the tradesmen undertake by contract management, or even directly, improvements or modifications to building systems so as to meet the needs of individual scientists.



Buildings and Grounds staff of Engineering Services are responsible for routine building maintenance, heating plant maintenance, alterations, and additions. During the past two years senior staff of this group have acted as inspectors during the construction of the new buildings at BIO (see also Section F). Above, a tradesman checks that the heat recovery system is functioning properly. (BIO 5203-5)

Staff of the Depot Workshops (Engineering Services Division) build mechanical and electromechanical prototype equipment designed at BIO. Tradesmen skilled in welding, machining, carpentry, and electrical work assist in overhauling launches and they carry out much of the maintenance on heavy mechanical equipment used on cruises.

Computing Services. This group provides two main services: support for the major Institute computer and co-ordination of general purpose minicomputers used at sea. The major computer consists of a medium-scale computer together with a wide variety of different input-output units including precise plotting facilities, analogue to digital conversion, seven to nine track magnetic tape conversion facilities, etc. Computing Services staff, as well as operating the main computer on a two shift basis, provide a limited keypunch service (together with keypunches for users wishing to do their own), a magnetic tape library, and assistance to users in the form of advice on the application of computing technology and consultation on the use of common programming languages, etc. Assistance with outside computing services, also a responsibility of this group, includes operation of remote job entry facilities and preparation and administration of contracts for external EDP (electronic data processing) services. Computing staff also compile for BIO the statistics required by Treasury Board as well as preparing the annual EDP report and plan, which includes all use of and requests for EDP related acquisitions, services, personnel, etc., by any operation in OAS Atlantic. Co-ordination of the shipboard minicomputers includes planning and scheduling of hardware, and the provision of system software for cruises. It also includes the operation and scheduling of the shore-based system(s) used for program development. Training courses on the operations of the minicomputers are provided as required. Computing services usually provides programming services only where they are of general use to BIO and when resources are available.

Library Services. The primary purpose of the BIO Library is to maintain a comprehensive collection of books and journals relevant to the research and survey programs carried out in the Institute. In addition, substantial effort goes into reader services such as assistance at the desk by the librarian on duty, interlibrary loans, and computer-based information searches.

Some years ago, the basic collection was spotty in coverage; cataloguing was sometimes inconsistent, and the emphasis was being placed on reader services, using material from other libraries. Improvements in the library holdings are being matched by similar improvements in cataloguing. It is intended to develop the collection, over a period of years, to the level of a national collection of oceanographic literature. Efforts are being made to acquire a basic collection of standard books appropriate to the needs of all who work at BIO, both scientists and support staff.

We are fortunate to be located in a region where there are several good science libraries. Close co-operation is maintained with area libraries and arrangements can be made for direct access by BIO users to these collections if this is required.

Publication Services. The main products of a research centre like BIO are publications and advice to government, industry, the scientific community, and the public. This group was formed in 1976 to facilitate and enhance BIO's publication effort: it is composed of the scientific information resources that were previously affiliated with the library and the central drafting and photographic services of the Institute. The mandate of the new group is to

The Drafting and Illustrations unit prepares maps, charts, graphs, sketches, and transparencies for use by Institute scientists in publications and as visual aids. (BIO 5179-1)

help BIO scientists prepare clear, concise, and appropriate scientific reports, photographs, and illustrations and to develop and implement photographic systems and techniques in support of field and laboratory-based studies. Major tasks include: providing an editing and review service for authors who wish to use it; planning, producing, and/or supervising the production and distribution of reports and documents published by the Institute; preparing scientific data as maps, charts, drawings, photographs, and transparencies for analysis, publication, projection, or display; providing deep-water, aerial, and other photographic support on cruises in support of the research; providing photomechanical services using a process camera, large vacuum frame, and an automatic processor in support of hydrographic chart preparation; and providing a variety of other routine publication and photographic services.

Wherever possible contracting out is used to increase our capability by meeting peak workloads and to reduce the load of routine tasks. Part of our budget, for example, is devoted to contracting out drafting jobs to local firms and the drafting section manages these contracts and assures that quality and deadlines are met. Report distribution and printing are handled by contract as is much of the routine darkroom production work such as slide duplication, colour processing, etc.

Highlights of Our 1977-78 Accomplishments

Despite the belt-tightening and reduced budgets we all faced, the past two years have been successful and productive as the selected activities below indicate. (You will find part of Ships Division's productivity summarized in Section F, Major Cruises of 1977-78.)

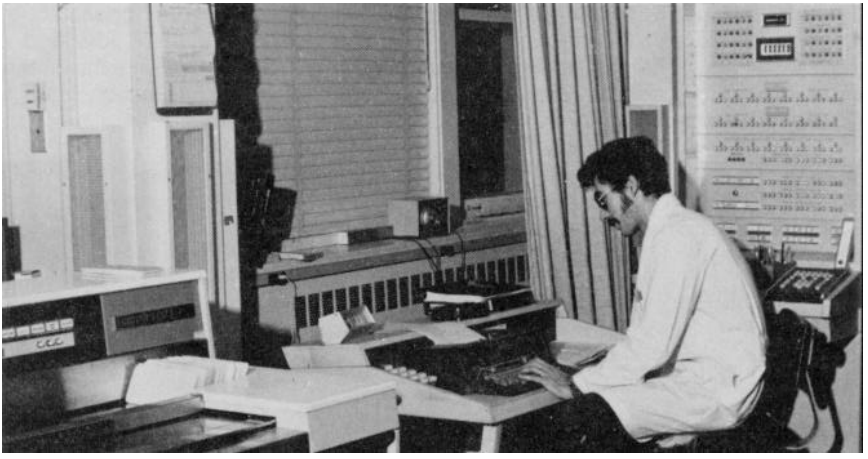
New engineering developments. The Systems Engineering group of Engineering Services Division was involved in a number of innovative projects. (1) BIONAV - its most ambitious undertaking - was a joint project with the Navigation Section, Hydrography Division, AOL. The group built a micro-processor based unit that can receive and process data from various devices

on the ship that sense propeller revolutions per minute, rudder angle, ship's heading, etc. The data alert the BIONAV computer to course and speed changes. Interfaced to a conventional Decca receiver, the microprocessor unit can compute latitude and longitude from Decca information.
(2) A microprocessor-based analog CTD deck unit was developed to interface the CTD to a minicomputer: This unit improves the usefulness of the existing CTD instrument, and conversion of the conductivity and temperature measurements to salinity is simpler than before. The unit can be used as a 'stand-alone' system.
(3) A moored instrument package used by MEL (Environmental Quality) to assess changes in the particulate matter content of sea water was developed. The system includes a low-power data logger and various sensors that measure conductivity, temperature, depth, light attenuance, and current speed of the water.
(4) A multiparameter system has been developed with Metrology Division (AOL) that permits use of a number of instruments simultaneously on a single conductor cable lowered over the side of the ship.
(5) A data collection system was devised for MEL to receive signals from various sensors (depth, temperature, conductivity, net attitude, towing speed) on a towed multiple-opening biological sampling net called BIONESS. It is used to compute salinity and the effective volume flow rate of water through the net. The various net openings are controlled by the system.

Mid-life refit for CSS Baffin. The administration section of Ships Division, as part of its goal to continue to improve the economical and efficient operation of the ships, is organizing and co-ordinating the mid-life conversion by contract of the CSS *Baffin.* Conversions (excluding the general maintenance) will cost about five million dollars in total and are being carried out gradually. The conversion is about halfway complete and another major part will be done in the winter of 1979. Major changes in 1978 included: (1) the replacement of the three 400-kilowatt generators by two 600-kilowatt Caterpillar diesel generators; (2) installation of a 400-horsepower bowthruster; and (3) strengthening of the fore end for navigation in ice infested waters.

CSS Baffin cruise to Peru. In the fall of 1977 the CSS *Baffin* participated in a Canada-Peru study of the Peruvian anchovy and its ecosystem with the Peruvian research vessel *SNP-1.* The study was funded largely by CIDA and involved 90 participants from some 12 institutions in Canada, Peru, the USA, the Federal Republic of Germany, Scotland, and Sweden. A report on the data and initial results was edited and produced by Publication Services in the BIO Report Series of technical reports (see Section F, BIO Technical Reports under Doe, L.A.E.). To satisfy demand for laboratory space on CSS *Baffin,* Ships Division modified a number of regular cargo containers and outfitted them as portable laboratories complete with equipment and services. Some of the results of this example of a major cruise are discussed in the research reports of AOL, MEL, and AGC.

Replacement of in-house major computer. The present in-house computer, a CDC 3150 system, was installed in 1965 and has served BIO well. It has been used extensively for analysing and reducing oceanographic data. However, the age of the facility has presented problems in maintenance and it lacks time-sharing facilities. In the review period, a submission to replace the in-house computer was presented to, and approved by the Treasury Board.



The present in-house CDC 3150 system is being replaced with a CDC Cyber 177 computer. Here an operator sits at the console of the CDC 3750. (BIO 5145)

Specifications functionally outlining our future hardware, software, and conversion requirements were issued in the summer of 1978, and evaluation and benchmarking of the responses were completed in the fall. The successful vendor was Control Data Canada, Ltd., *with* a *Cyber 171-98k* system, which is to be installed in March 1979.

Increased output in computer operations. The workload on the CDC-3150 increased 11 per cent despite a doubling of the use of external computing centres by BIO staff and the transfer of specialized functions to mini-computers. Use of plotting computers increased 130 per cent.

There were a number of other new developments in computing services in the review period. A permanent shore-based system for developing programs for shipboard processing was established: conversion of magnetic tape drives from seven to nine track on the shipboard minicomputers to ease data transfer to the new computer was begun: telecommunication facilities were expanded to access three new computer centres: and, our PDP-8 minicomputer was replaced by a multi-use Hewlett-Packard 2100 minicomputer, which supports the plotters, the analogue to digital conversion unit, and a seven to nine track magnetic tape conversion service.

Improvements in Library Services. During the review period, a written collection development policy was formulated that will define future progress. It is already in force in that development of the collection and production of more efficient means of accessing material were emphasized over the past two years. A computer-produced KWIC (key-word-in-context). index was developed for the report literature. It currently contains about 2200 items, and about 75 are added each month. Serials and reference materials are also KWIC indexed by significant title word. Monographs are processed through a co-operative cataloguing service (Blackwell North America), and older books are gradually being added to the system. The library will list all its holdings on a computer eventually, which will give it the capability to distribute catalogues locally and nationally on computer-output to microfiche. Early in 1977, a general recall of all books was initiated.

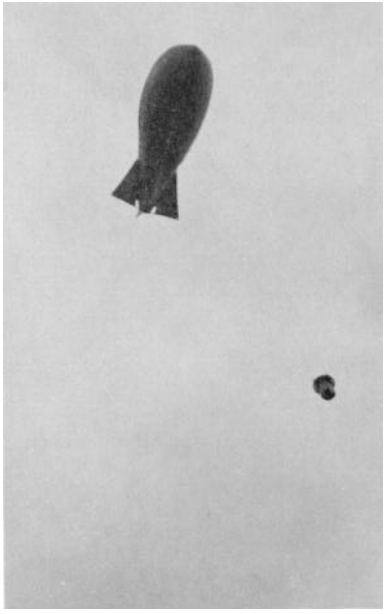
Prior to this, recalls had been issued only when books were requested by another individual, and a shelf reading in the summer of 1977 revealed a high loss rate. The regular recall system now in effect is making the library more useful to people who browse through the book collection and is reducing the loss rate.

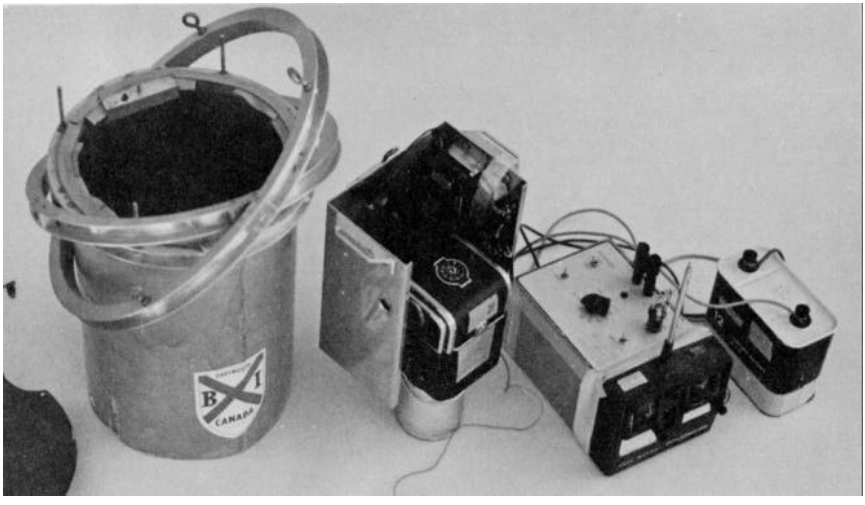
The Institute Library now contains about 12,000 books, 11,000 reports (8000 on microfiche), and 2000 serial titles (7200 of them current). It has access to more than 100 on-line retrospective bibliographic data bases through Lockheed's Dialog system, Systems Development Corporation's ORBIT Search Service (marketed in Canada by Infomart), and through the two Canadian systems CANIOLE and QL. CAN/SDI profiles provide current awareness service to users. A reference desk is staffed from 8:15 a.m. to 4:30 p.m. Monday to Friday during which time the public is welcome. The library maintains full interlibrary loan services for its in-house users and provides photocopy and loan service from its collection to other libraries and qualified individuals. Shown above is a general view of the library with various users browsing and the librarian at the reference desk (right background). (BIO 5188-1)

New format for BIO publications. In 1976 BIO converted from a paper to a microfiche format for its technical reports. In 1978, Publication Services assumed responsibility for production and distribution of the MEL Fisheries and Marine Service Technical and Data Reports, and these were also converted to microfiche at that time. In both cases the reasons for the conversion were to take advantage of the considerable cost savings microfiche provides over paper, to speed dissemination of the information, and to reduce demands on storage space for the reports. The microfiche format permits 98 pages of a report to be reproduced on a 4x6 inch plastic sheet from which acceptable 8½ x 11 inch paper copies can be readily produced using a microfiche duplicator. We are nonetheless continuing to produce a limited number of paper copies of reports for the use of authors, but the main distribution is in the microfiche format. Reaction to microfiche from our subscribers has been generally favourable although some did write or call to let us know that, in the words of one, though microfiche use "seems to be increasing, I for one remain a supporter of good old paper copies".

New application of an old photographic technique. How does one obtain sequential aerial photographs of a location over a period of time such as a tide cycle? Planes or helicopters are expensive and not really suited to this task. The answer of the photographic unit was to adapt and use a

balloon-supported camera system that was initially conceived by the Canada Centre for Remote Sensing. In 1858 the first aerial photographs were taken by a man suspended aloft in a gas balloon. In our system, a motorized, remotely controlled camera mounted on gimbal rings is slung 15 metres





The balloon-supported Hasselblad ELM camera system was used to record sediment movement in Minas Basin, NS. See also the Environmental Marine Geology Subdivision in Section 6. (B/O 4421)

below a helium-filled balloon, and the assembly is tethered with thin, very strong (breaking strength about 300 kilograms) Kevlar cord. The camera is in a protective container that also houses a radio receiver, a switching servo motor, and batteries for the receiver: control from the ground is by a radio transmitter, and the camera is tripped by transmitting a manual signal or a sequential timed signal. Pictures are normally taken from heights of 460 to 610 metres. The current design was achieved after field trials of the CCRS system in New Brunswick, and the system was later used successfully to record sediment movement at Economy Point in the Minas Basin (NS) for the Environmental Marine Geology group of AGC. Since then the balloon system was used successfully in several biological and geological research projects, and from this experience further refinements will be made that should enhance its uses in support of research.

ToC

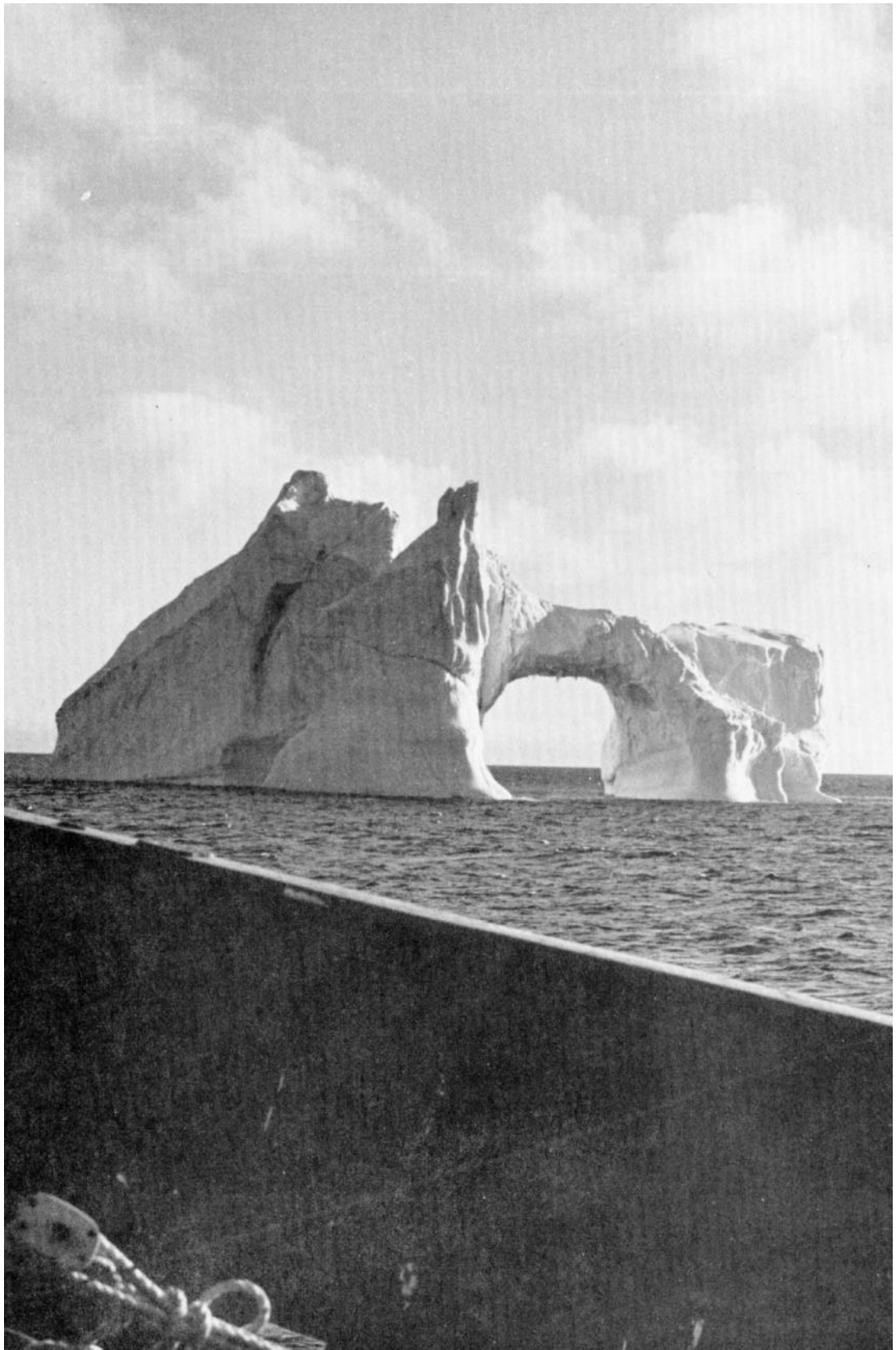
B

Atlantic Geoscience Centre
Geological Survey of Canada
Department of Energy, Mines and Resources

Director - M. J. Keen

- **Eastern Petroleum Geology Subdivision**
- **Environmental Marine Geology Subdivision**
- **Program Support Subdivision**
- **Regional Reconnaissance Subdivision**
- **Administration Subdivision**[1]

[1] The work of this Subdivision is not reported on In this rewiew.



Director's Remarks

Briefly stated, AGC's role is to advise and inform Canada about the earth beneath the sea, and about its shorelines. We do this by answering, or helping to answer, questions of practical importance. For example, we help estimate hydrocarbon quantities in the sediments beneath the continental margin off eastern Canada and the eastern arctic. Clearly, such work is needed in developing policies concerning energy supplies. Related questions arise in areas where there is hydrocarbon exploration: what, for example, will be the effects of iceberg scour upon well heads on the seafloor? To be able to advise in these sorts of ways, work had to begin years ago. As an example, in advising the Nova Scotia government about its drilling program for coal off Cape Breton, we made use of results of work done in 1874, 1949, and 1974. Consequently, a large part of our work has to be directed towards the questions we anticipate in the future, several years from now, or many years from now; it is, obviously, difficult to predict what these questions will be, and the best we can do is to advise on innovative scientific programs, and carry them out in conjunction with scientists from all sorts of institutions within Canada and abroad.

I think our program can be regarded as well integrated in the sense that many parts feed one upon the other, and I will illustrate this integration by looking at some scientific programs that revolve, directly and indirectly, around hydrocarbons. (It could be illustrated in a number of ways; we will see that this way is a convenient one.)

If we want to assess hydrocarbons (oil and gas) that may be offshore in eastern Canada, we must know a number of things: do the rocks contain enough organic matter? is it the 'right' type of organic matter? were these rocks cooked at a high enough temperature for long enough to generate hydrocarbons, or were the rocks so 'hot that no oil or gas remain? are there traps into which oil and gas could migrate and form reservoirs that remain for us to exploit? are these reservoirs large enough to exploit economically?

The answers to the questions I have posed concerning hydrocarbons amount to knowing the facts concerning the regional geology of the offshore, and understanding the mechanisms of hydrocarbon generation and accumulation. We know that the sedimentary wedge of eastern North America started to develop some 180 million years ago as a result of fragmentation of the continents, which we now call North America, Greenland, Europe, and Africa. This evolution continues today. The sediments on our margin are a result of the deposition of debris from the continent, of materials such as coral reefs derived from living animals, and of precipitates such as salt deposited inorganically when ocean circulation was very restricted. Among the things we want to know to answer specific questions about hydrocarbons is: when did this fragmentation of the continents occur? We learn this from the sorts of rocks deposited and from their age. How old are the sediments encountered in the wells? How hot did they get? How deep are they?

Relative ages are determined from fossils preserved in sedimentary rocks, and in our case we use most frequently the remains of foraminifera, dinoflagellates, and ostracods. We, in common with everybody else, of course, face a huge problem in handling the data that accumulate from a study of the fossils in the offshore wells, and this difficulty is compounded by the fact that the data may well be faulty and misleading. The problems can be illustrated as follows. More than 100 wells have been drilled offshore in eastern Canada. They may, collectively, contain 200 to 300 species of foraminifera, and so we are faced with the problem of comparing the order of occurrence in all these wells of all these species. But in obtaining the samples when wells are drilled some species get collected from the wrong place, and in identifying the species a paleontologist may err. Consequently, we, with mathematicians from the Regional and Economic Geology Division of GSC, have developed computer-based techniques for handling all the information, and separating the wheat from the chaff.

There are several ways of finding out how hot the sediments got. One is based on an observation that would have been familiar to an earlier generation, who used coal as a fuel. Organic matter, such as peat, that is compressed and heated loses its gaseous components and successively becomes lignite, bituminous coal, and anthracite. The different varieties of coal are successively more 'shiny' and can be distinguished by measuring the amount of light reflected from their polished surfaces. The measurement of 'reflectance' can be related empirically to the 'cooking' time and temperature. So if we make observations such as these in coaly materials from wells we can determine roughly the temperatures reached by rocks dated using fossils. Consequently, we can determine the age and depth at which hydrocarbons (cooked organic matter) are likely to be found.

We find that this depth (age) is greater beneath the Scotian Shelf than beneath the shelf off Labrador. Why is this? Our margins developed by rifting and ocean-floor spreading, which started some 180 million years ago; the (hot) margin has subsided since then at a rate similar to that of the ocean floor spreading from the mid-ocean ridge, and we can calculate the temperature in the sediment deposited on the subsiding margin. We find that because spreading started mulch earlier off Nova Scotia by comparison with the margin off Labrador, the temperatures of (say) rocks 50 million years old are lower in the case of the Scotian Shelf than in the case of Labrador. Simply speaking, 50 million year old rocks are further from the heat source beneath Nova Scotia than beneath Labrador. Hydrocarbons will be more difficult to find because they likely are deeper beneath the Scotian Shelf than beneath the Labrador Shelf.

Suppose we find hydrocarbons; their exploitation, if badly done, may be hazardous. Two hazards are: earthquakes, which generate slumps in unstable terrain, and ice-scour. Earthquakes are numerous in northern Baffin Bay, and potentially hazardous on the Labrador margin. We have recently attempted to address the problem in northern Baffin Bay by asking: how numerous are the earthquakes and where are they? The answers are not well known because the regular seismological network is not sufficiently dense in that region. We laid three ocean bottom seismometers in the summer of 1978 in northern Baffin Bay; the Earth Physics Branch of GSC set up three portable seismic stations on the Baffin Island Coast; and the Danish Geodetic Survey set up another station in western Greenland. Our ocean

bottom seismometers can record for only ten days, so an element of luck was required. The network was 'calibrated' using two 500 kilogram explosions, detonated at positions known by Loran-C (using the sky wave) and satellite navigation. Fortunately for us, and not, luckily, unfortunately for anyone else, one magnitude three earthquake occurred during our ten day window of opportunity, and lots of smaller events were also recorded at a majority of the ocean and land stations. As a consequence of this pilot experiment, we should be able to locate our own earthquakes and, with the calibrated network, use the observations of the regular network to relocate more precisely previous earthquakes.

Suppose a well-head is established on the seafloor; it could be wiped out by an iceberg running aground. Just as meteorite craters on the planets tell us of interplanetary debris, so do iceberg scours tell us of icebergs in the oceans. Observations with side-scan sonar tell us that groundings by icebergs have been very numerous. But how numerous? How old are the scours observed? Here is a fascinating area of research in which we can examine a marvellous variety of phenomena. Does an iceberg cut its way like a good machine tool or plough its way like a bad one? Will we find fewer scours in deep water than we anticipate because sea level has risen, globally, since deglaciation? But what is the rate of rise of land on the Labrador and Baffin shelves? And, what does this tell us about the physical properties of the crust and mantle beneath?

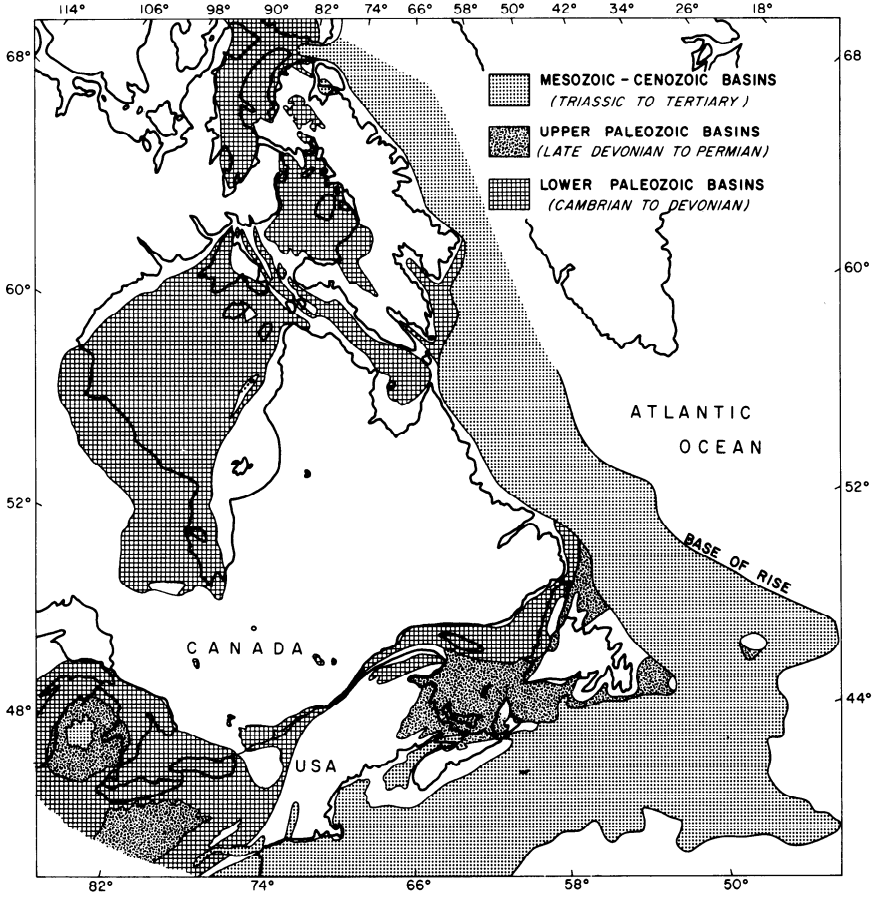
Many of the questions I have been asking require, for their answers, sophisticated technology: ocean bottom seismometers, side scan sonar suitable for use on our deep shelves and slopes, instruments to monitor sediment processes, high resolution seismic systems, and so on. To obtain access to these we develop our own, we work with technologists throughout the Institute, and we work with industry. When working with industry we try to transfer what we know about techniques and problems worth solving to a company. SEABED, a program with Huntec ('70) Ltd., is designed to attempt to determine the physical properties of the sea floor using acoustic techniques. The program is based upon the predictably repetitive sound source the company developed for its profiler, which is towed close to the sea floor. This program is beginning to succeed and we will soon be in a position to predict the properties of the sediments on the shelves from the acoustic signals with minimum sampling.

M. J. Keen
Director
Atlantic Geoscience Centre

ToC

Eastern Petroleum Geology

Eastern Petroleum Geology directs its main effort towards understanding the geological structure and history of the sedimentary basins of eastern Canada in both the onshore and offshore areas. This program facilitates the assessment of resources, especially oil and gas potential. Scientific studies are underway in each of the major basins outlined on the map. The emphasis of the work may vary according to the hydrocarbon potential of each area. Biostratigraphers, lithostratigraphers, geophysicists, and petroleum geologists combine their efforts in an integrated basin analysis program. In addition, scientists also pursue more independent lines of research to the benefit of their particular discipline and, ultimately, to the basin analysis objectives. The following are examples of some of our activities and results.



Sedimentary basins of eastern Canada and adjacent areas. (BIO 3573)

Grand Banks and Scotian Shelf covers Triassic, Jurassic, Cretaceous, and Cenozoic rocks; on the Labrador Shelf, Paleozoic, Cretaceous, and Cenozoic rocks are involved. Studies have provided a multiple biozonation for the Labrador Shelf' with emphasis on its North Atlantic character; a multiple Jurassic zonation for the Grand Banks with emphasis on its 'Old World' affinity; a detailed Cretaceous-Cenozoic palynology zonation for the Grand Banks - Scotian Shelf; and a foraminiferal-ostracod zonation for the Scotian Shelf.

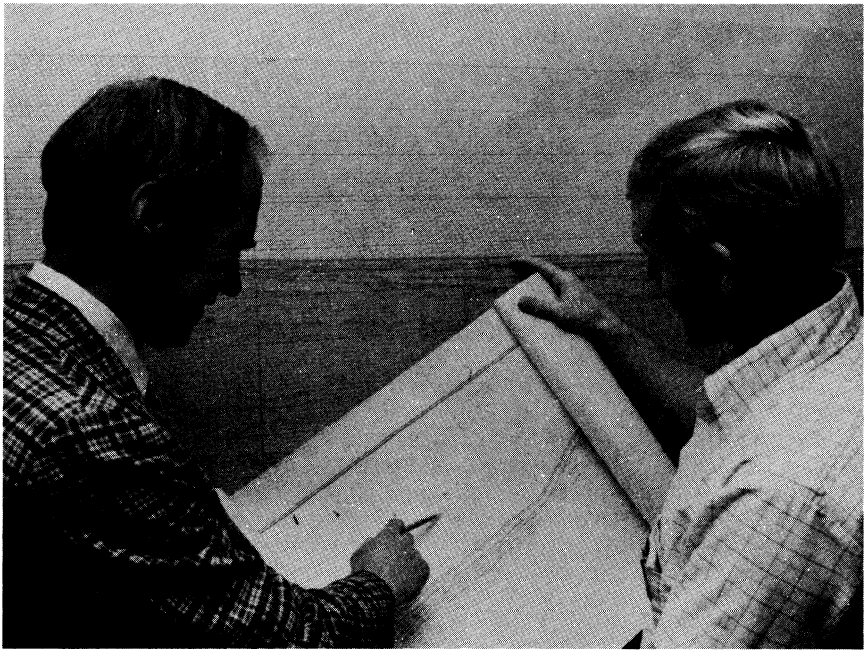
Participation in the Deep Sea Drilling Project, Legs 41 and 44, has provided excellent Cretaceous microfaunas and microfloras from deep water facies. The integration of these data with Grand Banks - Scotian Shelf biostratigraphy and paleoecology is a major stimulus for further North Atlantic basin studies. Palynological studies will be carried out on a further 132 DSDP sites from the Atlantic.

Studies of kerogen (organic matter) type and colouration in residues from well cuttings as an adjunct to our palynology and geochemistry studies have given some interesting results. These studies show that, in general, on the Grand Banks and Scotian Shelf most of the rocks encountered in exploratory wells are thermally immature and have poor potential for generating hydrocarbons. The younger sediments in these wells mostly contain immature kerogen, which is probably of marine origin and the most favourable type for the generation of oil. Deeper in the wells, where temperatures might have been high enough to generate oil from the marine material, mostly kerogen of terrestrial origin occurs. This material requires much higher temperatures to generate oil and gas. On the Labrador Shelf, the organic colouration studies indicate that terrestrial material near the bottom of some wells approached maturity and therefore formed gas. Marine organic matter in younger sediments is often in the immature-mature transitional stage, and, if areas on this shelf are found with mature material, oil might be expected.

The evaluation of hydrocarbon potential using organic type and colour does not take into account factors such as hydrocarbon geochemistry, porosity of sediments, presence of reservoir seals, or structural considerations. However, without the right kind of organic material, which has been heated strongly enough and for a sufficient length of time, large amounts of oil and gas should not be expected from the rock even though other factors may favour the presence of large hydrocarbon accumulations.

Basin analysis. As part of our basin analysis program we are continuing our participation in a Geological Survey of Canada inventory of evaporite deposits. The stimulus for the study was twofold: Atomic Energy of Canada Limited required data on salt beds as possible long term storage sites for nuclear wastes, and an inventory of evaporite occurrences in Canada was requested for economic consideration. Results of this study indicate several areas in Nova Scotia in which further detailed studies will be conducted to determine suitability of sites.

Our subsurface studies have been extended to the North Atlantic through participation in DSDP and we are also participating in workshops related to the naming of sedimentary formations of the North Atlantic. The Mesozoic sedimentary sequences of the western and eastern central North Atlantic Basin have very similar ages, faunal assemblages, and petrographic com-



Geologists discussing a seismic record. (BIO 4165-2)

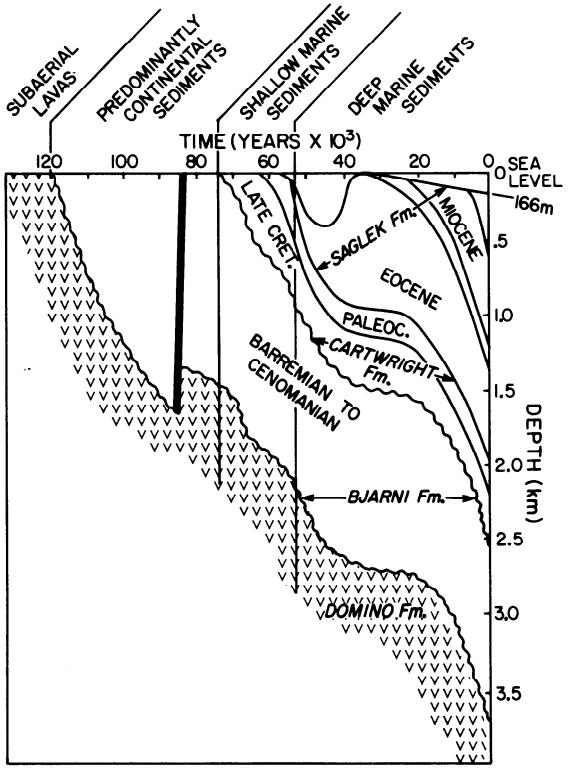
position, even though they are separated by the Mid-Atlantic Ridge. Seven sedimentary formations can be recognized in the central North Atlantic Basin. Study of the microfacies of the Jurassic sedimentary sequences narrowed the span of lithostratigraphic and biostratigraphic units. The indication is that the older sediments recovered by DSDP in the central North Atlantic are not older than the middle of the Late Jurassic. These sediments were deposited in an epibathyal environment, above the carbonate compensation depth (CCD). The sea bottom subsided below the CCD in Aptian time. The euxinic conditions in the Aptian-Cenomanian resulted from stagnation of bottom and intermediate water due to the disruption of the deep water circulation, which was related either to separation of the continental plates between the Grand Banks and Spain-Portugal (120 million years ago), or to erogenic movement in the Gibraltar - northwest Africa region, or to initiation of the break-up of Africa from South America. The bottom circulation was re-established in the Late Cretaceous.

By the end of 1977, nine wells had been drilled on the Labrador Shelf and information on these wells has been released from its confidential status. The sequences penetrated by these wells have now been analysed and from this the geological history and stratigraphic framework has been established. In general terms, the sequences can be divided into four formations, as follows:

(1) *The Domino Formation* is a series of subaerially extended basalt flows dated radiometrically as 139 to 120 million years old (Berriasian to Hauterivian in age).

(2) *The Bjarni Formation* consists largely of coarse clastics of Hauterivian to early Cenomian age deposited in predominantly continental environments around and over upfaulted basement blocks in a linear, fault-bounded basin during a time of limited tectonic activity. Wells on the flanks of the basement blocks penetrated a thick, complete sequence; wells drilled on the crests of the structures encountered a thin, stratigraphically restricted sequence. The basal part of the Bjarni Formation consists of coal measures *(i.e.,* non marine shale, sand, and coal seams up to ten metres thick) and it constitutes the Snorri Member.

(3) *The Carlwright Formation* is a series of shallow marine, predominantly shaley rocks of Turonian to late Paleocene age. Locally, a basal coarse clastic unit is developed (the Freydis Sand Member) and at or near the top another sand unit, the Gudrid Sand Member, is developed. In Snorri J-90, a well drilled off northern Labrador in 1975, gas and condensate were recovered from a ten metre thick interval in the Gudrid Sand Member. The Domino, Bjarni, and Cartwright Formations are largely restricted to a fault-bound linear basin, parallel to the present coastline and underlying the outer part of the Labrador Shelf. The southern terminus of the inshore basin is the northern flank of the Cartwright Arch, an eastward plunging basement feature on the southern Labrador Shelf.



Subsidence curve for the Herjolf M-92 well, which summarizes the stratigraphy and general development of the Labrador Shelf, (BIO 5129-2)

(4) *The Saglek Formation* of early Eocene to late Miocene age consists of a thick series of mudstones deposited mainly in deeper water environments as a seaward thickening clastic wedge overstepping the early Cretaceous to Paleocene inshore basin. In mid-Tertiary time (late Eocene and Oligocene) a temporary halt in the rapid subsidence of the Labrador margin occurred. During this interval, coarser clastics of the Leif Sand Member (late Eocene) and sandy mudstone with locally developed coal seams (Oligocene) were deposited.

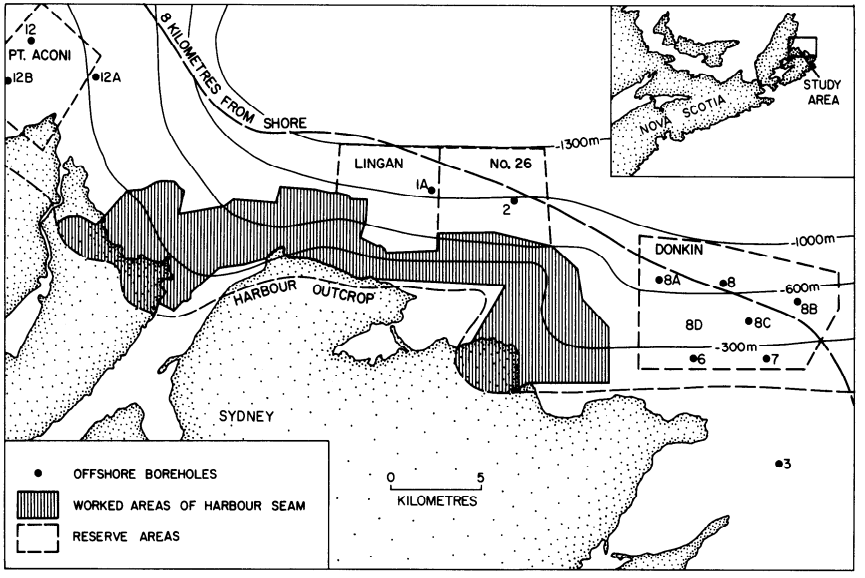
The stratigraphy and geological development of the Labrador Shelf can be summarized by the subsidence curve for Herjolf M-92, a well drilled in 1976. This well has the most completely developed stratigraphic sequence of any well.

Upper Paleozoic Basins

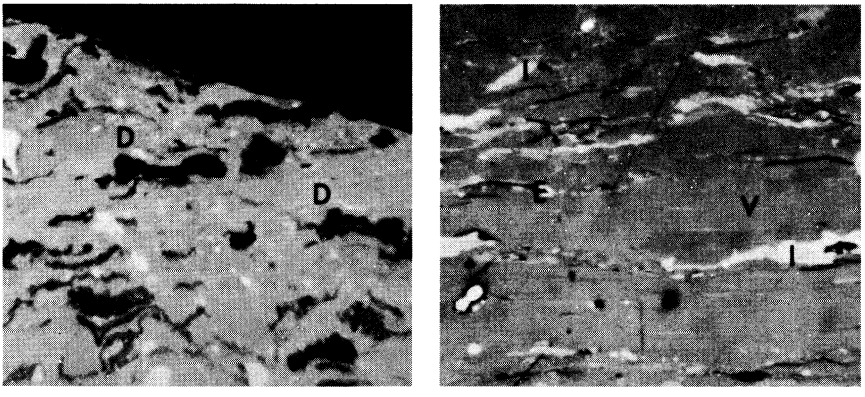
Surface and subsurface studies of the Upper Paleozoic basins in the Atlantic Provinces rely heavily upon the use of biostratigraphic zonations from fossil spores. Recently a major study has been directed towards an inventory of the Upper Paleozoic evaporite deposits as part of a Canada-wide evaporite study. The history of these evaporite deposits began with the continental collision of Africa with North America and Europe during the late Paleozoic Acadian orogeny; this resulted in uplift, folding, faulting, and granitic intrusion. As the orogeny waned, the highly fractured basement subsided forming a complex series of northeast-trending horst and graben structures. During the late Tournaisian and early Viséan, the area continued to subside resulting in the accumulation of playa lake deposits of the upper part of the Horton Group followed by the advance of the Windsor sea, which may have been an extension of the Viséan sea of northwest Europe. The restricted circulation of the Windsor sea in eastern Canada resulted in the accumulation of thick deposits of evaporites in the lower part of the Windsor group. During the upper-middle Viséan and into the late Viséan, the depositional environment of the Windsor sea became shallow and marine, and clastics and carbonates were deposited. From the late Viséan to the Permian, renewed compression, uplift, and erosion removed large areas of the Horton and Windsor Group rocks. This orogenic uplift changed the depositional environment of the area from marine to continental, which led to the accumulation of thick deposits of clastics, coal, and minor limestones.

Resource Evaluation

All aspects of our work contribute to a data base for estimating the hydrocarbon potential of the eastern Canadian sedimentary basins. This is a cooperative effort with several agencies within the Government of Canada that provide representatives to a Subcommittee on Geological Potential. (The methodology used was discussed in the 1973-74 Biennial Review). The Subcommittee completed a reassessment of major frontier areas with particular emphasis on the Labrador Shelf, MacKenzie delta, and Arctic islands. A method for determining pool size distributions was developed for use in an economic evaluation. Coal resource evaluations have been carried out in the Sydney and Mabou coalfields. A drilling program consisting of 15 offshore wells was undertaken jointly by DREE, the Nova Scotia Department of Mines, and DEMR during 1977-78. Well site selections, prognoses of seam intersections, seam correlations, logging of cores, and detailed petrographic analyses have been carried out, or are in progress. One result of the program is an outline of a most valuable virgin block of coal



A map of the Sydney coal field that shows the offshore borehole locations, reserve areas, and mined portion of the harbour seam. (BIO 5129-1)



Photographs of coals of different rank that depict differences in vitrinite reflectance (lower rank is darker grey). Coal macerals present are vitrinite (V), exinite (E), sporonite (D), and inertinite (I). These polished sections of coal, viewed with an oil immersion objective, are magnified 300 times.

in the Donkin submarine area of the Sydney field, which contains some 700 million tons of potential coal in three seams. It also blocked out some 400 millions tons in the Lingan/No. 26 reserve area, and provided valuable information for the new Prince Mine in the western part of the coalfield. At Mabou, the offshore area contains the coal sequence known from the Inverness field, situated 12 kilometres to the north. The Mabou seams proper occur at greater depths than anticipated, and only seams of the overlying Inverness sequence may have offshore mining possibilities. More detailed studies to evaluate these possibilities are required..

Environmental Marine Geology

The program of Environmental Marine Geology is directed toward improving our understanding of active geological processes and how these processes are responsible for the evolution of marine geological features and resources. The results of these programs are applied to determining, for example, the sensitivity of coastal areas to oil spills, the environmental impacts of ocean dumping, the feasibility of energy or mineral development, and the quality of the environment as part of basic knowledge in geoscience.

Scientists within the Subdivision are organized in three major discipline groups, but some staff from each of these groups contribute to multidisciplinary tasks or studies. They are organized into a coastal geodynamics group consisting of coastal geomorphologists and sedimentologists, a paleo-ecology group consisting of micropaleontologists specializing in foraminifera studies and a macropaleontologist specializing in the study of molluscs, and a geochemistry group consisting of specialists in organic and inorganic geochemistry.

Coastal Geodynamics

This group conducts projects in a wide range of areas from the Bay of Fundy to the Beaufort Sea. In 1978 the group was enlarged by the addition of four scientists and one technician from Terrain Sciences Division (GSC) in Ottawa.

Bay of Fundy. Three possible alternate sites were considered for the construction of tidal-power generating facilities by the Tidal Power Review Board, Phase 1 Studies. One of these sites was located in the Minas Basin (NS), one in Shepody Bay (NB), and one in Cumberland Basin (NS). During the past two years, intensive studies of the sedimentology have been carried out in the Minas Basin and in the Chignecto Bay area, which includes both Shepody Bay and Cumberland Basin.

Studies completed in the Minas Basin indicated that the high rates of coastline erosion, the massive intertidal movement of sands, and the net accumulation of muds in the upper part of the Bay might create significant difficulties if a barrage were to be constructed across Minas Basin.

Several new and innovative techniques were tested in the Minas Basin studies including: calibration of Landsat satellite data to determine the concentration of suspended sediments in surface waters; remote sensing of bedform movements using a tethered balloon and camera system; and sediment tracing using radioactive glass beads released in the surface sediments. Several of these techniques allowed researchers to gather quantitative data that could not otherwise have been collected.

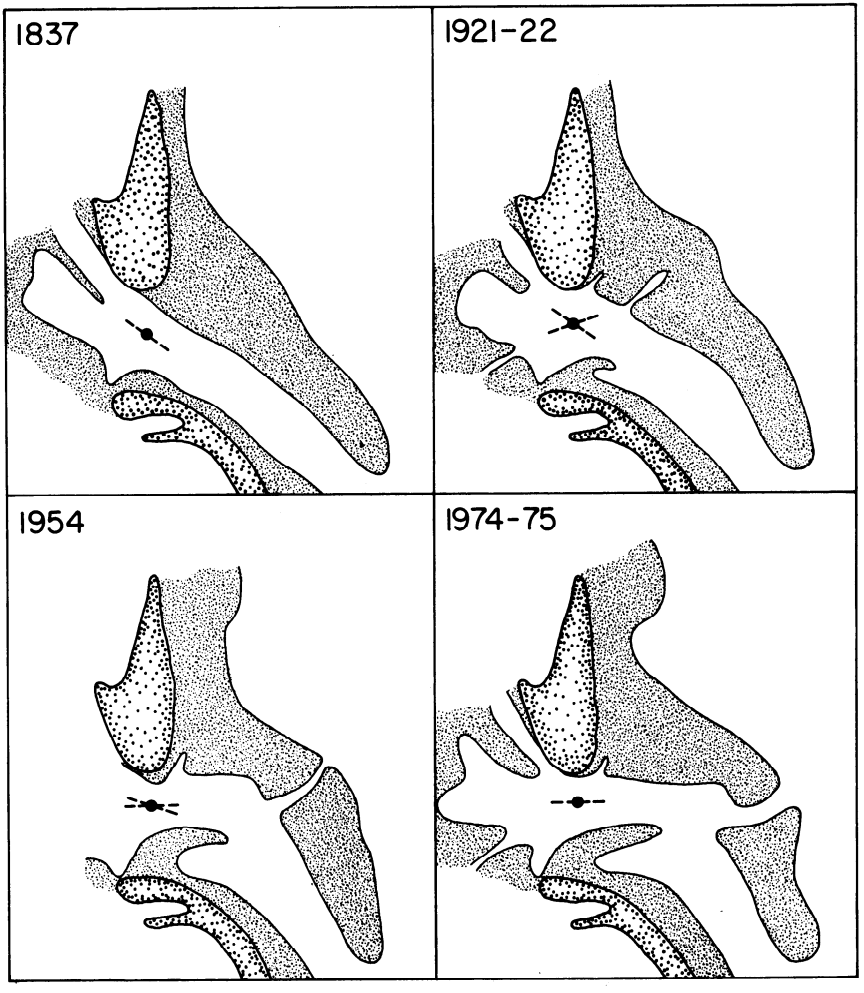
More recent studies have been concentrated in the Chignecto Bay area. Estimates of the sediment movement will be made and geophysical data will be used to construct a history of deposition to determine the rates of

Accumulations of mud in the Minas Basin have formed the Tantramar Marshes found near the Nova Scotia - New Brunswick border. In this photo of a meandering tidal creek on the Marshes can be seen various dykes built to reclaim land for agriculture. (BIO 4602-31)

sediment accumulation and the influences of various processes. Results show that there has been an increase in tidal amplitude during the past 6000 years.

Southern Gulf of St. Lawrence. The barrier islands of the Gulf of St. Lawrence are a major feature of the coastline of New Brunswick and Prince Edward Island. The evolution and stability of these features are now considered different in many respects to other barrier island coasts around the world. Recent studies have shown that tidal channels and storm-overwash channels are generally ephemeral features on a geological time scale and, indeed, even on a historical scale. These corridors are however the most important areas for the passage of sand toward the land in this prograding system. Detailed studies of the relationship between nearshore wave climate and erosion of the barrier islands revealed that critical wave heights approaching the shoreline from the northeast direction at Kouchibouguac Bay can cause extensive erosion in a matter of hours.

Labrador coast. The possibility of developing oil resources off the coast of Labrador has stimulated interest in the environmental sensitivity of that



A generalized diagram tracing the evolution of the main inlet to the Miramichi estuary, NB, from 1837 to 1975. Finely stippled areas are under less than five metres of water; the dashed lines-solid circles indicate the dominant water flow direction. (BIO 4284-7)

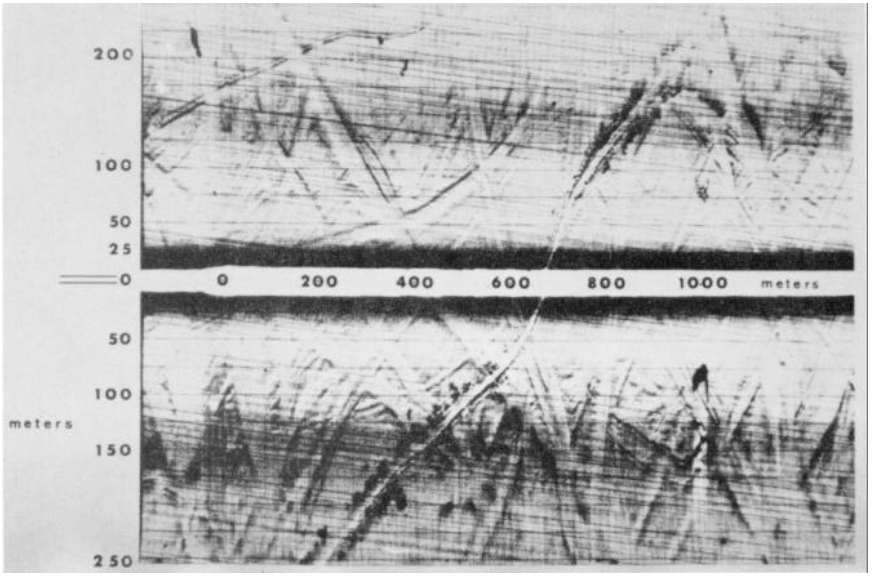
coast to oil contamination. As a first step in this analysis, reconnaissance mapping based on a classification scheme for sensitivity has been undertaken. Specific examinations of processes, such as ice push on the shore and ice rafting of boulders, have also been carried out. As a result of these studies unique observations of the mechanism of beach freeze-up and break-up have helped to explain the preservation of unusual structures in stratigraphic sequences.

Baffin Island coast. In co-operation with PetroCanada and the Arctic Marine Oil Spill Program, a team of coastal sedimentologists and marine biologists carried out surveys and sampling programs of the coasts of eastern Devon

Typical cobble beach embayments about 200 to 300 metres long along the north shore of Paminlik Bay, Labrador. The embayments in this aerial photo are separated by bedrock promontories. (BIO 4904-77)

Island and Baffin Island to assess the sensitivity of this ice-infested coast to oil spills. This large area of coast contains many varied environments ranging from the macrotidal bays along Hudson Strait to the high relief fjord coasts of central Baffin Island and the barren ice-capped, peneplane coast of Devon Island.

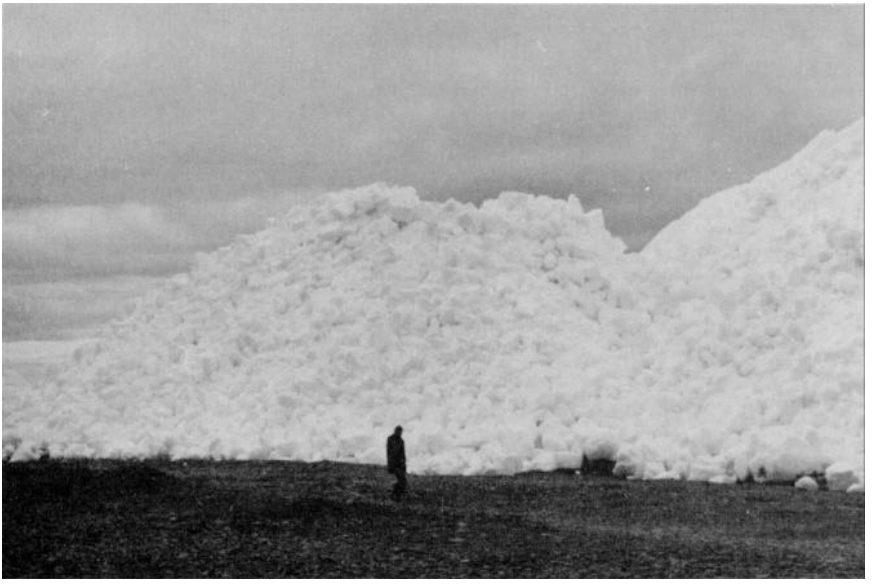
As was the case on the Labrador coast, the dominant processes affecting this coast are related to ice. The rapid and recent changes in relative sea level along these coasts have made the job of interpreting the effects of various processes difficult because the perceived process may no longer be active.



A sonograph of ice scours on the floor of the Beaufort Sea. A recent ice scour crosses from the lower to the upper part of the figure near the 700 metre mark. (BIO 5756)

Arctic Islands. Because of the identification of significant reserves of hydrocarbon gas in the area of the Sverdrup Basin, Central Arctic Islands, the Transportation Development Agency supported studies of the coastal geomorphology of key coastal areas where liquefied natural gas ports might be built. The coastlines of many of these islands are constantly in contact with the ice; even in areas where ice cover is not permanent, the hydrodynamic effects are dampened so that 'normal' rates of change of beach characteristics are much reduced, as compared with temperate or subarctic regions.

Beaufort Sea. The oil and gas potential of the Beaufort Sea area has attracted considerable exploration activity. One of the recognized hazards to drilling operations and to potential production facilities has been that of ice scour of the sea floor. Marine geological surveys of the southeast



Shorefast ice on Somerset Island, NWT, protects the upper beach from erosion. (Courtesy of the Geological Survey of Canada.)

Beaufort Sea and Amundsen Gulf have paid particular attention to the occurrence of ice scour, noting particularly areas where a high density of scours occurs. In addition to this information, the same surveys have helped locate deposits of aggregate, which may be used to construct additional artificial islands for Imperial Oil Company exploration drilling.

Coastal conference. In May 1977, a conference on the coastlines of Canada was organized by staff of the Subdivision and held in Halifax. This conference brought together more than 100 Canadian researchers who were active in studies of the coastlines of Canada. Papers were presented that dealt with the diverse problems of classification of coastal types, hydrodynamic processes, ice effects, erosion, and deposition. Representative studies were presented from the four major geographic coastal regions of Canada: Atlantic, Arctic, Great Lakes, and Pacific.

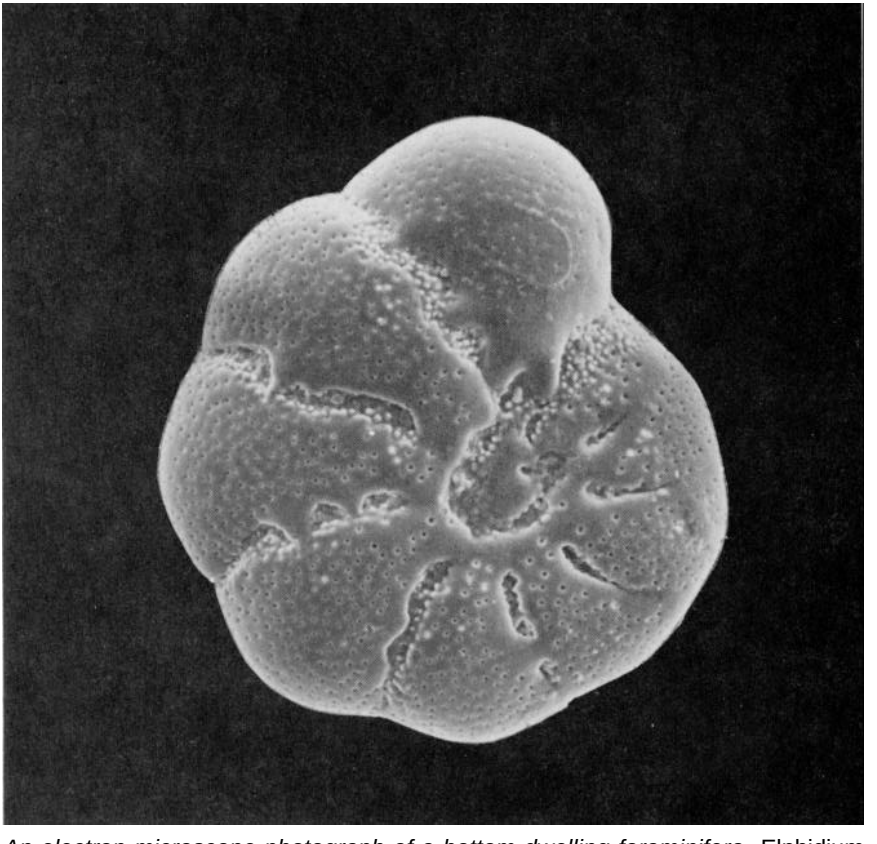
Paleo-ecology

The fossil remains of foraminifera and Mollusca provide valuable clues to past environmental conditions. The assemblages of these animals together with accurate dating techniques obtained from cored post-Pleistocene sediments allow assessments to be made of paleo-oceanographic conditions and in some cases to relate changes to the influence of man.

Paleo-oceanography. Two very different areas of the ocean have been studied to determine past oceanographic conditions. One of these, the Labrador continental shelf, has been under study for several years as part of the Labrador Sea studies. The other area, the Peru Shelf, came under investigation as part of a CIDA-sponsored international study of the problems related to losses in the anchovy fishery of Peru.

The Labrador Shelf sediment cores contained foraminifera and pollen species, which revealed that as early as 21,000 years ago the area was free of summer ice. This is a surprising discovery in that previous studies had concluded that extensive ice existed in the Labrador Sea at about that time. It now appears that the continental ice sheets on the Labrador mainland were of limited extent on the shelf.

Preliminary analyses of the Peruvian shelf cores already have indicated that they contain foraminiferal fossil assemblages representative of colder climates than the present. Absolute dating will be required in order to verify that these colder periods coincide with the fluctuations in the anchovy population.



An electron microscope photograph of a bottom-dwelling foraminifera, Elphidium clavatum, *magnified 240 times. Many of these protozoans are found in the late glacial sediments of the Labrador shelf.*

Environmental analysis - Newfoundland slope. The continental shelf slope off southeastern Newfoundland has unique features not found on other slopes along the North American continent. Unlike steep slopes where sediment is dispersed downwards, the gentle Newfoundland margin appears to be the site of alongslope dispersal, which takes place mainly under the influence of the undercurrent. Four major sedimentary environments have been recognized: (1) the upper slope, swept by the Labrador current; (2) the middle slope dominated by low current velocities; (3) the lower slope; and (4) the rise. The latter two areas are both swept by the Western Boundary Undercurrent.

Analysis of the gravel component in sediments on the Newfoundland slope and rise revealed the presence of ferromanganese coatings on clasts underlying a fast-flowing core of the Western Boundary Undercurrent at a depth of 2800 metres. Preliminary data suggest that the coatings have been forming over the last 5000 to 6000 years under conditions similar to those postulated for deep-sea nodule fields.

Deep sea mining. In co-operation with the Pacific Marine Environmental Laboratory of the NOAA at Seattle, Washington, an investigation of the effects of test mining of ferromanganese nodules from the Pacific Ocean was begun. A cruise on the USS Oceanographer was part of the American Program of Deep Ocean Mining Environmental Surveys conducted in the area where a belt of high concentrations of manganese nodules in the central Pacific Ocean exists. Canadian observation and study was on the last of a four-phase program and was concerned with sampling and photographing the ocean floor in the area where the test mining had taken place. In addition to the experience gained in precise sampling of the deep

Manganese nodules, baseball-sized rocks composed mainly of iron and manganese oxides and hydroxides, often contain one to two per cent copper, nickel, and cobalt. In the above box core, the typical distribution of the nodules on the ocean floor in undisturbed red clays is shown. (BIO 5746)

ocean sediments, samples were retained for foraminifera and geotechnical studies of red clays of the equatorial Pacific Ocean.

Geochronology of recent events. Over the past few years several experiments were undertaken to determine if absolute dating techniques using ^{210}Pb isotope in recent marine sediments could be correlated with fossil assemblages of foraminifera. In particular this method was applied to ongoing studies in Miramichi Bay and the upper Saguenay fjord. The methods were successful in identifying and segmenting the sedimentary material into zones that could be recognized as representing decades of deposition. In the Saguenay fjord, the unbioturbated sediments could even be resolved into thin layers representing seasonal variations of river discharge over the last decade.

Geochemistry

The geochemistry of natural organic compounds in recent marine sediments as well as the occurrence and nature of hydrocarbons found in the ancient sediments deeply buried below the continental shelf are part of the research interests of the organic geochemist. The concentration, means of transport, and mechanism of accumulation of trace metals in marine environments represent the main interests of inorganic geochemistry.

Hydrocarbon geochemistry. During the peak of exploration activity on the east coast continental shelves by oil companies, samples of the sedimentary strata were provided to the organic geochemistry laboratory for analysis. These data have now been interpreted and are being published in a series of papers that assess the regional differences in hydrocarbon occurrences on the Scotian Shelf, the Labrador Shelf, and the Grand Banks.

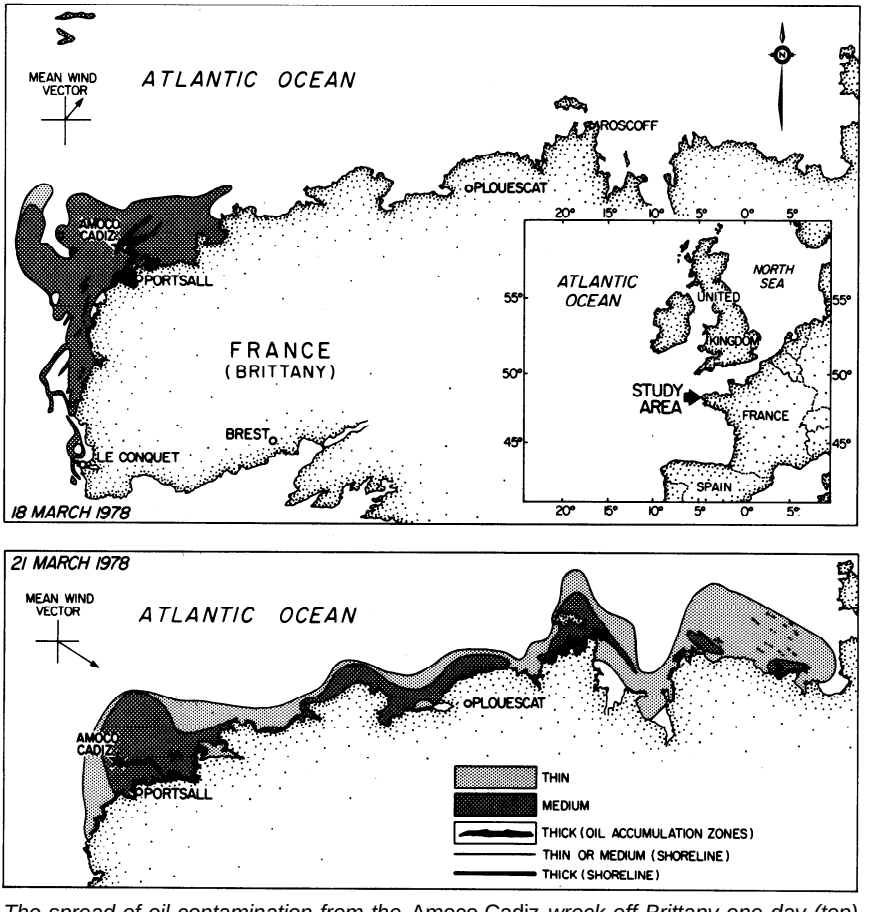
The basins in the Scotian Shelf contained the appropriate amount of organic matter to generate significant accumulations of hydrocarbons, but thick sections proved to be only marginally mature resulting in disappointing economic assessments. Detailed analyses of the type of organic matter, and the light and heavy hydrocarbons, indicate that there is a lack of thermal maturity because the original material is largely of terrestrial origin (requiring higher temperature for longer time) and because the present subsurface temperatures are the maximum reached and were only capable of generating oils in the relatively recent geological past.

The rocks from the Labrador Shelf and east of Newfoundland also contain ample organic matter. In the northern part of the Labrador Shelf many thick sections contained large concentrations of gas, but in the southern area the strata contained organic matter, which appeared to be below the threshold level of maturity to produce oil. This lack of maturity and the gas-prone nature of the area appear to be due to the accumulation of largely terrestrial material, which requires a longer diagenetic history in order to produce oil.

Inorganic geochemistry. Emphasis has been placed on research that will help to define the mechanisms of metal migration through river estuarine systems and to establish indicator metals that can be used to determine present and past oxidizing conditions. As part of the major multidisciplinary study of the Miramichi estuary system, detailed investigations were

carried out to determine how specific trace elements were transported by suspended particulate sediments - in solution or as part of an organic complex. These studies, now nearing completion, have indicated sources of metal input from natural erosion, mining activities, and specific industrial activities.

The +3 and +6 oxidized states of chromium metal have been successfully analysed from a number of different nearshore and deep-sea environments in the north and central Pacific. It has been shown that the relative proportion of these two oxidation states is related to the redox potential or to the biological activity of the water mass. It now appears that certain organisms fix chromium as $Cr+^{3}$ and then may release this form of the metal when they die and decompose at or near the sea floor.



The spread of oil contamination from the Amoco Cadiz *wreck off Brittany one day (top) and three days (bottom) after the spill began. Northerly and westerly winds influenced the heavy contamination of the coast.*

Multidisciplinary Studies

Miramichi Bay and estuary. The major multidisciplinary study of the past two years has been in the Miramichi estuary and Bay environment on the east coast of New Brunswick. This study has involved all of the disciplines of the Subdivision in a co-operative examination of the hydrology and physical oceanography of the system as well its sedimentology, geochemistry, and paleo-ecology. As a result of seasonal monitoring programs and extensive sampling, it is now possible to construct predictive models of the sediment fluxes between the River, estuary, and Bay. Knowledge of these fluxes is important because it will allow estimates to be made of the impact of discharges of suspended solids and associated chemical constituents. Proper management of the important estuarine systems, such as the Miramichi, depends on such predictive models.

Ocean dumping. During the past two years more than 250 applications for ocean dumping permits have been reviewed by the Subdivision. These applications, required by the Act to Control Ocean Dumping, provide information on the sedimentary and geochemical nature of spills. This information is now becoming a valuable data base concerning types of sediments, reasons for dredging, and stability of dump sites. Some specific studies have been undertaken of frequently used dump sites to determine their potential long-term effects on the environment.

Amoco Cadiz oil spill. When the supertanker *Amoco Cadiz* went aground on the coast of Brittany in March of 1978, a team of scientific specialists from BIO was quickly assembled to visit the spill site and make observations of the impact. This team included three geoscientists who combined with a chemical oceanographer, biologist, and toxicologist to assess the oil's impact on a coast in many respects like that of Nova Scotia.

The damage caused by the release of 220,000 tonnes of crude oil was extensive, contaminating more than 300 kilometres of coastline, causing high mortalities in shellfish and birds, and seriously affecting the tourist industry of the area.

Most of the sandy beaches were heavily contaminated with chocolate mousse, a form of water-in-oil emulsion. Several layers of oil were often found buried in the sand as a result of slicks coming ashore at various stages of the spring and neap tide cycles when the beach profiles were altered by sand movement on- and offshore. Continuing studies were begun to measure the rate of restoration of the coastal areas as the oil is weathered and mechanically removed.

ToC

Program Support

The primary responsibility of the Subdivision is to provide central support facilities and assistance in AGC field activities. Staff spend over 15 per cent of their time in the field. In both the laboratory and field they maintain, calibrate, and operate equipment and instrumentation and collect, process, and store field and geological samples. Another aspect of their work is the development of systems and equipment to improve the efficiency and capability of AGC projects.

During the last three years, but particularly during 1978, the Subdivision had the major responsibility for co-ordinating building space and facility requirements for AGC in the Institute's major building expansion program (described in section F). The result has been that RMCB and AGC are now located in one new area of the BIO complex, which includes large new geological sample curation facilities, laboratories, and offices for all the staff. This should result in greater efficiency and improved informal communications between all of the various staff. 'Recent examples of some of our other activities are discussed below.

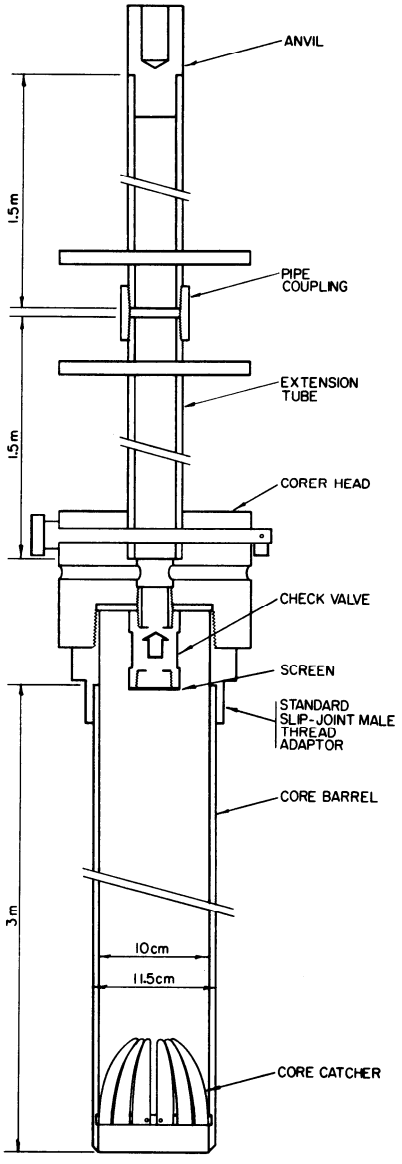
Instrument Operations and Maintenance

In February 1977, a major field project was supported in the Miramichi estuary, NB, that consisted of a comprehensive survey and geological sampling program from the ice surface. This required that portable field stations be constructed: these were towed on the ice from one survey site to the next. A portable vibracorer was constructed for taking cores of bottom samples through the ice.

During the fall of 1977, AGC carried out a sediment transport study off Economy Point in the Minas Basin area, NS, using radioactive isotope tracers. The Minas Basin is part of the Bay of Fundy system whose high tides made the work logistically very difficult. Helicopters were used to transport and install current meter arrays. All-terrain vehicles were used to place the radioactive tracers on sand bars during low tide and to carry the monitoring equipment during the many resurveys of the area to determine tracer transport. The high tide and extensive mud flats required that many innovative techniques be developed and used to safely and efficiently carry out the project.

During the summer of both 1977 and 1978, the CSS *Hudson* was fitted out for a major geological and geophysical survey of the Baffin Island continental shelf areas off Scott Inlet, Cape Dyer, Cumberland Sound, and Frobisher Bay. This involved detailed co-ordination of ship space and equipment requirements with staff of other research divisions at the Institute who were carrying out chemical, biological, and physical oceanographic investigations in similar or adjacent areas of the eastern arctic. With the large amount of sampling, surveying, and analytical equipment involved, this required a considerable effort by all the staff in the Subdivision.

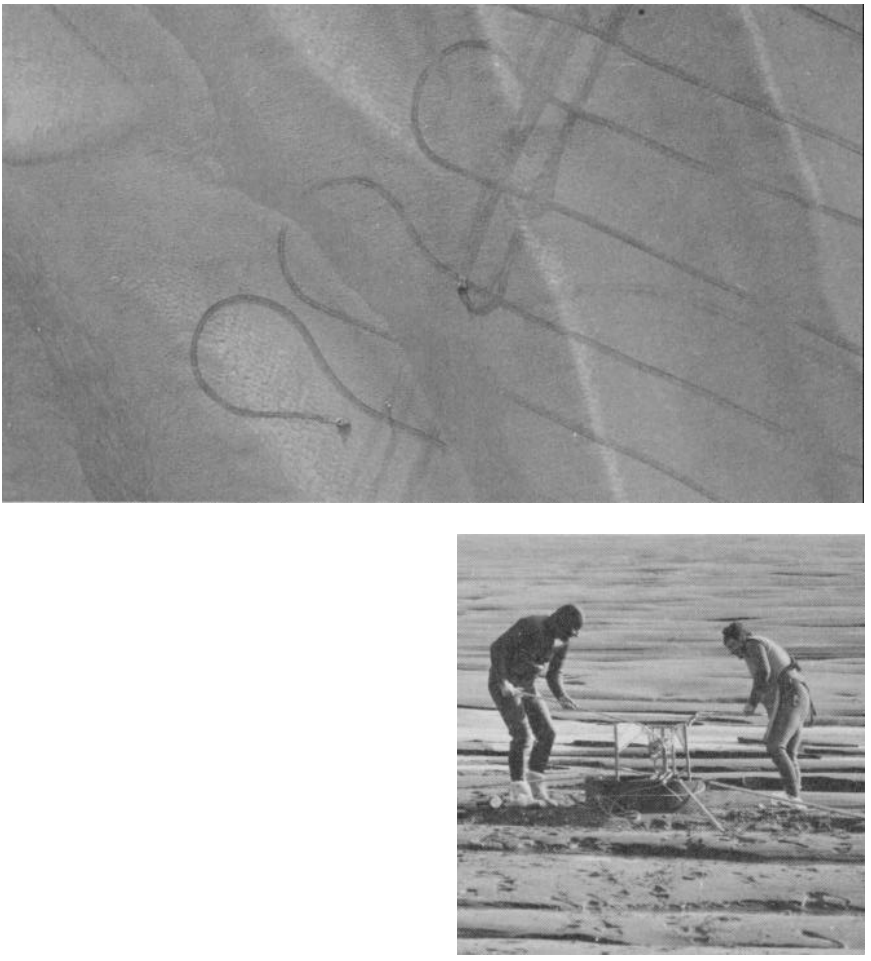
On April 1, 1978, instruments and technical staff whose work related to field and large seismic survey equipment were transferred to Regional Reconnaissance for day to day supervision.



The portavibe is an instrument that is mounted on an ice platform and used to core sediment that lies in water depths of 30 metres or less. (BIO 4272-3, 4272-5, and 4347)

Data Systems

The Subdivision has agreed, during 1978, on behalf of AGC with the U.S. National Geophysical and Solar-Terrestrial Data Centre in Boulder, Colorado, to the mutual exchange of marine geoscience data. We have already received some seismic data and our gravity and magnetic data will be sent to Boulder in the near future.



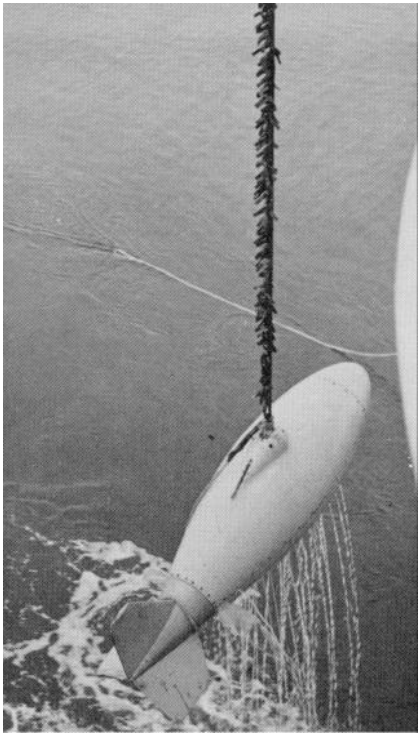
Top: A sand bar in the Minas Basin, NS, photographed by an unmanned balloon-supported camera and depicting the survey pattern used for radioactive tracer studies. Bottom left: a survey vehicle and marker on the bar. Bottom right: radioactive tracer is released on the sand bar.

An agreement has been made with the RMCB east coast office to combine geological sample curation facilities under one common facility in the Institute. This new facility has 3688 cubic metres of dry storage area and 184 cubic metres of refrigerated space for the storage of recent marine samples. The inventory now includes samples from 4600 geographic locations, but predominantly from the North Atlantic and eastern arctic areas. Much effort is now being devoted to improving data handling from sample analysis, and improved terminal facilities for AGC are planned to accompany the acquisition of a new computer at the Institute early in 1979. Preliminary plans are being carried out to develop and implement a new geophysical data storage and retrieval system (GEOFFREY) to replace our present ten-year old system (GEOFILE).

Systems Development

The primary project undertaken by this section during the last two years has been the development and construction of the ocean bottom seismometers (OBS). Four instruments have been built from a design that originated at the University of Hawaii but was modified by us. A system for releasing anchor weights and allowing the instrument to float to the surface was developed. It uses a vacuum chamber to hold the anchor and instrument together; by breaking this vacuum the anchor is released. The chamber rigidly couples the instrument to seismic vibrations of the ocean floor and it has the added advantage that all critical parts are in a vacuum instead of in the usual high-pressure corrosive environment of the ocean floor.

Another innovation is the use of a very small low power microcomputer to act as the clock and control section of the OBS. Its advantages are small size, low power consumption, and, most important, ease of modification to perform different tasks. Reprogramming this computer is far easier and quicker than changing a normal digital clock circuit to control, for example, a pinger. In the first year (1977) we had ten lowerings of the instrument and two losses. The eight recovered instruments all functioned properly and gave useful data. Part of this work was done from the German ship

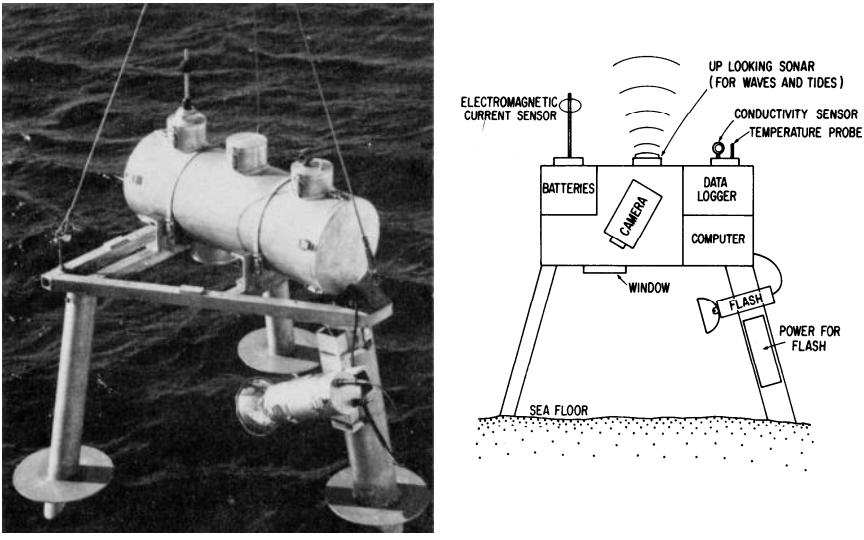


Left: a side-scan sonar survey record, which depicts changes in the sea floor charted over a 1500-metre wide track. Right: the side-scan sonar system is retrieved. (BIO 4978-10-8 and 5007-7-3)

FS Meteor on the Reykjanes Ridge. In early 1978, several more instruments were built and by the end of 1978, 17 of 19 lowerings were successfully completed.

These instruments give the marine geophysicists a valuable new tool to study the details of the earth's crust, particularly as surface waves can be recorded and the OBS's sensitivity is much greater thereby allowing smaller explosive charges to be used rather than the moored sonar buoys used previously.

The BIO side-scan system was updated and refurbished during the winter of 1977-78 with good survey results being obtained on the three 1978 cruises. Plans are being formulated to modify it for use in surveying in areas deeper than 250 metres by 1980 in the arctic.



This self-contained, bottom-mounted apparatus (called RALPH) is used to monitor sediment transport on the ocean floor. (BIO 5762-4 and 5723)

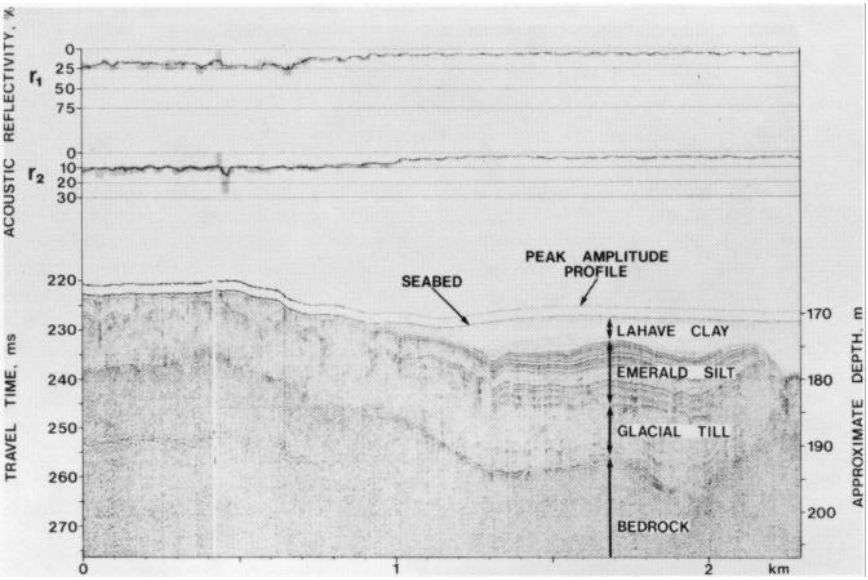
A self-contained bottom-mounted environmental monitoring system (named RALPH) has been designed and partially built to record, digitally and photographically, seafloor environmental parameters over long periods that are important to the study of marine sediment transport. The prototype will be field tested during 1979.

Regional Reconnaissance

The primary objective of the Regional Reconnaissance Subdivision is to understand the recent and ancient history of development of the continental margin of eastern Canada. This is primarily carried out by the interpretation of data collected during regional geoscience surveys of the margin and by the development of new technology and methodology to increase the scope and efficiency of these surveys. Systematic marine geological and geophysical surveys of the margin provide basic geoscience maps, which are then supplemented by regional studies in the adjacent oceanic areas and lead to regional analyses and syntheses concerning the geological development of the area. Our activities are subdivided according to the extent of our mapping both in depth (surficial geology, bedrock geology, and crustal structure) and in geographical area (Scotian Shelf, Grand Banks, Labrador Sea, Baffin Bay, Arctic Ocean). An attempt is being made to collect regional data and provide interpretative syntheses for all depths in all areas, and the primary achievements towards this end during the review period are summarized below.

Surficial Geology

SEABED is a 5-year research project of Huntec ('70) Ltd., Toronto, Ontario, financed by the federal government (DEMR, DFE, and NRCC) for the development of a remote method of determining quantitative parameters associated with surficial sedimentary units of the sea floor. The uniquely reproducible nature of the output pulse from a boomer developed by Huntec permits quantitative analysis of the return pulse for correlation with the sedimentary properties of the sea floor from which the pulse was reflected. During the previous review period (1975-76), the emphasis of the project was on engineering the deep tow system and on its use as a high resolution seismostratigraphic tool. Data processing has now taken on a more important role and development of the system as a lithostratigraphic tool is being emphasized. Two independent analyses of the scattering and reflection properties of the sea floor are particularly satisfying. The scattering properties of the sea floor are being investigated at Memorial University, Newfoundland, as a subcontract to SEABED, by an analysis of the coherence between successive return pulses. Coherence between successive pulses reflected from the same geological unit clustered in separate parts of a graph between cross-correlation and coherent reflected energy. The reflection properties are being investigated by SEABED at BIO. The reflected energy is measured within two time windows within the first metre beneath the sea floor, and the calculated acoustic reflectivity is displayed as a continuous profile alongside the seismic section. The reflectivity is a function of the geological unit from which the reflection occurs. However, neither of these two criteria provide unique identification of grain size, and additional correlations between geological properties and quantitatively determined properties of the reflected pulse are being sought As a result, there has been an increase in the effort to collect better geological ground truth in the form of long sediment cores at locations over which good, deep-towed, seismic reflection data have also been collected and



The Huntec deep-tow high-resolution seismic system provides detailed information on surficial sediments. The lower part of this figure is a profile of a typical basin section of the Scotian Shelf; the upper part is a quantification of the seabed profile data where r1 is a measure of coherently reflected energy from the seabed and r2 is a measure of the scattered energy from the top metre of the seabed. (BIO 5051)

from which properties such as sedimentary acoustic velocity, shear strength, density, and porosity may be determined. Because it is hoped that the deep tow system will be valuable to commercial operators concerned with the identification of sites for locating hydrocarbon drilling and production platforms, the availability of on-line recognition of sedimentary properties is a major attribute. A start has therefore been made on the building of microprocessors to carry out reflectivity analyses on-line. Such experience will be valuable when more sophisticated and it is hoped more discriminatory analytical methods have been developed.

Scientifically, we are anticipating that use of the deep tow system will minimize the requirement for extensive sampling in support of the bathymetric and high resolution seismic surveys we have traditionally carried out for identification of surficial geological units. The deep tow system has been used effectively as a stratigraphic tool to assist in the mapping of four primary areas during 1977 and 1978: the Grand Banks of Newfoundland, northeast Newfoundland Shelf, Saglek Bank (northern Labrador Shelf), and the Baffin Island Shelf. The work in progress on the Grand Banks south of Newfoundland will extend the coverage of our surficial map series from the areas completed to date: the Bay of Fundy, eastern Gulf of Maine, Scotian Shelf, and Chedabucto Bay. Additional data on end moraines and pockmarks were obtained on the Scotian Shelf during cruises designed for development of the side-scan and Huntec deep tow systems. Pockmarks, which are cone-shaped depressions in the unconsolidated sediments caused

by the release of gas from the underlying sediments, were found to show elongation and preferred orientation, both of which may be due to the influence of bottom currents. The morainic surfaces show well preserved relict iceberg furrows, which appear to be 19-20 thousand years old. The distal sides of the moraines consistently show an interbedded relationship with the proglacial, Emerald Silt formation. Although a number of piston cores for ground truth and real time analogue seismic records from the survey northeast of Newfoundland have permitted qualitative mapping of the surficial units, the recorded data are of sufficiently poor quality that subsequent quantitative analysis may be limited to restricted areas. On Saglek Bank, the near surface section containing the boulders that caused problems with the initial drilling of wells contains little internal stratification on the deep tow records although energy returns from a distinct reflector at depths of greater than 50 metres suggest that in some areas at least the near-surface section passes a significant amount of acoustic energy. Future hydrocarbon exploration and production on the Labrador Shelf is highly dependent upon a knowledge of the vertical and horizontal distribution of surficial sediments and their modifications through time. Whereas Hamilton Bank off southern Labrador was covered by a grounded ice sheet, and has been subsequently modified in a way that reflects changes in the circulation pattern of the Labrador Sea, Saglek Bank shows evidence from terracing on its seaward edge of extensive changes in sea level. Related transgressions have levelled most of the Saglek surface obscuring geomorphic evidence of glaciation except in a few isolated shelf basins. Off Baffin Island the surficial survey coverage awaits compilation and the collection of sediment core control.

Analysis of deep water cores from the northeastern Labrador Sea has been carried out to investigate the possibility of past deviations from the modern West Greenland Current pattern. Inter-core correlation of oxygen isotope ratios, volcanic ash zones, and microfauna provided the chronology for these investigations back to approximately 90 thousand years B.P. (before present). The stratigraphic chronology developed for the northern Labrador Sea is identical with that for the open ocean for the period 18 to 80 thousand years B.P., which indicates that the West Greenland Current was active during that period.

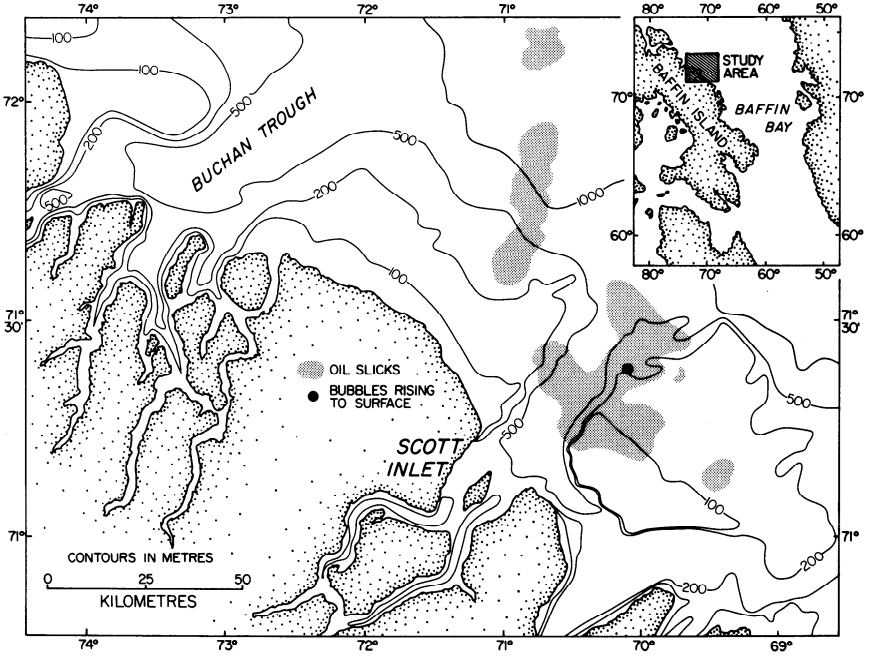
Bedrock Geology

The Huntec deep tow system has also provided impetus to the bedrock mapping program, because its resolution is sufficient to define locations where the bedrock surface is sufficiently close to the sea floor to allow for sampling with the BIO electric rock core drill, which has a maximum penetration of six metres. Bedrock mapping has proceeded in three areas: the central Grand Banks, northeast of Newfoundland, and off Baffin Island.

Seismostratigraphic mapping of the geological units on the central Grand Banks was completed in 1977 and confirmatory drilling was carried out. Interest was primarily focused on the extent of the Cambro-Ordovician strata over an area of at least 15,000 square kilometres offshore from the Avalon Peninsula in continuity with the strata of Bell Island in Conception Bay. An investigation of the significance of this unit is underway. In addition, granitic and volcanic samples were obtained from Flemish Cap, from which a previous sample gave a tentative late Precambrian age. If the newer, more reliable samples confirm that age, then correlation with the similar aged granites of the Avalon zone in Newfoundland and those recovered

at the outer edge of the continental shelf west of Brittany will provide constraints on the relative positions of continental blocks prior to opening of the present Atlantic, and also their subsequent relative vertical motion.

Northeast of Newfoundland, the effort in 1978 was concentrated on an investigation of the structure of the ultramafic units mapped offshore. These units are interpreted to be the source of the slices of ultramafic rock transported onto Newfoundland in mid-Ordovician time from an ocean that existed between eastern and western Newfoundland. Reliable samples of the ultramafic unit were not obtained off western Newfoundland but the eastern (Gander) ultramafic zone was traced offshore. Interpretation of the magnetic data indicates that the western ultramafic units dip eastward and a short refraction line was shot to confirm this and relate it to the longer refraction lines further offshore that indicate an eastward dipping ultramafic zone at depth. All indications are that the geological units of central Newfoundland trend northward offshore, and imply that a major bend existed in the Appalachian-Caledonide system before opening of the present Atlantic Ocean.



The location of oil slicks observed in the Scott Inlet area. See Chemical Oceanography in Section A-I for a photo of the slick area. (BIO 5168)

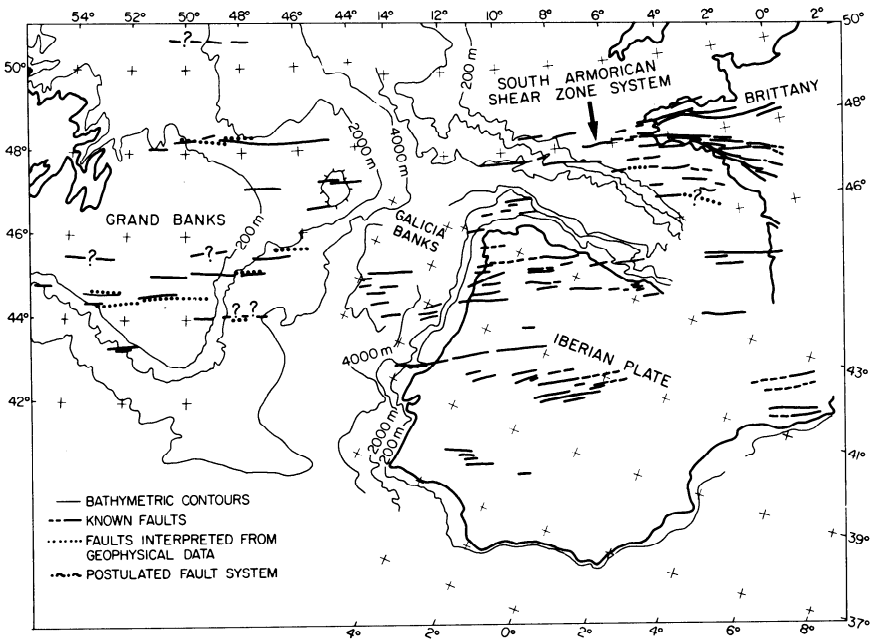
Mapping and sampling of the bedrock units southeast of Baffin Island is now almost complete. The Precambrian rocks outcropping on the Island are overlain by Ordovician rocks, which outcrop offshore within an approximately 50 kilometre wide zone fringing the coast. Although partially covered by late Cenozoic cover rocks, reliable drill samples have confirmed its age.

The greatest excitement was generated farther north at Scott Inlet where an oil seep was sighted in 1976. The seep encountered in 1977 was at least 40 kilometres long and may be caused by seepage from the rock formations that intersect the walls of the Scott Inlet submarine trough. Samples of the strata are extremely difficult to obtain, but a calcareous concretion of late Eocene age was recovered by dredging from the trough wall. Investigation of the source and nature of the seep are being carried out in conjunction with Chemical Oceanography (AOL).

Geophysical Surveys

The multiparameter surveys carried out through co-operation with Hydrography Division, AOL, are a continuing project to obtain hydrographic and geophysical coverage of the continental shelves and margins of eastern Canada to nationally accepted standards. The data are published as maps in the Natural Resource Series by the Canadian Hydrographic Service. The geophysical data are used extensively in regional geological interpretations.

Emphasis during the past two years has moved from the regional coverage of the Labrador Sea to more detailed work on the Labrador Shelf. Collection of that data almost completes nine kilometre coverage of bathymetry, gravity, and magnetic data along the entire continental margin between the Tail of the Banks and Cape Chidley, northern Labrador. South of Newfoundland, the coverage is less detailed but has permitted the definition of structural units and fault zones that may be correlated with equivalent zones in Europe,



Zones of faults in Spain, Portugal, and France can be correlated with faults on the Grand Banks to provide latitudinal control over the pre-continental drift relative positions of those continental areas. (BIO 5722)

thereby providing constraints on paleogeographic reconstruction. Markers have been recognized on both sides of the Atlantic in a co-operative project with the University of Rennes in France, tying Massachusetts through to Nova Scotia with northwest Africa, tying the Grand Banks with Iberia and France, and tying the margin northeast of Newfoundland with the margin west of Ireland and Scotland. These constraints on the relative location of the continental blocks immediately prior to opening of the Atlantic Ocean now have to be reconciled with the later evolution of the Atlantic and Labrador Sea as revealed by their magnetic lineations to determine the early history of opening.

Magnetic field data have also been collected during other operations of the Hydrography Division where collection of gravity data was either superfluous or unpractical. Such surveys have been carried out in the vicinity of Anticosti Island, Foxe Basin, and Ungava Bay complementing the data collected in adjacent areas as part of the federal-provincial aeromagnetic survey program.

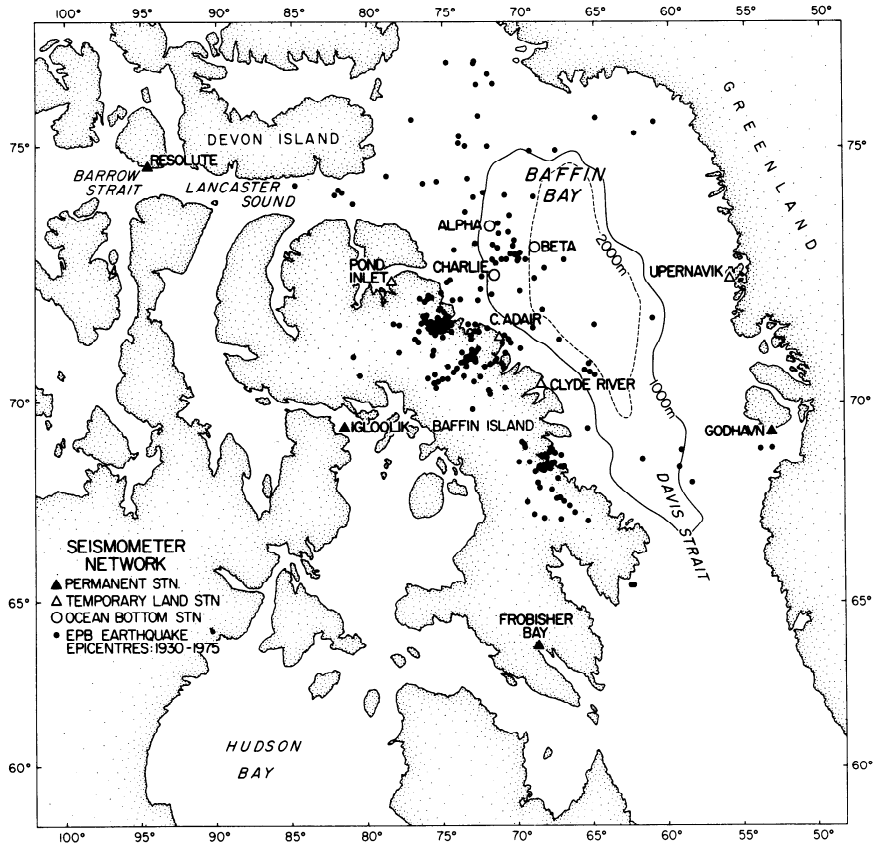
A major improvement in the means of interpretation of the geophysical data was provided by the development of an interactive graphic approach to the computation of gravity and magnetic anomalies. Model bodies may be defined and modified and their anomalies calculated by using a set of cross-hairs to invoke commands displayed on the screen of a CRT and identify the bodies or points within those bodies to be affected.

Ocean Basins and Margins

The completion of regional geophysical surveys in the Labrador Sea as part of the multiparameter survey operation with Hydrography Division enabled an interpretation to be made of the history of the development of the Labrador Sea from its initial opening at 85 million years B.P. (pre-anomaly 32) to its quiescence at 40 million years B.P. (pre-anomaly 13). In 1977 a larger scale multichannel seismic reflection survey was carried out by the Federal Institute for Geosciences and Natural Resources, Hannover, the interpretation for which was carried out jointly with AGC scientists. A continuous seismic cross-section of the Labrador Sea has been prepared, and tied in to exploration wells on the Labrador Shelf to provide some stratigraphic control. The thick prograding sedimentary wedge on the Labrador Shelf contrasts sharply with the thin sedimentary section overlying the strongly faulted basement on the Greenland margin. In addition there is an asymmetry in the geophysical anomalies associated with the margin. Modelling of the gravity data indicates an abrupt thickening of the crust landward of the sedimentary basin beneath the Labrador Shelf edge. The nature of the crust beneath the basin and hence the transition between oceanic and continental crust is still unclear. Refraction work is planned to look in detail at the differences in the nature of the transition zones off Labrador and west Greenland.

Completed development of the ocean bottom seismometer (OBS) system has had a profound effect on the seismic work associated with investigating deep crustal structure. The ability to use the OBS easily and successfully has attracted more users and consequently put a strain on the playback and interpretation facilities whose development has therefore had to be advanced. Also the proliferation of alternative OBS designs by many other institutions

led to the planning of a calibration and intercomparison experiment in which we participated.



Earthquake activity in Baffin Bay was studied in September 1978 using OBSs. (BIO 5132)

The primary use of our OBS has been in the definition of “standard” sections of the continental margin according to whose properties other margins might be categorized. Refraction lines have therefore been obtained across the rifted Nova Scotian margin, the transform southern Grand Banks margin, and the anomalous margin in the vicinity of Orphan Knoll. A section across the Orphan Basin provides the definitive case for identification of continental crust that has subsided and has been thinned in the transition between typical continent and typical ocean. The history of development of this transitional crust is still unknown, but the similarity between the depth to the Moho of 19 kilometres in Orphan Basin and 23 kilometres in Flemish Pass in the face of the great differences in distance between the shelf and the continental fragments at the seaward edge of the transition zone is not compatible with a simple stretching mechanism. Evaluation of the P and S wave velocities for each of these sections is still proceeding,

and will be used to determine the physical nature of each of the main crustal layers. The results of our investigations were compared with those from many other margins during an international conference entitled "Crustal Properties across Passive Margins", organized by AGC and Dalhousie University, and sponsored by the Interunion Commission in Geodynamics, the Commission on Marine Geology, and NRCC. The conference was a great success in providing a convivial forum in which mutual problems were discussed, and interpretations compared.

Determination of margin structure is only meaningful if from it can be deduced its history of development. Constraints on such processes are provided by the mechanism of seafloor spreading, which can only be evaluated in the ocean basins. Two activities have been directed to this end.

"So far so good guys. But how do I put a lid on this thing?" Building igloos was the main recreation of scientists at the Canada Basin in March 1978 where they first showed that the OBS could be used through ice.

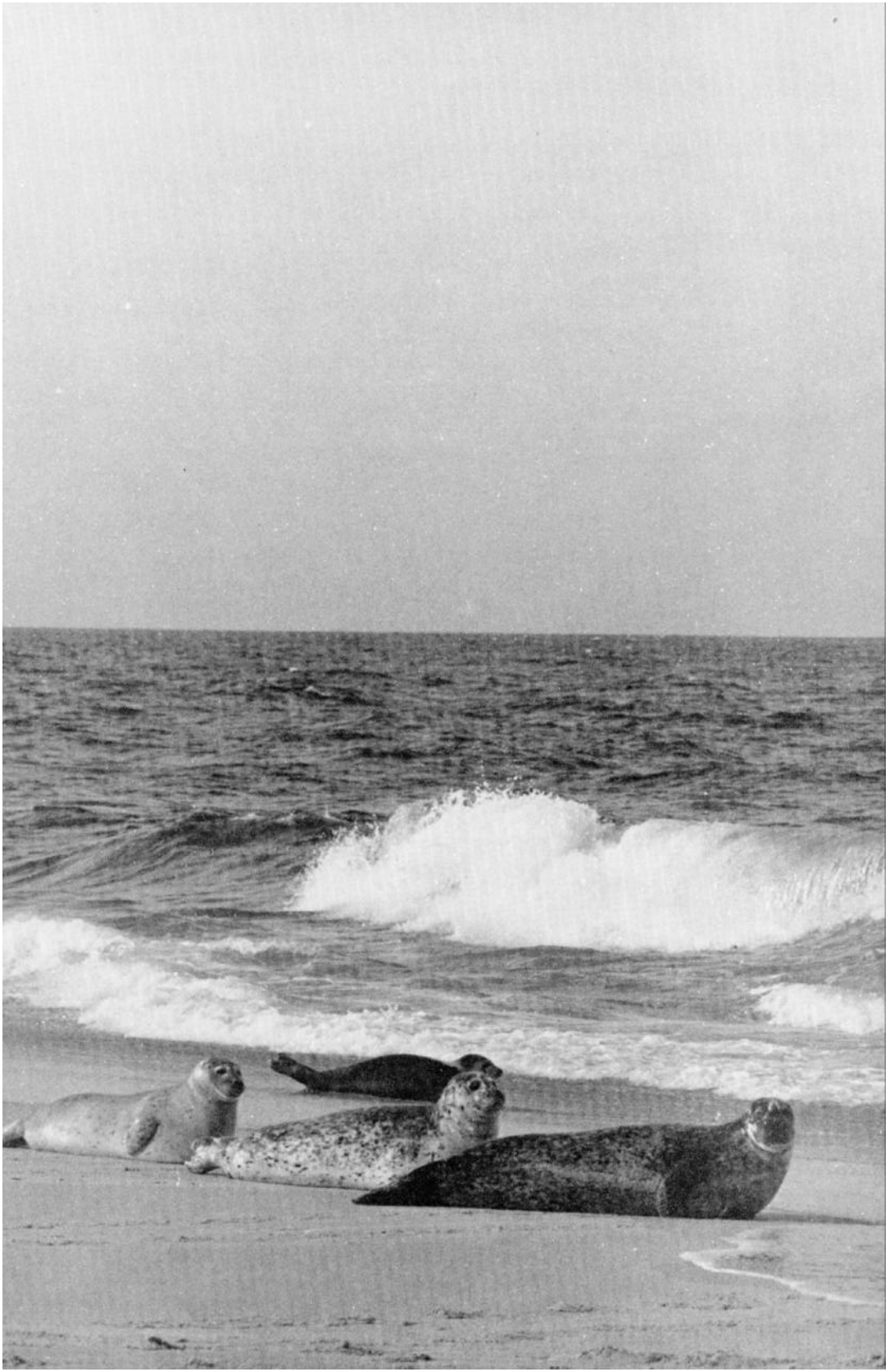
OBSs 'have been used to investigate the crustal structure in northern Baffin Bay as part of an experiment with the Seismology Division of the Earth Physics Branch, DEMR, in which the OBSs and temporary land seismographs provided a network for studying the offshore and onshore seismicity. Experience with arctic operations was gained in another co-operative venture with the U.S. Office of Naval Research when an OBS was deployed through the ice in Canada Basin to receive seismic signals generated by explosives dropped through leads in the ice. This experience will be beneficial to the success of operations on the Nansen Ridge planned for 1979. These results provide a small inroad into the search for a viable paleogeographic history of the Arctic Ocean basin.

Although the Reykjanes Ridge is in many ways atypical of the mid-Atlantic Ridge, it nevertheless has a major bearing upon North Atlantic Ocean

development. Determination of its crustal structure was the prime objective of a major international experiment led by the University of Hamburg in which AGC participated with the operation of four ocean bottom seismometers. The results show that seismic signal attenuation decreases with distance from the ridge and that high mantle velocities (Vm >8.3 kilometres per second) are to be found within 100 kilometres of the ridge crest. From an investigation of magnetic anomalies surveyed by the German Hydrographic Institute, the anomalously shallow Iceland-Faeroe Ridge appears to have developed prior to anomaly 22 time (approximately 54 million years BP.), since which time spreading has continued across the Reykjanes Ridge.

Marine Fish Division
Resource Branch
Fisheries Management
Department of Fisheries
and the Environment

Chief - R. G. Halliday



ToC

Marine Fish Division

In the 1975-76 re-organization of the Fisheries and Marine Service (DFE) both the Resource Branch, Fisheries Management, and the Marine Fish Division became organizational entities. The mandate of the Marine Fish Division is to provide scientific advice on the management of marine finfish resources and to conduct associated biological research. In 1977, the Division also assumed these responsibilities for grey and harbour seals.

With Canada's extension of fisheries jurisdiction at the beginning of 1977, additional manpower and money were made available for applied fisheries research and this resulted in a substantial increase in Marine Fish Division programs. On creation, the Division was based at the Biological Station, St. Andrews, NB. The expansion of Division programs allowed creation of a component at BIO, thus meeting the requirement to have Division management in the Halifax-Dartmouth area as part of the fisheries management team there on a day-to-day basis. The decision of senior management to have the Division located at BIO was based on the desire to promote co-operation between the scientific arms of the Service. While rounding out BIO-based programs to include some of the most applied aspects of fisheries research, this also provided the Division with a research oriented milieu and facility within which to work.

The Division became a tenant of the Institute when four staff relocated here in September 1976. Full time staff members presently number slightly over 30, and in the Division as a whole (including its component housed at the Biological Station, St. Andrews, NB) number approximately 70. The Division was invited to become a member (rather than a tenant) of the Institute, and the Division Chief a member of the committee of directors, in February 1978.

The Department took delivery of the research vessel *Lady Hammond* in June 1978 under a five-year charter agreement. The vessel is a converted fishing trawler with an overall length of 58 metres and a gross tonnage of 897 tonnes. The Marine Fish Division is the primary user. The vessel has become part of the research fleet at BIO.

Extension of fisheries jurisdiction, and the diminution this implied in the scientific functions of international fisheries commissions, provided sufficient stimulus for the creation of the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC). This committee of Federal Atlantic coast biologists provides peer-reviewed advice on fisheries management questions and also provides a co-ordinating mechanism for fisheries research. A permanent secretariat has been created to perform a staff function for CAFSAC. This secretariat is located at BIO in association with the Marine Fish Division.

The research of the BIO component of the Division is directed toward providing an understanding of the population dynamics of fish stocks, a description of the effects of fishing, and predictions of the response of

The Lady Hammond. *(BIO 5098-1)*

stocks to regulatory measures. It is with pleasure that I present the following accounts of the specific programs presently being conducted as our first contribution to the Biennial Review.

Fisheries Systems and Data Processing Group

This Group has three mandates: (1) managing the processing of Division data; (2) managing the Scotian Shelf Ichthyoplankton Program (SSIP); and (3) advancing the basic theory of fisheries science through single and multi-species modelling, and developing theoretical models useful in the continuing assessment of fish stocks. In the past the Group has carried a substantial responsibility in the area of stock assessment, but as the Population Dynamics Group moves toward full staffing under the Extended Jurisdiction Program, this Group will be gradually relieved of that responsibility.

Data Processing. The Marine Fish Division collects a vast amount of data from groundfish and pelagic survey cruises, plankton cruises, and biological samples from domestic and foreign commercial fishing operations. After collection, the data must first be audited and added to the base of historical information. They must then be summarized and analysed to provide the information required by researchers to assess the various fish stocks of the Maritime Region. To meet these demands, computers become essential and consequently this Group has established a sophisticated computer set-up to meet the needs of the Division. The BIO component of the Division uses IBM 370 and CDC 6400 computers. Jobs are submitted by terminal and printouts are returned either to a line printer attached to our remote-job-entry station or to the terminal that submitted the job. A

library of programs has been accumulated to perform some standard analyses such as producing age-length keys, calculating abundance estimates from stratified samples, and performing catch projections. In the future it is anticipated that additional programs will be written to do such things as produce computer plots of data and build up a formal data base for satisfying smaller information requests.

Scotian Shelf Ichthyoplankton Program. *(a)* The *field program* - In order to best manage a fishery and predict future yields, it is necessary to elucidate the factors, both biotic and abiotic, that govern the stock-recruitment relationship. It is the long-term aim of the Scotian Shelf Ichthyoplankton Program to provide the data necessary to understand the mechanisms that regulate larval fish distribution, growth, and mortality-

The first three years of the program will be used to define larval fish distribution in relation to that of primary and secondary productivity. At the same time abundance indices will be provided for use in stock assessments. Later on, patch studies will be incorporated into the survey plan. These specialized studies will act as a focus for both the biological and physical oceanographic groups involved in the program.

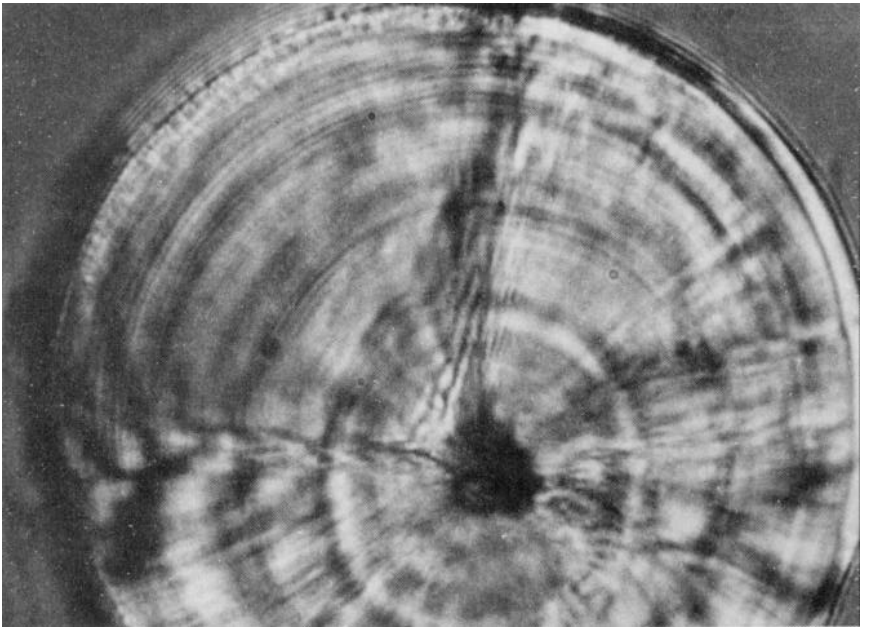
The standard tows to be used are the MARMAP oblique Bongo haul, and surface neuston and Isaacs-Kidd nets. This gear will initially be used over a 214 station fixed-grid on the Scotian Shelf. Throughout a cruise, water will be pumped from a specified depth, through an onboard fluorometer and HIAC particle counting system. As well, the Batfish will be towed along every second or third transect to provide hydrographic information required by the program along with data on fluorescence and particle distribution. Nansen bottle casts and bathythermograph drops will be made to provide water samples for chlorophyll analysis and calibration of the Batfish sensors.

The program is ambitious and will take at least a year to get off the ground properly. However, with the data provided, the program will have paid for itself in a very short time.

(b) Aging of larval fish - The aging of adult fish using scales and otoliths plays an important role in the study of population structure. Recently, interest in larval population dynamics has made accurate aging of larval fish increasingly important.

A program for the routine aging of larval fish using otoliths has been set up to provide information on both larval and adult populations. Aging of *Ammodytes* (sand lance) has been the first project. Otoliths are extracted from fresh frozen specimens and examined under high magnification (630-1000x). The ring structure seen is interpreted as daily growth zones. Results are used in the preparation of age/length keys. Resolution of the number of species of *Ammodytes* in local waters will be attempted using the characteristics of larval otoliths.

Single and multispecies modelling and assessment theory. *(a) Cod-Mackerel model* - Ichthyoplankton surveys have been conducted in the Gulf of St. Lawrence since 1965. In some years as many as six cruises were conducted so that the spawning cycles of most fish species could be defined. In addition, these surveys were also designed to investigate the



Fine ring structure seen on an otolith of a larval sand lance (Ammodyte), magnified 1000 times. (Courtesy of R. Halliday.)

stock-recruitment mechanism for cod, mackerel, herring, and other species, in addition to defining how different fish species interact during their early life history.

By building statistically supported submodels of the egg, juvenile, and adult phases of cod and mackerel, it has been possible to build a stochastic model of the cod-mackerel fishery, with recruitment being a function of parent-stock production and environmental parameters. It is very difficult to test the validity of such a model since it is constructed with the use of all available historical data. However, the most recent three years of data on year-class size in cod lend support to the model's predictions and it seems to be a promising future stock management tool.

A number of conclusions can be drawn from this particular study:

(1) The management of mackerel is far more important in the control of cod biomass than the management of the cod fishery itself.

(2) The model predicts that the 1973, 1974, and 1975 cod year-classes should be larger than average. This seems to also be the case in reality, based upon results from bottom trawl surveys.

(3) No clear stock recruitment curve is recognizable for either cod or mackerel over a wide range of stock sizes. However, this does not rule out a relationship but merely illustrates that there are many other factors to consider.

(b) Extended jurisdiction modelling exercises - An interesting exercise was recently carried out to model the effect of varying types and quality of

data on our ability to manage a fishery effectively. The particular stocks chosen were northwest Atlantic mackerel and Gulf of St. Lawrence cod because we have a better biological understanding of these stocks than we do for any of the alternative stocks and because we have working computer simulations for them. The simulations were incorporated into the larger model in such a way that they were assumed to be the true population. By writing separate subroutines to provide management advice depending on the assumed level of data availability and then feeding this advice back into the population as an allowable catch, it was possible to see the effect of spending money on certain types of data collection in terms of increased output or stability in the fishery.

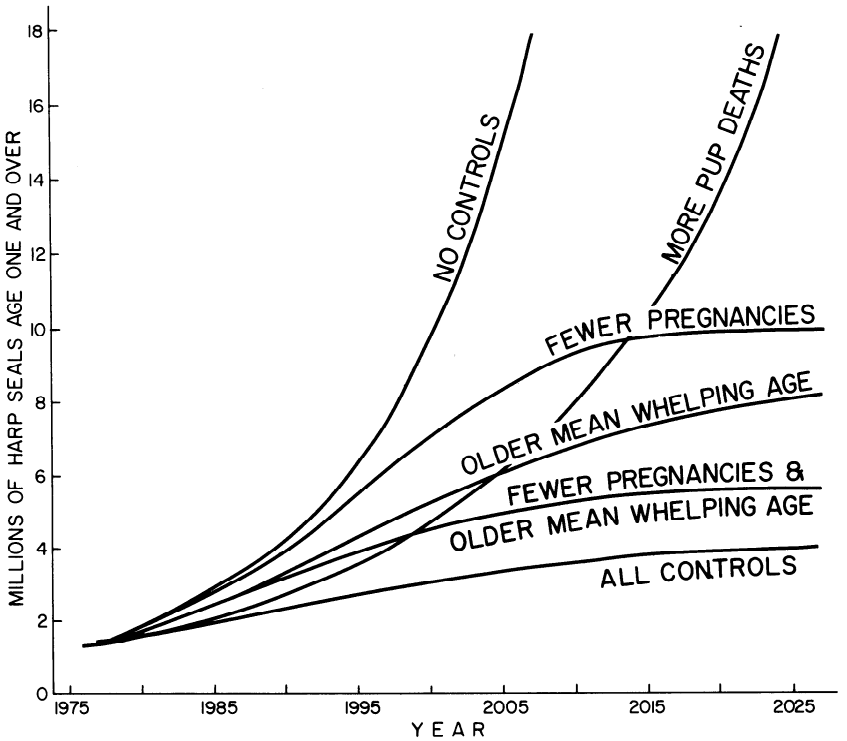
(c) Harp seal populations dynamics - More sophisticated models were developed to incorporate the increasing amount of data on the northwest Atlantic harp seal. These models considered the effects of density-dependent controls on management options for this herd. The latest model simulates the fall of pregnancy rate, mean age of whelping, and increasing pup mortality with increasing population size. Classical yield calculations of the Schaefer type are not directly applicable to the data that require a detailed simulation approach. Instead of the familiar parabolic shape the yield rises more quickly and falls more slowly. From this work the maximal sustainable yield is estimated to be 215,000 animals at a population size of 1.4 million.

A persistent problem in the biology of the harp seals is whether they are two subherds or one large intermixed herd. The answer has implications for management of the stock. In order to provide more data we undertook a large-scale tagging operation on pups born this spring (1978). However, approximately four years are required for the pups to mature and it will be some time before this 'program yields insights into the problem. As existing tag-return data from other studies imply separation of subherds, this effect was included in the most recent model. The model indicates that the catch should not be allowed to concentrate in one region.

The various published models of harp seal dynamics were used to study the structure and characteristics of the models themselves. The sensitivity and interactions of the parameters describing the population were analysed to illuminate the discrepancies between published models. The analysis revealed an increasing instability with smaller population densities. This study also showed the relative impact on herd dynamics of various management strategies.

(d) Least squares analysis of catch data - The standard tool used by the biologist to estimate from aged catch data the number of fish in a particular stock at each age and the mortality experienced by the stock due to fishing is virtual population analysis. This method has the advantage of always giving an answer and one that is usually reasonable due to its dependence on subjectively selected starting values. However, there is no way of measuring how well the results obtained fit the data.

Several people have tried to develop new methods of estimating these numbers, and fishing mortalities that would also allow for estimation of goodness of fit and confidence limits. The first attempts divided the fishing mortality into two components; a year effect (indications of the effort level



Available data indicate that density-dependent controls limit harp seal populations. As population increases, so do mean whelping age and pup death rate while pregnancies decline. Seals are currently hunted and mean whelping age and pup death rate are low while pregnancy rate is high. The graph projects growth as if hunting had ceased in 1976 except for the limited hunting by the Innuit. The "no controls" curve assumes all rates remain at 1976 levels and are unaffected by population size. The "all controls" curve assumes the controls are all in effect. Other curves reflect growth with one or more controls acting. The "all controls" curve is believed to best resemble the natural situation. (BIO 5170)

in the fishery) and an age effect (due to availability and selectivity of fishing gear). Individual mortalities were then estimated by combining these. Thus fewer degrees of freedom were used estimating parameters and some were left over for estimating error. Running these methods on real data usually gave wide confidence limits for the parameters. Also, even though the confidence limits usually contained reasonable points, the best estimates were often unreasonable. These methods are less subjective since they rely less on starting values and this, along with biases introduced by the incorporated assumptions and approximations, probably causes these problems.

It is felt that the wide confidence limits do not really reflect the amount of information contained in catch-at-age data because they do not properly account for inter-relations between the data points. Presently we are trying to locate the main sources of bias in our methods and to find some way of estimating more realistic confidence limits.

Biostatistics Group

The Biostatistics Group mandate is to collect all pertinent information on the commercial fisheries needed by the Division to assess the status of the stocks. Extension of jurisdiction by Canada has resulted in new initiatives in this area as briefly described below.

International Observer Program. This program, in conjunction with the policing responsibility of the Department, involves keeping 30 Canadian observers on foreign fishing boats operating on the Scotian Shelf. There is a similar program on the Grand Banks operated by the Newfoundland Region of the Department (DFE).

The observers ensure that foreign fishing vessels obey Canadian fishery regulations and collect information for stock assessment purposes. Analyses of the voluminous data collected by these observers have provided new insights and knowledge on species distribution and intermix, detailed information on foreign catch composition, distribution of foreign fishing effort, and areas of potential bycatch problems; they have also allowed more reliable estimation of foreign catch rates in various fisheries.

Canada currently is refining its management regime for foreign fisheries by using both catch and fishing effort controls. The data collected by this program allow calculation of the fishing effort required to catch fish quotas, taking into account the mixed fishery situation.

Canadian catch sampling. The functions of this program, which involves technicians permanently stationed in the major fishing ports, are to sample the Canadian groundfish and pelagic fish catch for size and age composition by stock and to liaise with the industry to collect information on the geographical distribution of catch and fishing effort. These data are essential to evaluate the status of the commercially exploited fish stocks and to permit projections of future yields. Further, these data are being used to generate maps of general fish distribution and to evaluate the possible effects of oil exploration on fish stocks and fisheries.

Domestic observer program. This fledgling program is an adjunct to the land-based sampling program for the Canadian fleet. Observers are placed on Canadian fishing vessels to collect information on catch composition, bycatch, and discards from the Canadian fishery. Since the land-based sampling program deals with fish that frequently have already been sorted into market categories that obviously exclude discards, this observer program will permit an analysis of the adequacy of the historical sampling program in assessing the status of fish stocks. The program further augments the data collected by the international and port sampling programs on species distribution and permits an audit of the effort information compiled from fishing log books.

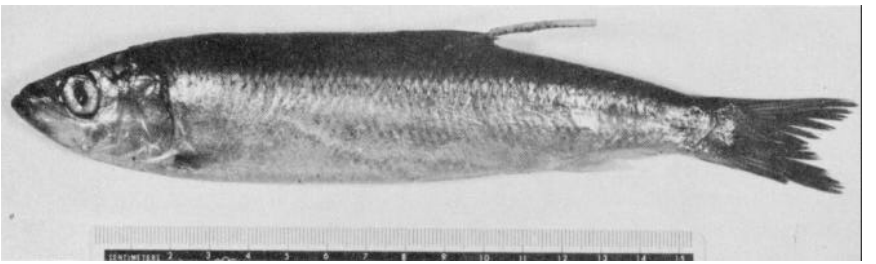
International research. One result of extension of jurisdiction has been that various countries have become more interested in conducting fisheries research in Canada's 320 kilometre zone. During the last two years several co-operative research projects have been conducted between the Marine Fish Division and foreign countries. Mesh selection studies on silver hake and squid have been conducted with Cuba, Japan, and the USSR with the result that new mesh regulations and gear types are being considered to

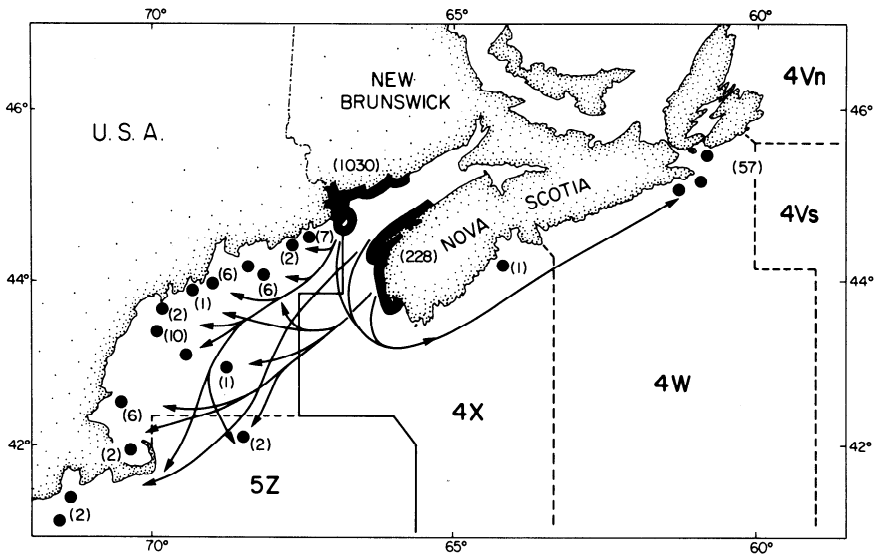
reduce the catch of juvenile fish. The USSR has also become involved in our ichthyoplankton program, which has resulted in increased temporal coverage of the Scotan Shelf. The results of these cruises will primarily pertain to geographical distribution of fish eggs and larvae at this time, but will augment the more intensive surveys being conducted by Canadian research vessels.

Population Dynamics and Stock Assessment Group

This group has the principal mandate of providing advice on fisheries management pertaining to catch and effort levels for groundfish, pelagic fish, and marine mammals. However, since reliable estimates of optimal catch levels can only be attained if the population dynamics of the species are well known, an important part of the function of this group is working on population biology.

The majority of scientific and technical personnel in this group has been assembled since extension of Canada's jurisdiction and consequently they are still developing their expertise and knowledge in the field of assessment and fisheries management.





Top: Tagged herring. Bottom: Distribution of recaptures from herring tagging experiments in ICNAF Division 4x in 1973/74. Dark areas and closed circles indicate recapture areas with numbers of recoveries in parentheses.

Even though these grey seals on Sable Island voice their objections about tagging, the usually get it in the end! (Courtesy of F. Bruemmer)

In addition to providing assessments and advice for as many as 16 individual finfish and mammal stocks in the Maritime Region, the group has provided considerable scientific documentation and logistic support for the 320 kilometre jurisdictional negotiations between Canada and the United States.

Specific biological studies on the dynamics of fish stocks include:

(7) Herring tagging. This program, which commenced in 1974, is providing critically important insights into herring stock inter-relationships and migration patterns. The results have been, and are being, used to revise management boundaries to provide closer control of the exploitation of particular biological unit stocks. For example it has been shown that the summer Bay of Fundy herring fishery is based on a complex of fish that in the winter are found both off Chedabucto Bay and as far west as Cape Cod. Recently, a new small Floy T-bar anchor tag has been developed that will allow us to tag juvenile herring (15 centimetres long) and thereby determine movements of the pre-recruit portion of the population; such a capability is especially important in determining the origin of herring supporting the New Brunswick sardine fishery.

(2) Grey and harbour seal tagging. Grey and harbour seals pup both on Sable Island and on the mainland Maritime area. To elucidate migratory patterns almost 100 per cent of the 1978 pups of grey seals (born in January-February) and harbour seals (born in May-June) on Sable Island were tagged. The subsequent 1978 bounty kill of grey seal pups in the Maritimes will allow a first estimate of the size of the 1978 grey seal cohort in addition to providing information on geographical dispersion. The harbour seal tagging program has yielded few recoveries because no bounty currently exists, but the tagging was part of a long-term project in anticipation of future requirements for dispersal information.

(3) Fecundity studies. The first stage of an extensive program is underway with egg counts for 21 species of pelagic and groundfish being completed. Subsequent stages will examine seasonal changes in egg numbers and fecundity-to-length relationships for at least this many species.

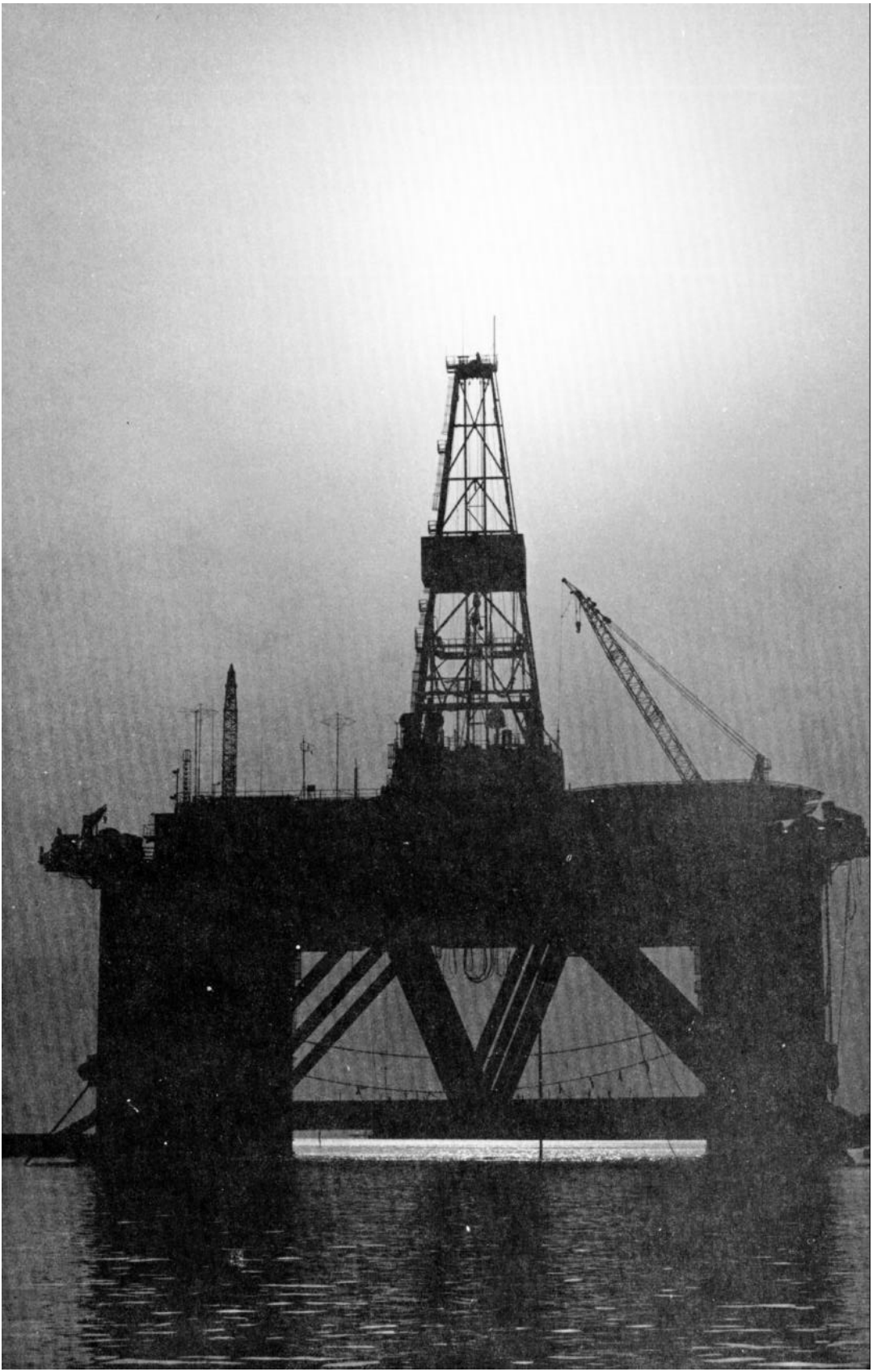
(4) Mesh selection. Mesh selection studies in co-operation with foreign countries were discussed earlier. Re-analyses of worldwide historical mesh selection studies are underway to evaluate the variability associated with fish species and net material. Preliminary results suggest that differences due to net material are not detectable given the variance associated with mesh selection studies and that theoretical calculations based on length-girth relationships may be equally reliable.

(5) Research vessel surveys. The 1970 to 1977 groundfish inventory cruise data are being analysed to determine if groundfish distribution is more closely associated with bottom type than depth. Such an association, if established, would provide the basis for restructuring our stratification scheme for the groundfish inventory program.

R. G. Halliday
Chief
Marine Fish Division

East Coast Office, Offshore Exploration
Resource Management and
Conservation Branch
Department of Energy,
Mines and Resources

Chief - T. W. Dexter



ToC

Resource Management and Conservation Branch, Operations Division, East Coast Office

The Resource Management and Conservation Branch at BIO exercises a double function related to east coast offshore oil and gas operations: it undertakes programmed engineering supervision of the operations and functions as a curator of the information generated by these operations.

Approval of a drilling program, a comprehensive contingency plan, the individual engineering conceptions for each well, and, finally, an abandonment program are the primary steps taken by the Branch to ensure that offshore operations are conducted in an efficient and safe manner as a defense against potentially hazardous incidents. Pursuant to the Oil and Gas Production and Conservation Act, RMCB requires that companies conduct their offshore activities in such a way as to ensure the economic and physical conservation of the resource, to ensure the safety of the rig and security of the well, to prevent injury and loss of life, to prevent fires, explosions, blow-outs, and collisions, to prevent pollution, and to ensure protection of the environment.

To accomplish this the Branch sets standards for such items as: the seaworthiness of drilling vessels and their marine performance in the operating areas and seasonal period; navigation and marine safety aids; weather and sea state forecasts; surveillance for ice and other hazards; suitable drilling and ancillary equipment; proper control of drilling-mud properties; good casing and cementing programs; blow-out prevention systems with adequate pressure ratings; trained and experienced crews and adequate crew facilities; effective application of new equipment and techniques; and adequate supply craft and 24-hour land-based support. Branch inspectors monitor all drilling activities, visit the rig as operations progress, and constantly check rig records.

Under the Oil and Gas Production and Conservation Act and related regulations shortly to be promulgated, adequate equipment is required to prevent pollution from fluids used on board, for collecting waste oils, and for burning, storing, or transporting them in a safe and clean way. Effective procedures must be devised for handling consumable items on the drilling rig such as drilling mud additives and fuels, and waste materials such as drill cuttings and galley wastes, and for ensuring that they are so disposed of that they do not create a hazard to the environment. Hydrocarbons produced during well tests must be stored in suitable tanks or burned as approved to minimize the possibility of accidental pollution of the marine environment. The contingency plan provided by the operators and their oil spill countermeasures must be compatible with the national plan and acceptable to the Departments of Transport (Canadian Coast Guard) and Fisheries and the Environment.

To enhance the safety of operations and to determine the effect these operations may have upon the environment, the Branch requires operators to undertake physical and biological studies in areas where active offshore exploration is taking place. Notably, operators must measure, record, and report oceanographic and meteorological data on site prior to and during the course of drilling operations. Joint bodies such as the East Coast Petroleum Operators Association have undertaken a series of environmental studies off the east coast relating to marine mammals, sea birds, fish, weather, and sea conditions. The Branch is the federal government curator of these studies.

Information generated from offshore oil and gas operations, which the Branch requires for curation in the National Archives, is sent to the core laboratory at BIO or to ISPG (Calgary, Alberta) for analysis, retention, and if necessary redistribution.

RMCB receives a 500 gram unwashed sample, which is catalogued and its depth in the well recorded. The samples and containers are dried for storage. A composite 9.1 metre sample is made up and a preliminary wash carried out through a nest of screens. The sample retained on the coarse screen is used for petrographic thin sections and samples from the finer screens are used exclusively for micropaleontological and palynological microscope slide preparations. The remainder of each of these samples is stored for future reference or use as required. Also received is a full set of washed well samples in 7 dram vials and a set of unwashed bag samples with depth in the well corresponding to the vial samples for use as reference lithology only.

In addition, sidewall core samples are received, catalogued, and stored for specific reference such as lithology and biostratigraphy. These are used when increased accuracy is needed. The conventional core received is slabbed three ways and RMCB receives the Centre portion and catalogues and stores it. Canned cuttings from 9.1 metre intervals are initially shipped from the rig to RMCB, recorded, and forwarded to ISPG for geochemical analysis. Excess material is returned to RMCB for curation. Micropaleontological and palynological slides are prepared from the unwashed drill samples. Curation of sidewall cores and cores on a two-year confidential basis is a requirement of the Oil and Gas Production and Conservation Act.

Well History Reports are received on completion of the well and after the customary two-year confidential period are available to the public through our off ices. Similarly, geophysical activity reports are available on open file after a 12-year confidential period. This period is considered too long and legislation has now been proposed to reduce it to five years. This legislation, Bill C-20, the new Canada Oil and Gas Act, had first reading in the House of Commons in 1977. Bill C-20 describes the new minerals rights regime for the Yukon and Northwest Territories and the Canadian offshore. It contains numerous clauses relating to research, feasibility and environmental studies, and the confidential nature of information and reports submitted by industry in connection with their oil and gas permit work obligations.

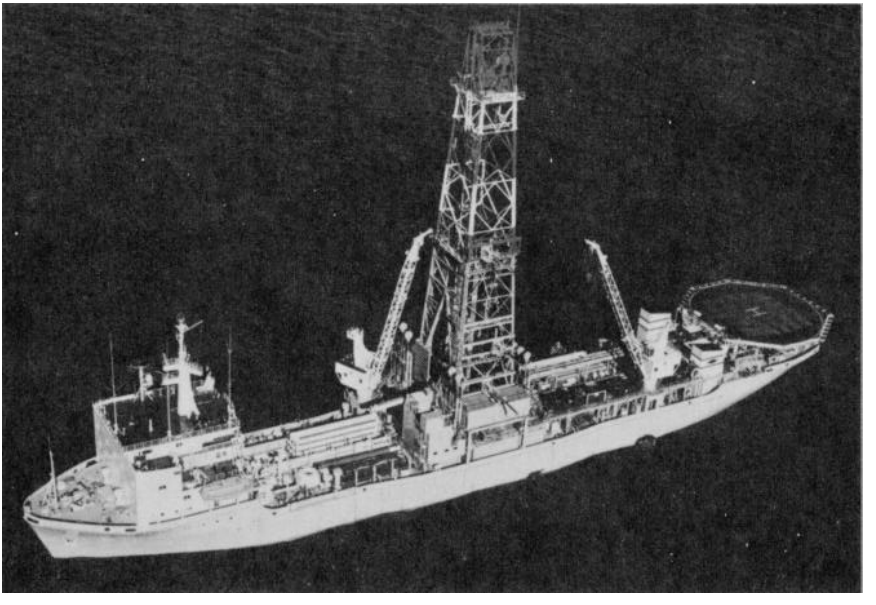
With respect to federal versus provincial jurisdiction over offshore mineral resources, all areas off Canada's seacoasts with the exception of certain harbours, bays, estuaries, and other similar inland waters are considered

by the federal government to fall under its jurisdiction. This premise has been challenged by several coastal provinces, but was tested in the Supreme Court of Canada off the west coast. In an Opinion handed down November 7, 1967, the Court found unanimously in favour of the federal government with respect to ownership of mineral resources seaward from the "ordinary low-water mark".

As regards resources off the east coast, a Memorandum of Understanding was signed February 1, 1977 by the Premiers of Nova Scotia, New Brunswick, and Prince Edward Island and the Prime Minister, paving the way for an agreement whereby administration of offshore minerals will be a joint federal-provincial function, and revenues from mineral resource activities will be shared between the federal government and adjacent provinces. No such understanding has been reached with Quebec or Newfoundland. With respect to Newfoundland, a joint Federal-Provincial Reference to the Supreme Court is presently in preparation, to determine the ownership of mineral resources in the offshore of that province.

During 1977 and 1978 eight wells were drilled to completion off the Canadian east coast; one was drilled to a sufficient depth to set surface casing and another has recently been commenced near Sable Island. The depth drilled was about 34,500 metres total for the two-year period. In the same area, 17 offshore geophysical survey programs were completed by industry, mostly in the Labrador Sea but also in the northern Grand Banks, Grand Banks, and Scotian Shelf areas.

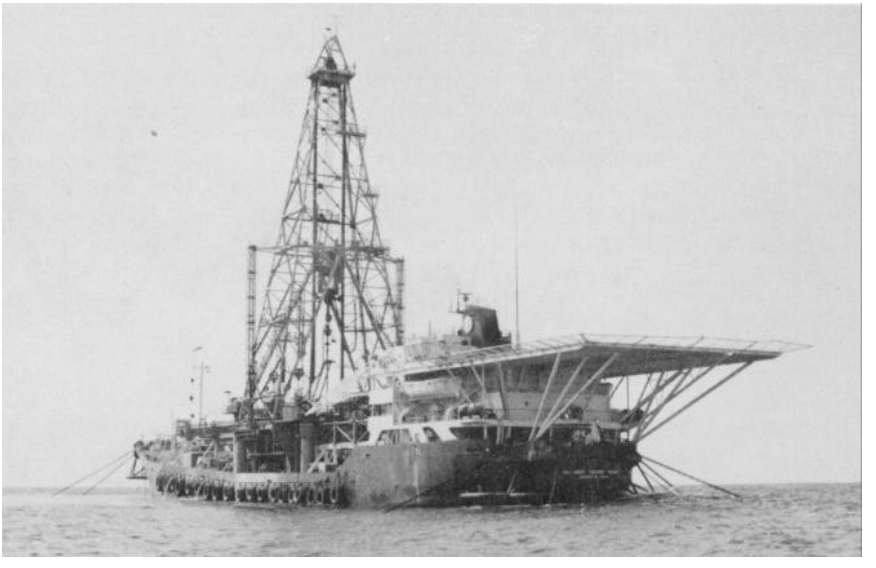
Over 50 environmental research programs were commercially sponsored in 1977 and an equivalent number were sponsored in 1978 covering a broad



The French drill ship Pelerin.

field embracing seabird distribution, current profiling, ice field surveys, iceberg severity, bottom profiling, and wind, wave, and current data gathering. Most programs were run in the Labrador Sea with a lesser number run on the Grand Banks and Scotian Shelf.

Between October 2 and November 17, 1977, six shallow wells were drilled offshore by the Nova Scotia Department of Mines, and from May 29 to October 23, 1978, nine more holes, all designed to delineate the extent of offshore coal seams east and west of the Cape Breton coast, were drilled. Funding in both years, was 80 per cent federal and 20 per cent provincial. Drilling has been carried out by two ship-shaped vessels, the *Glomar Conception* in 1977 and the *Glomar Grand Banks* in 1978, and due to the

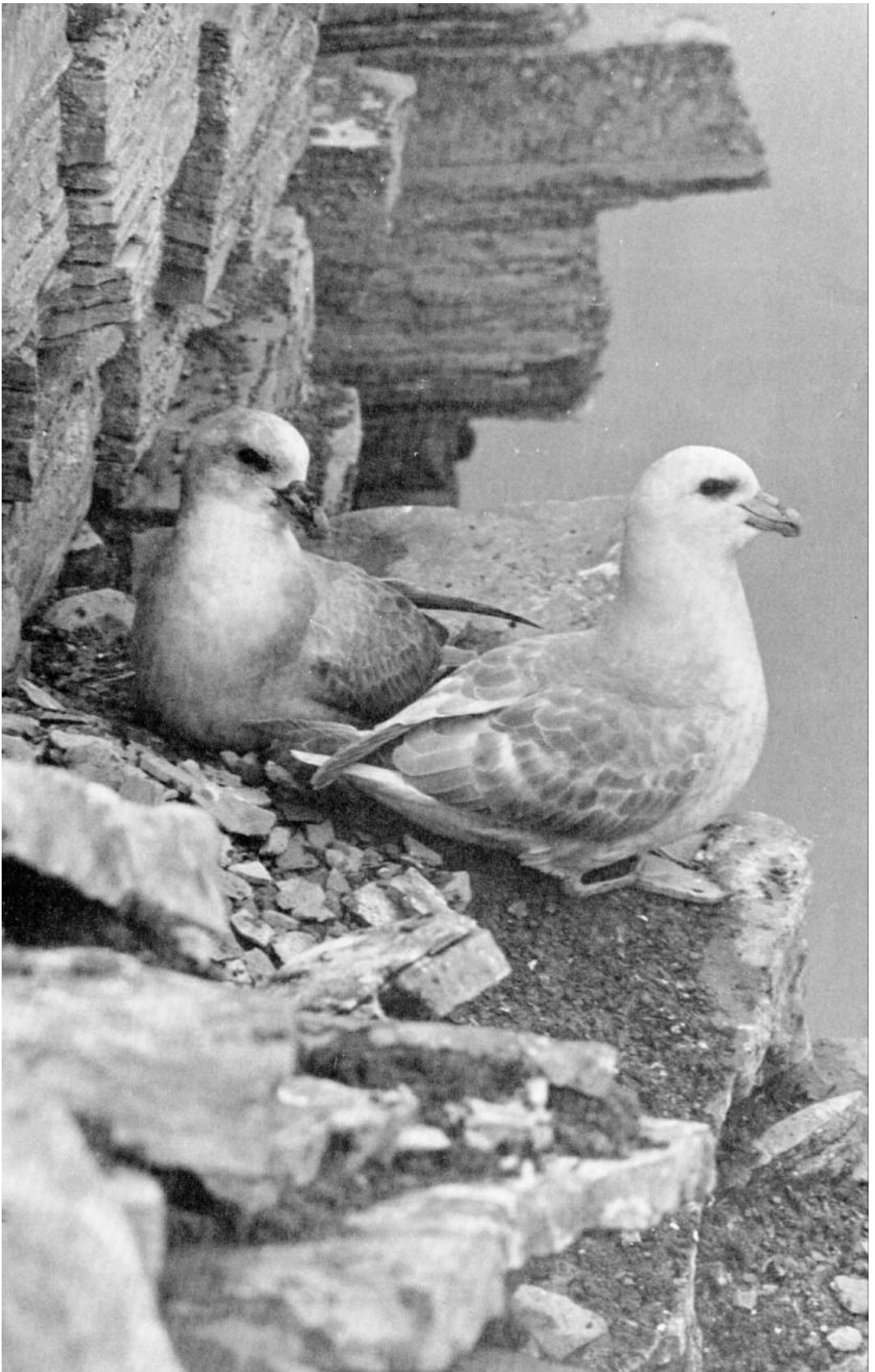


The Glomar Grand Banks, *which was used in the 1977 and 1978 drilling program to define the aerial extent of coal seams off cape Breton. (Courtesy of the NS Department of Mines)*

need for seafloor control and the shallowness of the water in certain locations considerable ingenuity was required to complete the program without mishap.

Coring techniques for coal in offshore areas have been developed only recently; they differ considerably from oil well coring techniques and have been carried out previously only in the North Sea off the Yorkshire coast and off the coast of Chile. The techniques developed for offshore Cape Breton will add considerably to the meagre fund of expertise currently available for submarine area coal coring operations.

Seabird Research Unit
Canadian Wildlife Service
Environmental Management Service
Department of Fisheries
and the Environment



ToC

Canadian Wildlife Service Seabird Research Unit[1]

The vast numbers of seabirds assembling in and utilizing the coastal and offshore waters of Canada have become increasingly endangered due to the acceleration of certain activities by man. Pollution of the seas by oil, the largest single threat to seabirds at present, is widespread and continues at an alarming rate. Most of this marine pollution in the past has come from deliberate dumping by oil tankers at sea or from accidents at oil drilling sites and during the transportation of oil at sea. The present threat, however, is even more ominous as the exploration and exploitation of offshore oil rapidly increase in the eastern Canadian arctic and the Atlantic Provinces where information, skills, technology, and conditions for safe underwater drilling are limited.

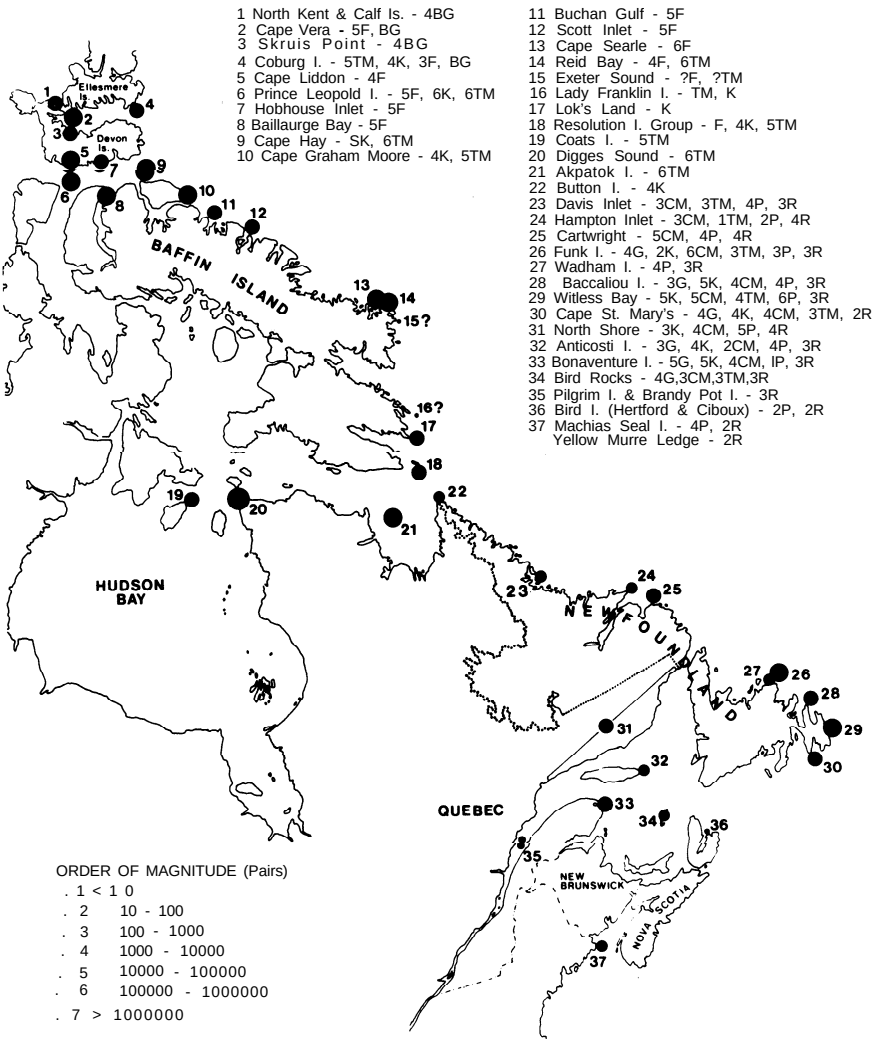
The growing hazard to marine birds and other marine life led the Canadian Wildlife Service in 1969 to organize and initiate a comprehensive investigation of the breeding and pelagic or oceanic distributions of seabirds in eastern Canada. The immediate aims were:

Common Murres (foreground) and Northern Gannets on Funk Island, Newfoundland. The Island have declined in recent years (see text). (Courtesy of D. N. Nettleship)

[1]The following paper is associated with the program "Studies on northern seabirds", Canadian Wildlife Service, Department of Fisheries and the Environment (Canada), Report No. 67.

(1) to catalogue breeding sites (location, species composition, population size) in the eastern Canadian arctic and in the Atlantic Ocean north of 40°N and west of 40°W; and
(2) to collect quantitative observations of the distributions of seabirds at sea in the same area to show their water habitat usage and other environmental requirements through the annual cycle.

The overall objective was to develop a data base that would allow resource managers to make informed estimates and predictions of the impact of



The major seabird colonies in eastern Canada are shown. Total colony size and individual main species population size are given as number of breeding pairs within orders of magnitude, Symbols: F, Northern Fulmar; G, Northern Gannet; K, Black-/egged Kittiwake; R, Razoibill; CM, Common Murre; TM, Thick-billed Murre; BG, Black Guillemot; and P, Atlantic Puffin.

industrial expansion and resource development activities on populations of seabirds in eastern Canada - in particular, in assessing the likely impacts of oil pollution and comparable environmental hazards. Seabird research at BIO began in 1971, and the Seabird Research Unit was established in 1976. The results of our studies to date are summarized in Brown et al. (1975)* and Nettleship (1977a) (See Section F, Major Publications of 1977/78, CWS Seabird Research Unit Publications).

Studies associated with the seabird program in marine regions of eastern Canada in 1977 and 1978 included:

(1) the completion of a 4-year study (197578) of community structure and resource allocation of populations of seabirds breeding at Prince Leopold Island, Lancaster Sound;
(2) oceanographic surveys (by ship and aircraft) of the distributions of birds at sea in areas of Lancaster Sound, Baffin Bay, Davis Strait, Labrador Sea, and the western North Atlantic;
(3) analyses of populations of Northern Fulmar *Fulmarus glacialis,* Black-legged Kittiwake *Rissa tridactyla,* and Thick-billed Murre *Uris lomvia* in Lancaster Sound and Jones Sound; and
(4) preliminary surveys of colonial nesting seabirds along the coast of Labrador from the Strait of Belle Isle to Cape Chidley.

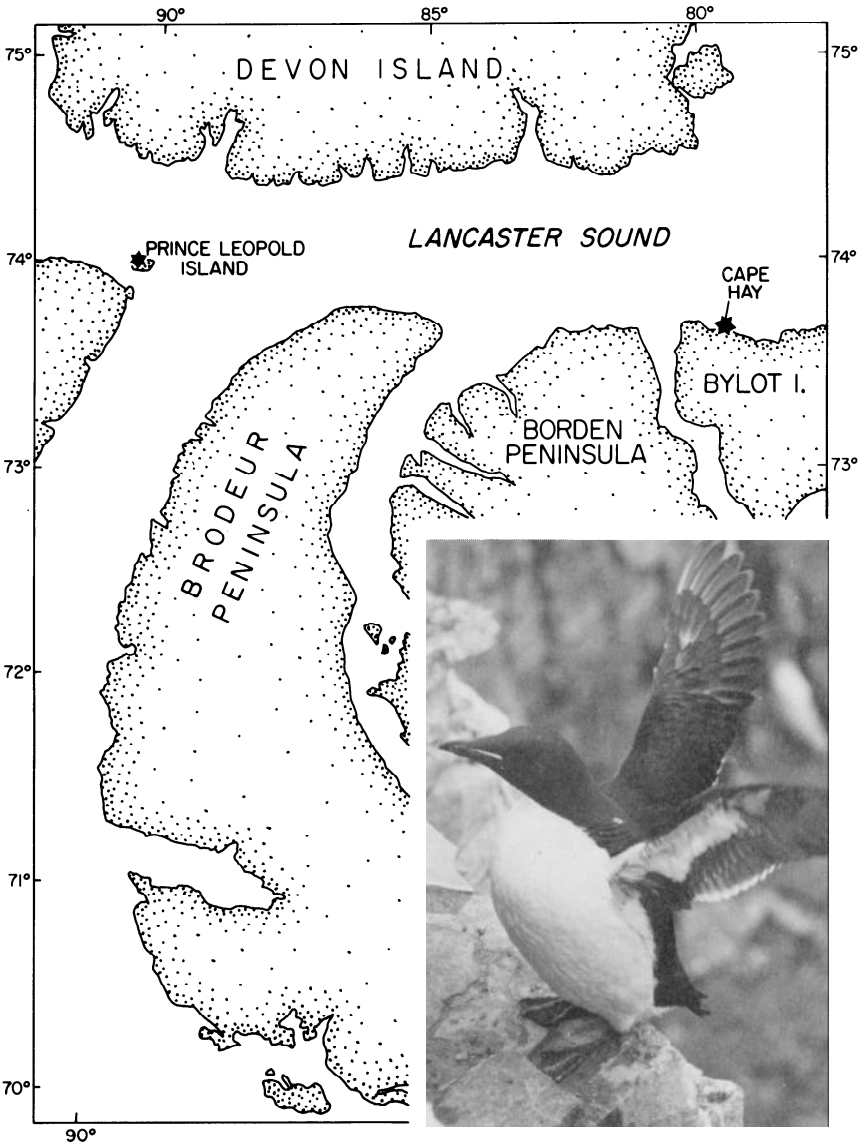
The Seabird Research Unit's program separates clearly into two parts: the reproductive and pelagic ecology of seabirds. Mr. F. Brazeau, Mr. R. Elliott, Mr. E. Greene, Mr. M. Malone, and Mr. S. Tingley assisted in the work of the Seabird Research Unit in 1977 and 1978. A summary of the highlights of work done during 1977 and 1978 follows.

Studies of Breeding Birds

The major project of 1977-78 was the continuation and completion of the investigation of the abundance, habitat usage, timing of breeding, breeding performance, and feeding ecology of populations of five species of seabirds (Northern Fulmar, Glaucous Gull *Larus hyperboreus,* Black-legged Kittiwake, Thick-billed Murre, and Black Guillemot *Cepphus grylle)* on the cliffs at Prince Leopold Island (see Nettleship, 1977b), supplemented by the examination of features of breeding of kittiwakes and murres at Cape Hay, Bylot Island, and at Coburg Island. Preliminary results from the analysis of certain population variables associated with reproduction show, among other things, that arctic cod *Boreogadus saida* are as central to the feeding ecology of high arctic seabirds as capelin *Mallotus villosus* are to those off Newfoundland, and anchovetas are for the seabirds of Peru. The work in the summer of 1978 was particularly important, because it documented the birds' responses to severe climatic conditions in a year when the ice in Lancaster Sound failed to break up. The long-term aim of this work is to provide a baseline and simulation model from which estimates and predictions of population density flux, biomass changes, and bioenergetic demands of resident breeding species populations, especially with reference to the breeding season, can be made. Together, these data will assist in the formulation of management policy and the identification of processes by which these endangered populations can be protected and maintained. The immediate need is for this work to show the possible effects of a pipeline crossing in Barrow Strait, and deep-water oil drilling at the eastern entrance to Lancaster Sound and northwestern Baffin Bay.

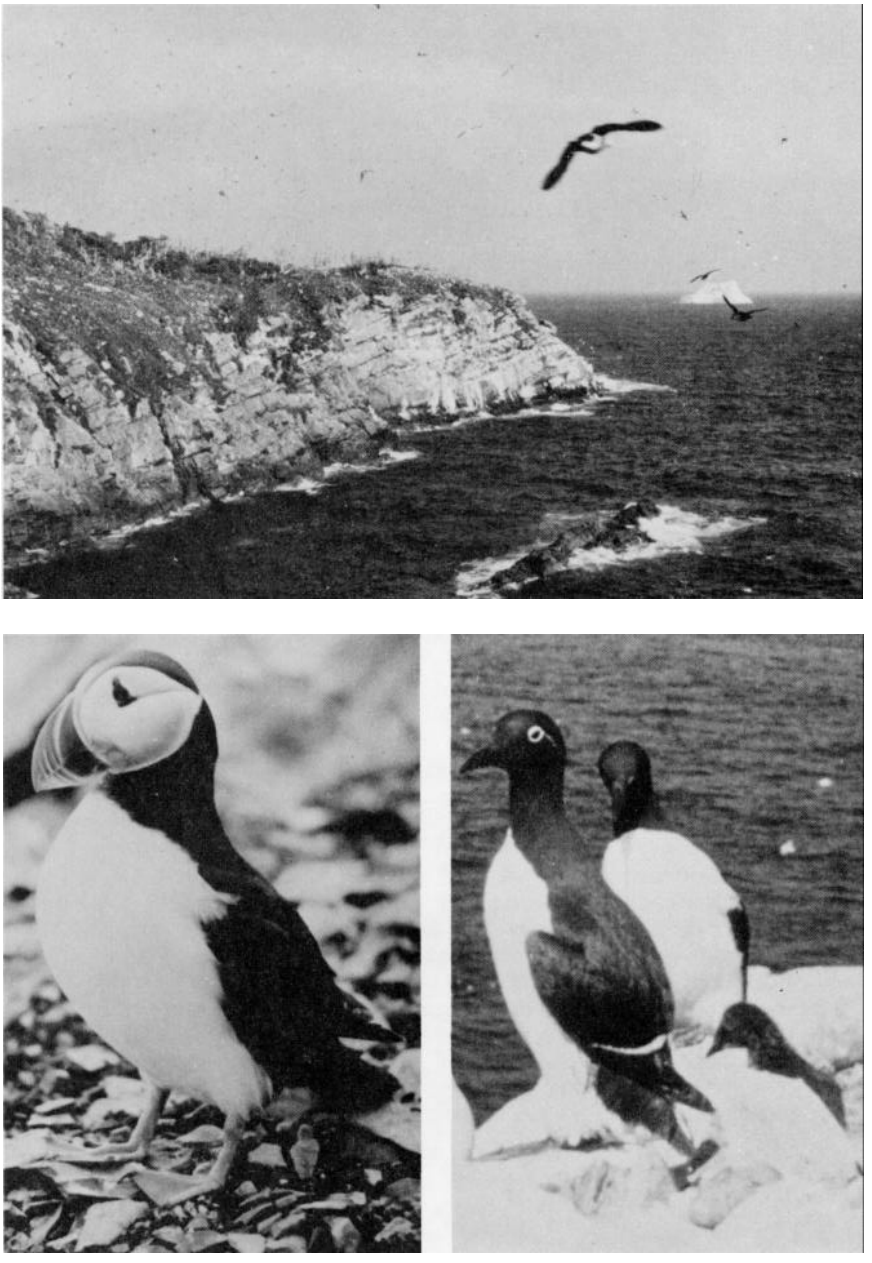
*Brown, R. G. B. et al. 1975. Atlas of eastern Canadian Seabirds. Can. Wildlife Serv., Ottawa: 220 pp.

A re-examination of the Thick-billed Murre colony at Cape Hay, Bylot Island, in 1978 supports the results from earlier studies that a decrease in population in the order of 20 to 40 per cent has taken place between 1957 and 1976. Excessive mortality of birds drowned in salmon drift-nets and killed by hunters since 1957 while in West Greenland away from their colony may account for this decline. Some evidence exists to indicate that such a decline is not confined to the Cape Hay colony, but may also



The populations of Thick-billed Murres at Cape Hay (Bylot Island) and Prince Leopold Island have declined in recent years (see text). (Courtesy of D.N. Nettleship)

have occurred at other colonies in Lancaster Sound and Hudson Strait. This investigation will continue in 1979.



Great Island, Newfoundland, is the most important breeding site (top) for the Atlantic Puffin (bottom left) in North America. Common Murres (bottom right) also nest there. (Courtesy of D. N. Nettleship)

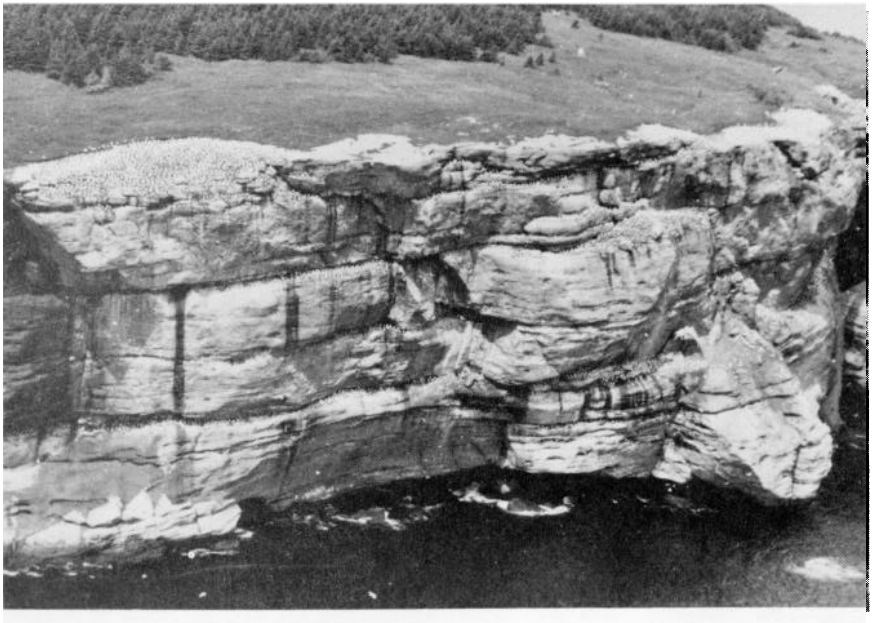
Further south, the Unit flew an aerial survey of the east coast of Labrador in 1978, locating 12 new seabird colonies in the process. Observers were put ashore at several Labrador colonies, both to estimate the sizes of the breeding populations and to establish permanent study plots for measuring changes in population levels in the future. Studies were also made in 1978 of the infra-colony structure of Herring Gulls *Larus argentatus* and of the attendance patterns of Atlantic Puffins *Fratercula arctica* at breeding colonies on Great Island, Witless Bay, Newfoundland.

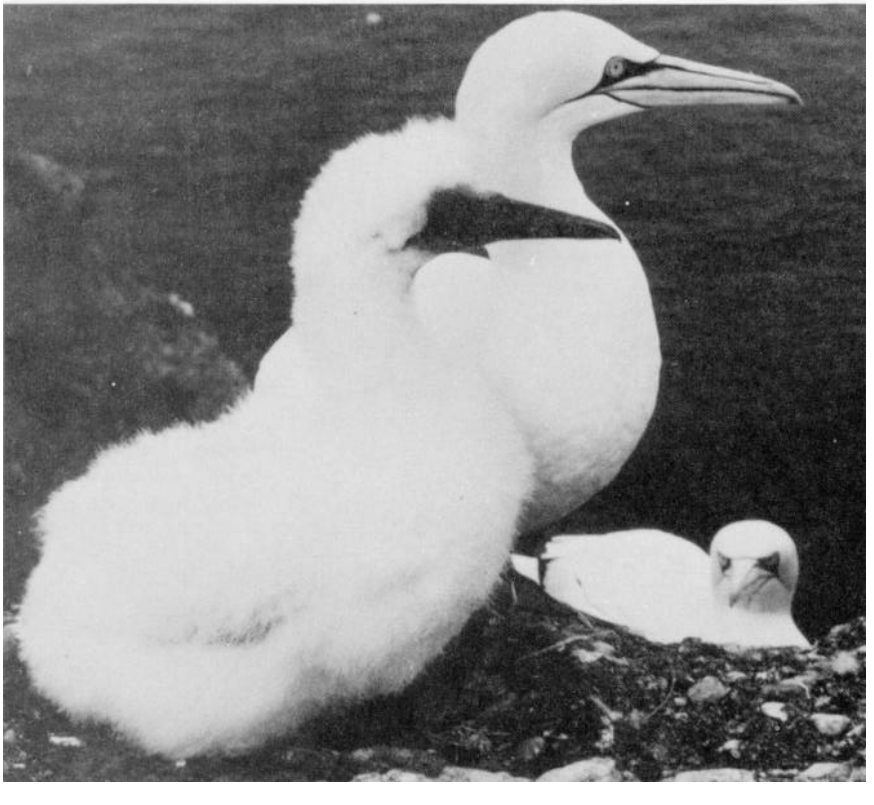
Studies of Birds at Sea

In order to expand our coverage of seabird distributions, the Unit placed observers on several BIO cruises in 1977 and 1978 - for example, on the two cruises by CSS Hudson into northern Baffin Bay. Because of the economic importance of seabirds in Peru the Unit also took part in the CSS *Baffin* cruise down there in late 1977; the seabird program was in fact the only one carried out for the full length of this cruise. A great deal of information was collected on the pelagic ecology of the Peruvian guano seabirds, and comparisons and contrasts could be made between the birds of this upwelling and those in the much weaker system off Senegal, surveyed during CSS Baffin's cruise there in early 1976. The Unit also placed observers on board fisheries cruises working out of St. John's, Newfoundland. The emphasis here was on the relationships between seabirds and capelin, an important and now heavily-fished prey.

Since 1974, the Unit has been investigating the relationships between seabirds and various oceanographic parameters off Brier Island, Nova Scotia, at the entrance to the Bay of Fundy. Large numbers of migrant Greater Shearwaters *Puffinus gravis* and Red Phalaropes *Phalaropus fulicarius* occur there in late August and early September, in what is clearly an area of high local food abundance. The basic mechanism for this could be described as a "tidal pump". Strong tidal streams run up against steep underwater ledges, which reach up almost to the surface. There is considerable vertical turbulence, and cool bottom water is brought to the surface, drifts downstream, and eventually sinks in a series of convergence fronts. Copepods are brought up to the surface at the same time, and are concentrated over the ledges and in the fronts, where they are preyed on by the phalaropes. Large swarms of the euphausiid *Meganyctiphanes norvegica* also come to the surface in daylight, apparently to feed on the copepods; they in turn are preyed on by the shearwaters, by large gulls, and by baleen whales, mackerel *Scomber scombrus,* herring *Clupea harengus,* and squid ///ex *illecebrosus.* In 1977 and 1978 the Unit investigated another "tidal pump", in Head Harbour Passage, New Brunswick, on the opposite side of the Bay of Fundy. This too brings copepods and euphausiids to the surface but, for reasons not yet fully understood, they are preyed on by Northern Phalaropes *Lobipes lobatus* instead of Reds, and by Bonaparte's Gulls *Larus philadelphia* instead of shearwaters.

Above (facing page) is an aerial view of a portion of the Northern Gannet colony on Bonaventure Island, Quebec, which shows the principal nesting habitats; below is a nestling (foreground) and one of its parents. (Courtesy of D.N. Nettleship)





Future Studies

While the Seabird Research Unit's work on the pelagic and breeding ecology of seabirds will continue in regions of the eastern Canadian arctic and West Greenland, the main thrust in 1979 and 1980 will be the initiation of an integrated breeding colony and pelagic program centring around the southern Labrador Shelf. The major component of the scientific program will be the comparative ecology of the five breeding species of auks. This work on Labrador seabirds will form the Canadian Wildlife Service's contribution to the Offshore Labrador Biological Survey (OLABS). And finally, a project will be undertaken to examine a number of population parameters (productivity, adult survival, survival to breeding age) in an effort to construct life tables for the Razorbill *AIca torda,* Thick-billed Murre, Common Murre *Uria aalge,* Black Guillemot, and Atlantic Puffin in eastern Canada.

R. G. B. Brown and D. N. Nettleship

ToC

F

Appendices

- **Research, Survey, and/or Senior Support Staff**
- **Major Publications of 1977/78**
- **Major Cruises of 1977/78**
- **Dr. W. L. Ford Retires**
- **BIO Building Expansion**

Research, Survey, and/or Senior Support Staff

A. Ocean and Aquatic Sciences, Atlantic

W. L. Ford[2] - Director-General

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H. B. Nicholls - Program Analyst and Project Co-ordinator

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S. M. Eddy[2] L. Hume E. Pottie[1]

Material Management Services: A. R. Mason, Head

B. V. Anderson B. G. Martin

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G. H. Seibert
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V. J. Gaudet
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H. P. Varma
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J.-G. Dessureault
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D. M. Ware

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D. I. Ross[2]
M. Snoek[1,2]
S. P. Srivastava
W. J. M. van der Linden[2]
J. M. Woodside

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R. G. Halliday - Division Chief

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L. Belzile	D. Gray	M. Sinclair
D. Clay	J. Hurley[2]	D. Waldron

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D. Geddes

Fisheries Systems: P. F. Lett, Head

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T. W. Dexter - Manager, East Coast Offshore Exploration

D. C. Hunt	G. D. Karg

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R. G. B. Brown	A. J. Gaston	D. N. Nettleship
D. S. Currie	A. Linton	

[1]Joined BIO during **1977** or **1978.**
[2]Left BIO during 1977 or **1978.**
[3]Postdoctoral fellow.
[4]Marine Fish Division moved to the Institute during the period under review.
[5]Research associate.

Major Publications of 1977/78

Bedford Institute of Oceanography Contributions

Contributions by staff of the Atlantic Oceanographic Laboratory, Marine Ecology Laboratory, and Atlantic Geoscience Centre during 1977 and 1978 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, and a few 1976 articles not available when the previous Biennial Review was published are included. Periodical abbreviations follow the Chemical *Abstracts Service Source Index: 1907- 1974 Cumulative.*

ADDISON, R. F. 1976. Organochlorine compounds in aquatic organisms: their distribution, transport and physiological significance. In Effects of Pollutants on Aquatic Organisms, *ed.* A. P. M. Lockwood. *Society for Experimental Biology Seminar Series 2:* 127-143. (658)

ADDISON, R. F. 1977. Diphenyl ether - Another marine environmental contaminant. *Mar. Poll. Bull. 8 (10): 237-240.* *(773)*

ADDISON, R. F. and BRODIE, P. F. 1977. Organochlorine residues in maternal blubber, milk, and pub blubber from grey seals *(Halichoerus grypus)* from Sable Island, Nova Scotia. *J. Fish. Res. Board Can. 34 (7):* 937-941. (654)

ADDISON, R. F. and WILLIS, D. E. 1978. The metabolism by rainbow trout *(Salmo gairdnerii)* of ^{14}C-p,p'-DDT and some of its possible degradation products labelled with ^{14}*C. Toxicol. Appl. Pharmacol. 43:* 303-315. (711)

ADDISON, R. F. and ZINCK, M. E. 1977. Rate of conversion of ^{14}C-p,p'-DDT to p,p'-DDE by brook trout *(Salvelinus fontinalis):* Absence of effect of pretreatment of fish with compounds related to p,p'-DDT. *J. Fish. Res. Board Can. 34 (1):* 119-122. (632)

ADDISON, R. F., ZINCK, M.E., ACKMAN, R. G., and SIPOS, J. C. 1978. Behavior of DDT, polychlorinated biphenyls (PCBs) and dieldrin at various stages of refining of marine oils for edible use. *J. Am. Oil Chem. Soc. 55 (4): 391-394.* (705)

ADDISON, R. F., ZINCK, M. E., and WILLIS, D. E. 1977. Mixed function oxidase enzymes in trout *(Salvelinus fontinalis)* liver: absence of induction following feeding of *p,p'-DDT* or p,p'-DDE. *Comp. Biochem. Physiol. 57C: 39-43.* (748)

ADDISON, R. F., ZINCK, M. E., and WILLIS, D. E. 1978. Induction of hepatic mixed-function oxidase (MFO) enzymes in trout *(Salvelinus fontinalis)* by feeding AroclorR' 1254 or 3-methylcholanthrene. *Comp. Biochem. Physiol. 61 C: 323-325.* (748)

AMOS, C. L. 1978. The postglacial evolution of the Minas Basin, Nova Scotia; a sedimentological interpretation. *J. Sediment. Petrol. 48 (3); 965-982.* (717)

AMOS, C. L. and COLLINS, M. B. 1978. The combined effects of wave motion and tidal currents on the morphology of intertidal ripple marks: The Wash, U.K. *J. Sediment. Petrol.* 48 (3): 849-856. (749)

BARRETT, D. L. and PURDY, G. M. 1978. IPOD survey area AT-6: Seismic refraction results. *In* Initial Reports of the Deep Sea Drilling Project, *ed.* W. G. Melson, P. D. Rabinowitz *et a/.* U.S. Government Printing Office, Washington, 45: 49-53. (827)

BEAMISH, P. 1978. Evidence that a captive humpback whale *(Megaptera novaeanglaie)* does not use sonar. *Deep-Sea Res. 25 (5): 469-472.* (774)

BENJAMINSEN, T., BERGFLODT, B., ØRITSLAND, T., BJØIRGE, A., BRONNDAL, N., PAASCHE, A., SIVERTSEN, K., BRODIE, P., and TOKLUM, K. 1978. Harbour seal and grey seal investigations on the Norwegian coast from Nordmore to Sørhelgeland in 1977. *Saertykk av "Rapporter" 1:* 9-12. (750)

BENJAMINSEN, T., BERGFLODT, B., HUSE, I., BRODIE, P., and TOKLUM, K. 1977. Grey seal investigations on the Norwegian coast from Lofoten to Froya; September-November 1976. *Saertrykk av Fiskerinae ringens Forsoksfond "Rapporter" 1: 24-33. (685)*

BEWERS, J. M. and YEATS, P. A. 1977. Oceanic residence times of trace metals. *Nature* 268 (5621): 595-598. (652)

BEWERS, J. M. and YEATS, P. A. 1978. Trace metals in the waters of a partially mixed estuary. *Estuarine Coastal Mar. Sci. 7 (2):* 147-162. (692)

BLACKFORD, B. L. 1978. Wind-driven inertial currents in the Magdalen Shallows, Gulf of St. Lawrence. *J. Phys. Oceanogr. 8 (4): 653-664.* (721)

BLACKFORD, B. L. 1978. On the generation of internal waves by tidal flow over a sill - a possible nonlinear mechanism. *J. Mar. Res. 36 (3):* 529-549. (722)

BRODIE, P. F. 1977. Form, function and energetics of Cetacea: A discussion. *In* Functional Anatomy of Marine Mammals, *ed.* R. J. Harrison. Academic Press (London, New York, San Francisco) 3: 45-58. (829)

BRODIE, P. 1978. Alternative sampling device for aquatic organisms. *J. Fish. Res. Board Can. 35 (6):* 901-902. (713)

BROOKE, J. and ELLIOTT, J. A. 1978. The Canadian Ocean Data Buoy System. *In* Oceanology International 78, *ed.* B. McCartney. The Institution of Electrical Engineers, UK: 57-63. (834)

BUJAK, J. P., BARSS, M. S., and WILLIAMS, G. L. 1977. Offshore Eastern Canada. Parts 1 and 2 - Offshore eastern Canada's organic type and color and hydrocarbon potential. *Oil Gas J.:* 198-201 (April 4) and 96-100 (April 11). (795)

BUJAK, J. P. and WILLIAMS, G. L. 1977. Jurassic palynostratigraphy of offshore eastern Canada. *In Stratigraphic* Micropaleontology of Atlantic Basin and Borderlands, *ed.* F. M. Swain Elsevier Scientif. Publ. Co., Amsterdam: 321-339. (796)

BUTLER, J. N. and LEVY, E. M. 1978. Long-term fate of petroleum hydrocarbons after spills - compositional changes and microbial degradation. *J. Fish. Res. Board Can. 35 (5);* 604-605. (703)

CLARKE, R. A. 1976. Measurements of a small near-bottom cyclonic circulation near the Gulf Stream axis. *J. Fish. Res. Board Can. 33 (70); 2197-2202.* *(680)*

CONOVER, R. J. 1978. Feeding interactions in the pelagic zone. *Rapp. P.-V. Reun., Cons. Int. Explor. Mer. 173: 66-76.* (775)

CONOVER, R. J. 1978. Transformation of organic matter. In Marine Ecology - A Comprehensive, Integrated Treatise on Life in the Oceans and Coastal Waters. Volume IV. Dynamics. John Wiley and Sons, Chapter 5: 221-499. (719)

CONOVER, R. J. and PARANJAPE, M. A. 1977. Comments on the use of a deep tank in planktological research. *Helgol. Wiss. Meeresunters. 30;* 105-117. (684)

CRANSTON, R. E. and MURRAY, J. W. 1978. The determination of chromium species in natural waters. *Anal. Chim. Acta 99: 275-282.* *(776)*

DARROW, D. C., ADDISON, R. F., and BAYNE, B. L. 1978. Induction of hypoxemia in brook trout *(Salvelinus fontinalis)* following their exposure to n-decanohydroxamic acid, a component of an experimental iron ore flotation agent. *Comp. Biochem. Physiol. 60C:* 83-87. (732)

DARROW, D. C., ADDISON, R. F., and LAW, F. C. P. 1978. Disposition of diphenyl ether following intravenous administration to thorny skate *(Raja radiata). Comp. Biochem. Physiol. 61C:* 317-321. (742)

DEAN, W. E., GARDNER, J. V., JANSA, L. F., CEPEK, P., and SEIBOLD, E. 1977. Cyclic sedimentation along the continental margin of northwest Africa. In Initial Reports of the Deep Sea Drilling Project, ed. Y. Lancelot, E. Seibold, et al. US Government Printing Office, Washington, 41: 965-990. (817)

DENMAN, K. L. 1977. Short term variability in vertical chlorophyll structure. Limnol. *Oceanogr. 22 (3):* 434-441. (676)

DENMAN, K. L. and HERMAN, A. W. 1978. Space-time structure of a continental shelf ecological system measured by a towed porpoise vehicle. J. *Mar. Res. 36 (4):* 693-714. (777)

DENMAN, K., OKUBO, A., and PLATT, T. 1977. The chlorophyll fluctuation spectrum in the sea. *Limnol. Oceanogr. 22 (6):* 1033-1038. (746)

DENMAN, K. L. and PLATT, T. 1977. Biological prediction in the sea. *In* Modelling and Prediction of the Upper Layers of the Ocean, ed. E. Kraus. Pergamon Press, Oxford, UK and New York, NY, chapter 14: 251-260. (657)

DOBSON, F. W. and ELLIOTT, J. A. 1978. Wave-pressure correlation measurements over growing sea waves with a wave follower and fixed-height pressure sensors. *In* Turbulent Fluxes through the Sea Surface, Wave Dynamics, and Prediction, ed. A. Farre and K. Hasselmann. Plenum Press, New York and London: 421-432. (797)

ELLIOTT, J. A. and OAKEY, N. S. 1976. Spectrum of small-scale oceanic temperature gradients. *J. Fish. Res. Board Can. 33 (10): 2296-2306.* *(639)*

EVITT, W. R., LENTIN, J. K., MILLIOUD, M. E., STOVER, L. E., and WILLIAMS, G. L. 1977. Dinoflagellate cyst terminology. *Geol. Surv. Can., Pap. 76-34;* 1-11. (636)

FADER, G. B., KING, L. H., and MacLEAN, B. 1977. Surficial geology of the eastern Gulf of Maine and Bay of Fundy. *Geol. Surv. Can., Pap. 76-17lMarine Science Pap. 19: 22* pp. + map. (661)

FILLON, R. H., FERGUSON, C., and THOMAS, F. 1978. Cenozoic provenance and sediment cycling: Hamilton Bank, Labrador Shelf. *J. Sediment. Petrol. 48 (1): 253-268.* *(648)*

FILLON, R. H., FOLINSBEE, R. A., and PALMER, R. 1978. Deep shelf and slope terraces off northern Labrador. *Nature 273 (5665): 743-746.* (704)

GARDNER, J. V., DEAN, W. E., and JANSA, L. 1977. Sediments recovered from the northwest African continental margin. Leg 41, Deep Sea Drilling Project. *In* Initial Reports of the Deep Sea Drilling Project, ed. Y. Lancelot, E. Seibold, et *al.* US Government Printing Office, Washington, 41: 1121-1134. (818)

GARRETT, C. J. R., KEELEY, J. R., and GREENBERG, D. A. 1978. Tidal mixing versus thermal stratification in the Bay of Fundy and Gulf of Maine. *Mar. Poll. Bull. 9; 403-423.* *(726)*

GILFILLAN, E. S. and VANDERMEULEN, J. H. 1978. Alterations in growth and physiology in soft-shell clams, *Mya arenaria,* chronically oiled with Bunker C from Chedabucto Bay, Nova Scotia, 1970-1976. *J. Fish. Res. Board Can. 35 (5): 630-636.* *(778)*

GORDON, D. C., JR. 1977. Variability of particulate organic carbon and nitrogen along the Halifax-Bermuda Section. *Deep-Sea Res. 24; 257-270.* *(655)*

GORDON, D. C., JR., DALE, J., and KEIZER, P. D. 1978. Importance of sediment working by the deposit-feeding polychaete *Arenicola marina* on the weathering rate of sediment bound oil. *J. Fish. Res. Board Can. 35(5):* 591-603. (708)

GORDON, D. C., JR., KEIZER, P. D., and DALE, J. 1978. Temporal variations and probable origins of hydrocarbons in the water column of Bedford Basin, Nova Scotia. *Estuarine Coastal Mar. Sci. 7(3): 243-256.* (826)

GRADSTEIN, F. M. 1978. Jurassic Grand Banks foraminifera. *J. Foraminiferal Res. 8 (2):* 97-109. (779)

GRADSTEIN, F. M. 1978. Biostratigraphy of Lower Cretaceous Blake Nose and Blake-Bahama Basin foraminifers, DSDP Leg 44, western North Atlantic Ocean. *In* Initial Reports of the Deep Sea Drilling Project, ed. W. E. Benson, R. E. Sheridan, *et a/.* US Government Printing Office, Washington, 44: 663-702. (798)

GRADSTEIN, F. M. 1978. 1. Foraminifera from DSDP Site 370, Leg 41, eastern North Atlantic Ocean. *In* Initial Reports of the Deep Sea Drilling Project, Supplement to Volumes 38, 39, 40, and 41. US Government Printing Office, Washington, Part IV: 779-782. (830)

GRADSTEIN, F. M., BUKRY, D., HABIB, D., RENZ, O., ROTH, P. H., SCHMIDT, R. R., WEAVER, F. M., and WIND, F. H. 1978. Biostratigraphic summary of DSDP Leg 44: Western North Atlantic Ocean. *In* Initial Reports of the Deep Sea Drilling Project, ed. W. E. Benson, R. E. Sheridan, *et a/.* US Government Printing Office, Washington, 44: 657-662. (799)

GRADSTEIN, F. M., GRANT, A. C., and JANSA, L. F. 1977. Grand Banks and J-Anomaly Ridge: A geological comparison. *Science 197:* 1074-1076. (751)

GRADSTEIN, F. M., GRANT, A. C., and JANSA, L. F. 1978. Grand Banks and J-Anomaly Ridge: A reply. *Science 202; 73.* (752)

GRANT, A. C. 1977. Multichannel seismic reflection profiles of the continental crust beneath the Newfoundland ridge. *Nature 270 (5632): 22-35.* (694)

HALL, J. M., BARRETT, D. L., and KEEN, C. E. 1977. The volcanic layer of the ocean crust adjacent to Canada - a review. *In* Volcanic Regimes in Canada, ed. W. R. A. Baragar, L. C. Coleman, and J. M. Hall. *Geol. Assoc. Can. Spec. Pap.* 16; 425-444. (800)

HALL, G. C., WILLIS, D. E., ADDISON, R. F., and LAW, F. C. P. 1978. A spectrophotometric assay of trout *(Salvelinus fontinalis)* liver diphenyl ether hydroxylase activity. *Anal. Biochem. 90:* 510-515. (753)

HARDING, G. C. H. 1977. Surface area of the euphausiid *Thysanöessa raschii* and its relation to body length, weight, and respiration. J. *Fish. Res. Board Can. 34 (2);* 225-231. (635)

HARDING, G. C. H. and VASS, W. P. 1977. Uptake from sea water and clearance of ^{14}C7p,p'-DDT by the marine copepod *Calanus finmarchicus. J. Fish. Res. Board Can. 34 (2):* 177-182. (633)

HARGRAVE, B. T. 1978. Seasonal changes in oxygen uptake by settled particulate matter and sediments in a marine bay. J. *Fish. Res. Board Can. 35 (12);* 1621-1628. (746)

HARGRAVE, B. T. and CONNOLLY, G. F. 1978. A device to collect supernatant water for measurement of the flux of dissolved compounds across sediment surfaces. *Limnol. Oceanogr. 23 (5):* 1005-1010. (715)

HARGRAVE, B. T. and KAMP NIELSEN, L. 1977. Accumulation of sedimentary organic matter at the base of steep bottom gradients. *In* Interactions Between Sediments and Water, ed. H. L. Golterman. Pudoc Publ., Amsterdam: 168-173. (781)

HARGRAVE, B. T. and KRANCK, K. 1976. Adsorption and transport of pollutants on suspended particles. *In* Proceed. Symposium on Non-biological Transport and Transformation of Pollutants on Land and Water: Processes and Critical Data Required for Predictive Description, May 11-13, 1976. National Bureau of Standards, Gaithersburg, Maryland, USA. (739)

HARGRAVE, B. T. and PHILLIPS, G. A. 1977. Oxygen uptake of microbial communities on solid surfaces. *In* Aquatic Microbial Communities, ed. J. Cairns. Garland Publ. Co., New York, NY: 545-587. (745)

HARGRAVE, B. T. and TAGUCHI, S. 1978. Origin of deposited material sedimented in a marine bay. *J. Fish. Res. Board Can. 35 (12):* 1604-1613. *(744)*

HAWORTH, R. T. 1977. The continental crust northeast of Newfoundland and its ancestral relationship to the Charlie Fracture Zone. *Nature 266 (5599):* 241-249. *(628)*

HAWORTH, R. T. 1978. Interpretation of geophysical data in the northern Gulf of St. Lawrence and its relevance to lower Paleozoic geology. *Bull. Geol. Soc. Am. 89:* 1097-1110. (770)

HAWORTH, R. T., LEFORT, J. P., and MILLER, H. G. 1978. Geophysical evidence for an east dipping Appalachian subduction zone beneath Newfoundland. Geology 6: 522-526. (771)

HAWORTH, R. T. and MACINTYRE, J. B. 1977. Gravity and magnetic fields of the Gulf of St. Lawrence, Canada. *Marine Science Pap. 15lGeol. Surv. Can., Pap.* 75-42: 1-11. (634)

HEFFLER, D. E. and LOCKE, D. R. 1977. A deep ocean release mechanism. *Mar. Geophys. Res. 3: 229-232.* (672)

HERMAN, A. W. and DENMAN, K. L. 1977. Rapid underway profiling of chlorophyll with an *in situ* fluorometer mounted on a "Batfish" vehicle. *Deep-Sea Res. 24 (4):* 385-397. (642)

HOUGHTON, R. W., SMITH, P. C., and FOURNIER, R. O. 1978. A simple model for cross-shelf mixing on the Scotian Shelf. *J. Fish. Res. Board Can. 35 (4):* 414-421. (754)

HYNDMAN, R. D., ROGERS, G. C., BONE, M. N., LISTER, C. R. B., WADE, U. S., BARRETT, D. L., DOWS, E. E., LEWIS, T., LYNCH, S., and SEEMAN, D. 1978. Geophysical measurements in the region of the Explorer Ridge off western Canada. *Can. J. Earth Sci. 15* (9): 1508-1525. (679)

JACKSON, H. R., KEEN, C. E., and BARRETT, D. L. 1977. Geophysical studies on the eastern continental margin of Baffin Bay and in Lancaster Sound. *Can. J. Earth Sci. 14:* 1991-2001 (701)

JANSA, L., GARDNER, J. V., and DEAN, W. E. 1977. Mesozoic sequences of the central North Atlantic. *In* Initial Reports of the Deep Sea Drilling Project, *ed.* Y. Lancelot, E. Seibold, et *a/.* US Government Printing Office, 41: 991-1032. (819)

JANSA, L. F., MAMET, B., and ROUX, A. 1978. Visean limestones from the Newfoundland Shelf. *Can. J. Earth Sci. 75 (9):* 1422-1436. (782)

JANSA, L. F. and McQUEEN, R. 1978. Hydrocarbon potential of the central North Atlantic Basin. *Geosci. Can. 15 (4):* 176-183. (801)

JONES, E. P. and SMITH, S. D. 1977. A first measurement of sea-air CO_2 flux by eddy correlation. *J. Geophys. Res. 82 (37): 5990-5992.* (671)

JONES, E. P. and SMITH, S. D. 1978. Eddy correlation measurement of sea-air CO_2 flux. *In* Turbulent Fluxes through the Sea Surface, Wave Dynamics, and Prediction, *ed.* A. Farre and K. Hasselmann. Plenum Press, New York and London: 137-149. (802)

JONES, E. P. and SMITH, S. D. 1978. The air density corrections to eddy flux measurements. *Boundary-Layer Meteorol. 15: 357-360.* *(755)*

JONES, E. P., WARD, T. V., and ZWICK, H. H. 1978. A fast response atmospheric CO_2 sensor for eddy correlation flux measurements. *Atmos Environ. 12:* 845-851. (670)

JOSENHANS, H. W., KING, L. H., and FADER, G. H. 1978. A side-scan sonar mosaic of pockmarks on the Scotian Shelf. *Can. J. Earth Sci. 75 (5):* 831-840. (706)

K&E, R. H. and CLARKE, R. A. 1978. High frequency internal waves in the upper thermocline during GATE. *Deep-Sea Res. 25(9):* 815-826. (835)

KEEN, C. E., HALL, B. R., and SULLIVAN, K. D. 1977. Mesozoic evolution of the Newfoundland Basin. *Earth Planet. Sci. Lett. 37; 307-320.* (659)

KEIZER, P. D., AHERN, T. P., DALE, J., and VANDERMEULEN, J. H. 1978. Residues of Bunker C oil in Chedabucto Bay, Nova Scotia, six years after the *Arrow* spill. *J. Fish. Res. Board Can. 35 (5): 528-535.* (783)

KEIZER, P. D., DALE, J., and GORDON, D. C., JR. 1978. Hydrocarbons in surficial sediments from the Scotian Shelf. *Geochim. Cosmochim. Acta 42;* 165-172. (697)

KEIZER, P. D., GORDON, D. C., JR., and DALE, J. 1977. Hydrocarbons in eastern Canadian marine waters determined by fluorescence spectroscopy and gas-liquid chromatography. *J. Fish. Res. Board Can. 34 (3): 347-353.* (638)

KERR, S. R. 1977. JPU theory and the apotheosis of simulacra. *J. Fish. Res. Board Can.* 344: 580-581. (772)

KERR, S. R. 1977. Structure and transformation of fish production systems. *J. Fish. Res. Board Can. 34:* 1989-1993. (738)

KERR, S. R. and RYDER, R. A., 1977. Niche theory and percid community structure. *J. Fish. Res. Board Can. 34:* 1952-1958. (737)

KING, L. H. and YOUNG, I. F. 1977. Paleocontinental slopes of the East Coast Geosyncline (Canadian Atlantic margin). *Can. J. Earth Sci. 14(11): 2553-2564.* (700)

LANCELOT, Y., SEIBOLD, E., CEPEK, P., DEAN, W. E., EREMEEV, V., GARDNER, J., JANSA, L., JOHNSON, D., KRASHENINNIKOV, J. V., PLAUFMANN, U., RANKIN, J. G., TRABANT, P., and BURKY, D. 1977. Part II: Site reports. *In* Initial Reports of the Deep Sea Drilling Project, *ed.* Y. Lancelot, E. Seibold, et *a/.* US Government Printing Office, Washington, 41: 19-492 (six site reports). (820)

LAZIER, J. and SANDSTROM, H. 1978. Migrating thermal structure in a freshwater thermocline. *J. Phys. Oceanogr. 8 (4):* 1070-1079. (756)

LEFORT, J. P. and HAWORTH, R. T. 1978. Geophysical study of basement fractures on the western European and eastern Canadian shelves: transatlantic correlations, and late Hercynian movements. *Can. J. Earth Sci. 15(3): 397-404.* (689)

LEVY, E. M. 1977. The geographical distribution of tar in the North Atlantic. *Rapp. P.-V. Rem., Cons. Int. Explor. Mer. 777: 55-60.* (690)

LEVY, E. M. 1978. Visual and chemical evidence for a natural seep at Scott Inlet, Baffin Island, District of Franklin. *Geol. Surv. Can., Current Res., Pap. 78-1B:* 21-26. (688)

LEVY, E. M., CUNNINGHAM, C. C., CONRAD, C. D. W., and MOFFATT, J. D. 1977. A titration apparatus for the determination of dissolved oxygen in seawater. *J. Fish. Res. Board Can. 34(11):* 2218-2220. (662)

LONGHURST, A. R. 1978. Ecological models in estuarine management. *Ocean Manag.* 4: 287-302. (833)

LORING, D. H. 1978. Geochemistry of zinc, copper, and lead in the sediments of the estuary and Gulf of St. Lawrence. *Can. J. Earth Sci. 15(5): 757-772.* (734)

LORING, D. H. 1978. Industrial and natural inputs, levels, behavior, and dynamics of biologically toxic heavy metals in the Saguenay Fjord, Gulf of St. Lawrence, Canada. *In* Proceed. of the Third International Symposium on Environmental Biogeochemistry. Volume 3: Methods, Metals, and Assessment, *ed.* W. E. Krumbein. Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, Chapter 83: 1025-1040. (757)

LORING, D. H. and BEWERS, J. M. 1978. Geochemical mass balances for mercury in a Canadian fjord. *Chem. Geol. 22; 309-330.* *(709)*

LOUCKS, R. H. and SUTCLIFFE, W. H., JR. 1978. A simple fish-population model including environmental influence, for two western Atlantic shelf stocks. *J. Fish. Res. Board Can. 35(3): 279-285.* *(696)*

MacCAULL, W. A. and PLATT, T. 1977. Diel variations in the photosynthetic parameters of coastal marine phytoplankton. *Limnol. Oceanogr. 22(4): 723-731.* *(675)*

MacLEAN, B., FADER, G. B., and KING, L. H. 1977. Surficial geology of Canso Bank and adjacent areas. *Geol. Surv. Can., Pap. 76-15lMarine Science Pap. 20;* 11 pp. + map. (702)

MacLEAN, B., FALCONER, R. K. H., and CLARKE, D. B. 1978. Tertiary basalts of western Davis Strait: bedrock core samples and geophysical data. *Can. J. Earth Sci. 15(5): 773-780.* *(707)*

MacLEAN, B., JANSA, L. F., FALCONER, R. K. H., and SRIVASTAVA, S. P. 1977. Ordovician strata on the southeastern Baffin Island Shelf revealed by shallow drilling. *Can. J. Earth Sci. 14(8):* 1925-1939. (641)

MANN, C. R. 1977. Currents and water masses in the vicinity of Drake Passage. *In* Polar Oceans, *ed.* M. J. Dunbar. Arctic Institute of North America, Calgary, Alberta; 121-128. (803)

MAYZAUD, P. 1976. Respiration and nitrogen excretion of zooplankton. IV. the influence of starvation on the metabolism and the biochemical composition of some species. Mar. *Biol. 37(1): 47-58.* (723)

McBEAN, G. A. and ELLIOTT, J. A. 1978. The energy budgets of the turbulent velocity components and the velocity-pressure gradient interactions. *J. Atmos. Sci. 35:* 1890-1899. (804)

McCAIN, B. B., HODGINS, H. O., GRØNLUND, W. D., HAWKES, J. W., BROWN, D. W., MYERS, M.S., and VANDERMEULEN, J. H. 1978. Bioavailability of crude oil from experimentally oiled sediments to English sole *(Parophrys vetulus),* and pathological consequences. *J. Fish. Res. Board Can. 35(5): 657-664.* (784)

McCANN, S. B., REINSON, G. E., and ARMON, J. W. 1977. Tidal inlets of the southern Gulf of St. Lawrence, Canada. *In* Coastal Sediments '77, 5th Symp. of Waterway Port Coastal and Ocean Div. *Am. Soc. Civ. Eng., NY:* 504-519. (678)

MESHAL, A. H. 1977. Comparison of drag coefficients over water measured directly and determined by wind profile. *Atmosphere 75(4):* 166-177. (758)

MOORE, J. G., BROWN, J. D., and RASHID, M. A. 1977. The effect of leaching on the engineering behaviour of a marine sediment. *Geotechnique 27(4):* 517-531. (698)

MORTIMER, A. R., EATON, R. M, and GRAY, D. H. 1978. Calibration of the west Canadian Loran-C chain. *Can. Aeronaut. Space J. 24(3):* 129-136. (759)

NICKERSON, T. B. and DOWD, R. G. 1977. Design and operation of survey patterns for demersal fishes using the computerized echo counting system. *Rapp. P.-V. Reun., Cons. Int. Explor. Mer. 170: 232-236.* (646)

OAKEY, N. S. and ELLIOTT, J. A. 1977. Vertical temperature gradient structure across the Gulf Stream. *J. Geophys. Res. 82;* 1369-1380. (617)

OWENS, E. H. 1977. Temporal variations in beach and nearshore dynamics. *J. Sediment. Petrol. 47(l):* 168-190. (629)

OWENS, E. H. and FROBEL, D. H. 1977. Ridge and runnel systems in the Magdalen Islands, Quebec. *J. Sediment. Petrol. 47(1):* 191-198. (630)

PARSONS, T. R., TAKAHASI, M., and HARGRAVE, B. T. 1977. Biological Oceanographic Processes, second edition. Pergamon Press, Oxford: 332 pp. (785)

PETRIE, B. 1978. Numerical model of the circulation in an open bay. *J. Fish. Res. Board Can. 35(12)* and DRINKWATER, K.S. 1978. (786)

PETRIE, B. and DRINKWATER, K. 1978. Circulation in an open bay. *J. Fish. Res. Board Can. 35(8):* 1116-1173. (727)

PETRIE, B. and SMITH, P. C. 1977. Low frequency motions on the Scotian Shelf and Slope. *Atmosphere 15:* 117-140. (787)

PLATT, T. 1978. Spectral analysis of spatial structure in phytoplankton populations. *In* Spatial Pattern in Plankton Communities, ed. J. H. Steele. Plenum Publ. Corp., New York, NY: 73-84. (760)

PLATT, T. and DENMAN, K. L. 1977. Biological prediction in pelagic marine ecosystems. *In* Oceanic Sound Scattering Prediction, ed. N. R. Andersen and B. J. Zahuranec. Plenum Press, New York, NY: 803-809. (656)

PLATT, T. And DENMAN, K. L. 1977. Organization in the pelagic ecosystem. *Helgol. Wiss. Meeresunters. 30:* 575-581. (788)

PLATT, T., DENMAN, K. L., and JASSBY, A. D. 1977. Modelling the productivity of phytoplankton. *In* The Sea: Ideas and Observations on Progress in the Study of the Seas, ed. E. D. Gildberg. John Wiley & Sons, New York, NY. VI: 807-856. (643)

PLATT, T. and JASSBY, A.D. 1976. The relationship between photosynthesis and light for natural assemblages of coastal marine phytoplankton. *J. Phycol. 12(4):* 421-430. (643)

PLATT, T., SUBBA RAO, D.V., and DENMAN, K. L. 1977. Quantitative stimulation of phytoplankton productivity by deep water admixture in a coastal inlet. *Estuarine Coastal Mar. Sci. 5(5): 567-573.* (674)

POCKLINGTON, R. 1977. Chemical processes and interactions involving marine organic matter. *Mar. Chem. 5: 479-496.* (695)

POCKLINGTON, R. 1978. Climatic trends in the North Atlantic. *Nature 273: 407.* (761)

POISSON, A., DAUPHINEE, T., ROSS, C. K., and CULKIN, F. 1978. The reliability of standard seawater as an electrical conductivity standard. *Oceanol. Acta 1(4):* 425-433. (805)

PURCELL, L. P., RASHID, M.A., and HARDY, I. A. 1978. Hydrocarbon geochemistry of the Scotian Basin. Proceed. Offshore Technol. Conf., Paper No. OTC 3053: 87-92. (806)

PURDY, G. M., SCHOUTEN, H., CROWE, J., BARRETT, D. L., FALCONER, R. K. H., UDINTSEV, G. B., MAROVA, N. A., LITVIN, V. M., VALYASHKO, G. M., MARKUSHEVICH, V. M., and ZDOROVENIN, V. V. 1978. IPOD survey area AT-6; A site survey. *In* Initial Reports of the Deep Sea Drilling Project, ed. W. G. Melson, P D. Rabinowitz, *et al.* US Government Printing Office, Washington, 45: 39-44. (807)

QUON, C. 1977. Axisymmetric states of an internally heated rotating annulus. Tellus 29: 83-96. (609)

QUON, C. 1977. Free convection in an enclosure revisited. *Trans. Am. Soc. Mech. Eng.* 99: 340-342. (650)

QUON, C. 1977. A severely truncated mixed spectral and finite difference model to study resonant interaction of finite amplitude baroclinic waves. In Computing Methods in Geophysical Mechanics. *Am. Soc. Mech. Eng., Appl. Mech. Div. 25:* 117-129. (710)

RANTALA, R. T. T. and LORING, D. H. 1977. A rapid determination of ten elements in marine suspended particulate matter by atomic absorption spectrophotometry. At. *Absorpt. Newsl. 16(2):* 51-52. (645)

RANTALA, R. T. T. and LORING, D. H. 1978. Atomic absorption analysis of USGS Reference Sample Marine Mud MAG-1 for selected trace elements. *Geostandards Newsl.* 2(2): 125-127. (762)

RASHID, M. A. 1978. The influence of a salt dome on the diagenesis of organic matter in the Jeanne d'Arc Subbasin of the northeast Grand Banks of Newfoundland. Org. *Geochem.* 1: 67-77. (763)

RASHID, M. A. and McALARY, J. D. Early maturation of organic matter and genesis of hydrocarbons as a result of heat from a shallow piercement salt dome. *J. Geochem. Explor. 8: 549-569.* (665)

RASHID, M. A. and VILKS, G. 1977. Environmental controls of methane production in Holocene basins in eastern Canada. Org. *Geochem. 1: 53-59.* (669)

REINSON, G. E. 1977. Tidal-current control of submarine morphology at the mouth of the Miramichi estuary, New Brunswick. *Can. J. Earth Sci. 14(11): 2524-2532.* *(664)*

RISK, M. J., VENTER, R. D., PEMBERTON, S. G., and BUCKLEY, D. E. 1978. Computer simulation and sedimentological implications of burrowing by *Axius serratus. Can. J. Earth Sci. 15(8):* 1370-1374. (789)

ROSS, C. K. 1977. Preliminary results of recent overflow measurements in Denmark Strait. *In* Polar Oceans, *ed.* M. J. Dunbar. Arctic Institute of North America, Calgary, Alberta: 99-106. (631)

ROSS, C. K. and NEEDLER, G. T. 1976. Spectral analysis of the long-term oceanographic time series at Ocean Weather Station "P". *J. Fish Res. Board Can.* 33(10): 2203-2212. (631)

ROSS, D. I. and FALCONER, R. K. H. 1977. Mid-Atlantic Ridge at 37°N: Geophysical anomalies in the area of Leg 37 drilling. *Can. J. Earth Sci. 14 (4-part 2); 664-673.* (649)

RYDER, R. A. and KERR, S. R. 1978. The adult walleye in the percid community - A niche definition based on feeding behaviour and food specificity. Am. *Fish. Soc. Spec. Pub/. 11:* 39-51 (832)

SAMEOTO, D. D. 1978. Zooplankton sample variation on the Scotian Shelf. *J. Fish. Res. Board Can. 35 (9):* 1207-1222. (733)

SAMEOTO, D. D., JAROSZYNSKI, L. O., and FRASER, W. B. 1977. A multiple opening and closing plankton sampler based on the MOCNESS and N.I.O. nets. *J. Fish. Res. Board Can. 34:* 1230-1235. (677)

SANDSTROM, H. 1976. On topographic generation and coupling of internal waves. *Geophys. Fluid Dynam. 7: 231-270.* (836)

SCHAFER, C. T. and COLE, F. E. 1978. Distribution of foraminifera in Chaleur Bay, Gulf of St. Lawrence. *Geol.* Surv. *Can., Pap. 77-30; 55* pp. (699)

SCHAFER, C. T. and WAGNER, F. J. E. 1978. Foraminifera-mollusc associations in eastern Chaleur Bay. *Can. J. Earth Sci. 15(6): 889-907.* *(828)*

SCOTT, D. B., MEDIOLI, F. S., and SCHAFER, C. T. 1977. Temporal changes in foraminiferal distributions in Miramichi River estuary, New Brunswick. Can. *J. Earth* Sci. 14(7): 1566-1587. (667)

SHELDON, R. W. and SUTCLIFFE, W. H., JR. 1978. Generation times of 3 h for Sargasso Sea microplankton determined by ATP analysis. *Lirnnol. Oceanogr. 23(5):* 1051-1055. (764)

SHELDON, R. W., SUTCLIFFE, W. H., JR., and PARANJAPE, M. A. 1977. Structure of pelagic food chain and relationship between plankton and fish production. *J. Fish. Res. Board Can. 34: 2344-2353.* (687)

SHIPBOARD SCIENTIFIC PARTY. 1978. Part II: Site reports. *In* Initial Reports of the Deep Sea Drilling Project, *ed.* W. E. Benson, R. E. Sheridan, et *al.* US Government Printing Office, Washington: 21-410. (810)

SILVERT, W. 1978. Anomalous enhancement of mean population levels by harvesting. *Math. Biosci. 42: 253-256.* *(809)*

SILVERT, W. and PLATT, T. 1978. Energy flux in the pelagic ecosystem: A time-dependent equation. *Limnol. Oceanogr. 23(4):* 813-816. (718)

SMITH, P. C. 1978. Low-frequency fluxes of momentum, heat, salt, and nutrients at the edge of the Scotian Shelf. *J. Geophys. Res. 83 (C8): 4079-4096.* *(720)*

SMITH, P. C., PETRIE, B., and MANN, C. R. 1978. Circulation, variability, and dynamics of the Scotian Shelf and Slope. *J. Fish. Res. Board Can. 35(8):* 1067-1083. (765)

SMITH, S. D. 1978. Eddy fluxes of momentum and heat measured over the Atlantic Ocean in gale force winds. *In* Turbulent Fluxes through the Sea Surface, Wave Dynamics, and Prediction, *ed.* A. Farre and K. Hasselmann. Plenum Press, New York and London: 35-50. (811)

SNYDER, R. L., LONG, R. B., DOBSON, F. W., and ELLIOTT, J. A. 1978. The Bight of Abaco pressure experiment. *In* Turbulent Fluxes through the Sea Surface, Wave Dynamics, and Prediction, *ed.* A. Farre and K. Hasselmann. Plenum Press, New York and London: 433-444. (812)

SRIVASTAVA, S. P. 1978. Evolution of the Labrador Sea and its bearing on the early evolution of the North Atlantic. *Geophys. J. Roy. Astron. Soc. 52;* 313-357. (668)

STEWART, I. C. F. and KEEN, C. E. 1978. Anomalous upper mantle structure beneath the Cretaceous Foyo Seamounts indicated by P-wave reflection delays. *Nature* 274; 788-790. (790)

SULLIVAN, K. D. and KEEN, C. E. 1977. Newfoundland seamounts: petrology and geochemistry. *In* Volcanic Regimes in Canada, *ed.* W. R. A. Baragar, L. C. Coleman, and J. M. Hall. *Geol. Assoc. Can. Spec. Pap. 16;* 461-476. (813)

SULLIVAN, K. D. and KEEN, C. E. 1978. On the nature of the crust in the vicinity of the southeast Newfoundland Ridge. *Can. J. Earth Sci. 15:* 1462-1471. (791)

SUNDBY, B. and LORING, D. H. 1978. Geochemistry of suspended particulate matter in the Saguenay Fjord. *Can. J. Earth Sci.* 15(6): 1002-1011. (766)

SUTCLIFFE, W. H., JR., DRINKWATER, K., and MUIR, B. S. 1977. Correlations of fish catch and environmental factors in the Gulf of Maine. *J. Fish. Res. Board Can. 34:* 19-30. (683)

TAGUCHI, S. and HARGRAVE, B. T. 1978. Loss rates of suspended material sedimented in a marine bay. *J. Fish. Res. Board Can. 35(12):* 1614-1620. (743)

TAGUCHI, S. and PLATT, T. 1977. Assimilation of $^{14}C0_2$ in the dark compared to phytoplankton production in a small coastal inlet. *Estuarine Coastal Mar. Sci. 5(5): 679-684.* *(673)*

TAN, F. C. and WALTON, A. 1978. Stable isotope studies in the Gulf of St. Lawrence, Canada. *In* Stable Isotopes in the Earth Sciences, *ed.* B. W. Robinson. *N.Z. Dept.* Sci. *Ind. Res., Bull.* 220: 27-37. (682)

TANG, C. L. and MYSAK, L. A. 1976. A note on “Internal waves in a randomly stratified fluid”. *J. Phys. Oceanogr. 6(2): 243-266.* *(663)*

THERRIAULT, J.-C., LAWRENCE, D. J., and PLATT, T. 1978. Spatial variability of phytoplankton turnover in relation to physical processes in a coastal environment. *Limnol. Oceanogr. 23(5):* 900-911. (767)

THERRIAULT, J.-C. and PLATT, T. 1978. Spatial heterogeneity of phytoplankton biomass and related factors in the near-surface waters of an exposed coastal embayment. *Limnol. Oceanogr. 23(5): 888-899.* (712)

VANDERMEULEN, J. H. 1978. Introduction to the symposium on recovery potential of oiled marine northern environments. *J. Fish. Res. Board Can.* 35(5): 505-508. (794)

VANDERMEULEN, J. H. and PENROSE, W. R. 1978. Absence of aryl hydrocarbon hydroxylase (AHH) in three marine bivalves. *J. Fish. Res. Board Can.* 35(5): 643-647. (792)

VANDERMEULEN, J. H., BUCKLEY, D. E., LEVY, E. M., LONG, B., McLAREN, P., and WELLS, P. G. 1978. Immediate impact of *Amoco Cadiz* environmental oiling: oil behavior and burial, biological aspects. *In* Journee speciale *"Amoco* Cadiz", Brest, France, June 7, 1978. Publ. CNEXO Serie *"Actes de Colloques" 6;* 159-174. (793)

VILKS, G. 1977. Trends in the marine environment of the Canadian Arctic Archipelago during the Holocene. *In* Polar Oceans, *ed.* M. J. Dunbar. Arctic Institute of North America, Calgary, Alberta: 643-654. (814)

VILKS, G., HALL, J. M., and PIPER, D. J. W. 1977. The natural remanent magnetization of sediment cores from the Beaufort Sea. Can. *J. Earth Sci.* 14(9): 2007-2012. (647)

VILKS, G. and MUDIE, P. J. 1978. Early deglaciation of the Labrador Shelf. Science 202: 481-483. (728)

VILKS, G. and RASHID, M. A. 1977. Methane in the sediments of a subarctic continental shelf. *Geosci. Can.* 4(4): 191-197. (666)

WADE, J. A. 1978. The Mesozoic-Cenozoic history of the northeastern margin of North America. *Proceed. Offshore Technol. Conf., Paper No. OTC 3266:* 1849-1854. (823)

WADE, J. A. 1977. Stratigraphy of Georges Bank Basin: interpreted from seismic correlation to the western Scotian Shelf. *Can. J. Earth Sci. 14(10): 2274-2283.* (681)

WAGNER, F. J. E. 1977. Paleoecology of marine Pleistocene Mollusca, Nova Scotia. *Can. J. Earth Sci. 14(6): 1305-1323.* (653)

WAGNER, F. J. E. 1977. Recent mollusc distribution patterns and paleobathymetry, southeastern Beaufort Sea. *Can. J. Earth Sci. 14(9): 2013-2028.* (651)

WARE, D. M. 1977. Spawning time and egg size of Atlantic mackerel, *Scomber scombrus,* in relation to plankton. *J. Fish. Res. Board Can. 34;* 2308-2315. (686)

WARE, D. M. 1978. Bioenergetics of pelagic fish: theoretical change in swimming speed and ration with body size. *J. Fish. Res. Board Can. 35(2): 220-228.* *(735)*

WILLEY, J. D. 1977. Coprecipitation of zinc with silica in sea water and in distilled water. *Mar. Chem. 5: 267-290.* (640)

WILLIAMS, G. L. 1977. Dinocysts - Their classification, biostratigraphy and paleoecology. *In* Oceanic Micropaleontology, Vol. 2, *ed.* A. T. S. Ramsey. Academic Press Inc. (London) Ltd., Chapter 15: 1231-1326. (780)

WILLIAMS, G. L. 1978. Dinoflagellates, acritarchs, and tasmanitids. *In* Introduction to Marine Micropaleontology, *ed.* B. U. Haq and A. Boersma. Elsevier Publ. Co., Amsterdam and NY: 400 pp. (824).

WILLIAMS, G. L. 1978. 2. Palynological biostratigraphy, Deep Sea Drilling Project Sites 367 and 370. *In* Initial Reports of the Deep Sea Drilling Project, Supplement to Volumes 38, 39, 40, and 41. US Government Printing Office, Washington, Part IV: 783-815. (831)

WILLIAMS, G. L. and BUJAK, J. P. 1977. Distribution patterns of some North Atlantic Cenozoic dinoflagellate cysts. *Mar. Micropaleontol. 2; 223-233.* **(815)**

WILLIAMS, G. L. and BUJAK, J. P. 1977. Cenozoic palynostratigraphy of offshore eastern Canada. *In* Contributions of Stratigraphic Palynology. Vol. 1 - Cenozoic Palynology, *ed.* W. C. Elsik. *Am. Assoc. Stratigr. Palynol., Contrib. Ser. 5A:* 14-47. (816)

WILLIAMS, G. L., SARJEANT, W. A. S., and KIDSON, E. J. 1978. A glossary of the terminology applied to dinoflagellate amphiesmae, cysts and acritarchs. *Am. Assoc. Stratigr. Palynol. Contrib. Ser. 2.* *(825)*

WILLIS, D. E., ZINCK, M. E., and ADDISON, R. F. 1978. Identification, synthesis and estimation of the major components of a PCB replacement based on butylated monochlorodiphenyl ethers. *Chemosphere 10: 787-790.* (769)

YEATS, P., BEWERS, J. M., and WALTON, A. 1978. Sensitivity of coastal waters to anthropogenic trace metal emissions. *Mar. Poll. Bull. 9: 264-268.* (770)

Bedford Institute of Oceanography (BIO) Technical Reports

The Institute publishes a Report, a Data, and a Computer Note Series of technical reports in a microfiche format.

AMOS, C. L. and JOICE, G. H. E. 1977. The sediment budget of the Minas Basin, Bay of Fundy, Nova Scotia. *BIO, Data Series, BI-D-77-3.*

COOTE, A. R. and HILTZ, R. S. 1978. Overflow 73 - Denmark Strait. Volume 1: Oxygen and nutrient sections. *BIO, Data Series, BI-D-78-4.*

DELORME, P. 1978. Evaluation of direct and inverse geodetic algorithms. *BIO, Computer /Vote Series, BI-C-78-2.*

DEONARINE, B. and VILKS, G. 1977. Sediment cores from the Labrador Shelf. *BIO, Data Series, BI- D- 77-4.*

DOBSON, D. 1977. Temperature, salinity, and density distributions of the Halifax Section. *BIO, Data Series, BI-D-77-2.*

DOBSON, D. 1978. Temperature, salinity, and density distributions of the Halifax Section. *BIO, Data Series, BI-D-78-3.*

DOBSON, D. and JORDAN, F. 1978. The Labrador Sea: A bibliography of physical oceanography. *BIO, Data Series, BI-D-78-5.*

DOE, L. A. E. 1978. Project ICANE: A progress and data report on a Canada-Peru study of the Peruvian anchovy and its ecosystem. *BIO, Report Series, BI-R-78-6.*

ELLIOTT, J. A. 1978. Oceanographic survey of Porters Lake, N.S. *BIO, Report Series, BI-R-78-5.*

GORDON, D. C., JR. 1977. A secchi disk study of Dartmouth's lakes, 1976 - Citizen involvement in water quality measurements. *BIO, Report Series, BI-R-77-2.*

GORDON, D. C., JR. 1978. Secchi disk observations in Dartmouth's lakes, 1977. *BIO, Report Series, BI- R-78-2.*

GREGORY, D. and DOBSON, D. 1978. Long term temperature monitoring program. *BIO, Data Series, BI-D-78-7.*

LENTIN, J. K. and WILLIAMS, G. L. 1977. Fossil dinoflagellates: Index to genera and species. *BIO, Report Series, BI-R-77-8.*

LENTIN, J. K. and WILLIAMS, G. L. 1978. Alphabetical listing of fossil dinocyst species. *BIO, Report Series, BI-R-78-4.*

LEONARD, J. 1977. Organohalogens in coastal sediments from the Maritime Provinces, Canada. *BIO, Report Series, BI-R-77-6.*

LEVY, E. M. 1977. Fluorescence spectrophotometry: Principles and practice as related to the determination of dissolved/dispersed petroleum residues in ,sea water. *BIO, Report Series, BI-R-77-7.*

LEVY, E. M., CUNNINGHAM, C. C., CONRAD, C. D. W., and MOFFATT, J. D. 1977. The determination of dissolved oyxgen in sea water. BIO, Report Series, *BI-R-77-9.*

NEU, H. J. A. and JORDAN, F. 1977. The physical oceanography and sedimentation of Riviere au Tonnerre, P.Q. BIO, Report Series, *BI-R-77-4.*

OAKEY, N. 1977. Octuprobe III: An instrument to measure oceanic turbulence and microstructure. BIO, *Report Series, BI-R-77-3.*

PETRIE, B. 1977. An intercomparison of data from Endeco 174 and Braincon 381 current meters. *BIO, Report Series, BI-R-77-10.*

PETRIE, B. and DRINKWATER, K. 1977. Physical oceanographic measurements in St. Georges Bay, Nova Scotia. *BIO, Report Series, BI-R-77-5.*

PETRIE, B. and DRINKWATER, K. 1977. The physical oceanography of St. Georges Bay, Nova Scotia. *BIO, Report Series, BI-R-77-11.*

POCKLINGTON, R. 1978. Organic matter in waters off Senegal and The Gambia. *BIO, Report Series, BI- R-78- 1.*

REID, S. J. 1977. Circulation and mixing in the St. Lawrence estuary near Ilet Rouge. *BIO, Report Series, BI-R-77- 1.*

ROSEN, P. S. (Editor). 1977. Workshop on coastal research and planning in Labrador. *BIO, Report Series, BI-R-77- 12.*

ROSS, C. K. 1977. Overflow 73 - Denmark Strait. Volume 2: Moored instrument time series. *BIO, Data Series, BI-D-77-5.*

SHIH, K. G., KEEN, C. E., JOHNSTON, B. L., JACKSON, H. R., and KEEN, M. J. 1978. Geophysical data collected in the northwestern Atlantic Ocean - Report of cruise 73-011, *CSS Hudson. BIO, Data Series, BI-D-78-6.*

SMITH, P. C., DOBSON, F. W., and BROWN, R. F. 1978. A set of programs to compute and plot rotary spectra. *BIO, Computer /Vote Series, BI-C-78-1.*

SMITH, P. C., FOOTE, T. R., and BOYCE, R. 1978. */n situ* calibrations of temperature and salinity for the Aanderaa RCM-5 current meter. *BIO, Report Series, BI-R-78-7.*

TAYLOR, G. B. 1978. Oceanographic observations in the River, Estuary, and Gulf of St. Lawrence, 30 March - 26 April 1974. *BIO, Data Series, BI-D-78-7.*

WALKER, R. E. 1977. Wave statistics for the North Atlantic - 1971. *BIO, Data Series, BI-D-77- 1.*

WALKER, R. E. 1978. Wave statistics for the North Atlantic - 1972. *BIO, Data Series, Bl- D- 78-2.*

WELLS, D. E. and VANICEK, P. 1978. Least squares spectral analsysis. *BIO, Report Series, BI-R-78-8.*

WINTERS, G. V., FITZGERALD, R. A., and BUCKLEY, D. E. 1978. Analyses of water volume and bottom sediment samples from the Miramichi estuary, New Brunswick. *BIO, Data Series, Bl-D-78-8.*

WINTERS, G. V. and BUCKLEY, D. E. 1978. *In* situ monitoring data on the water column in the Miramichi estuary, New Brunswick. *BIO, Data Series, BI-D-78-9.*

Fisheries and Marine Service (FMS) Reports

This is a national series of reports co-ordinated by the Scientific Information and Publications Branch, Fisheries and Marine Service, Department of Fisheries and the Environment, Ottawa, Ontario K1A 0E6. The technical and data reports of MEL staff in this series are produced and distributed on microfiche.

DENMAN, K., IRWIN, B., and PLATT, T. 1977. Phytoplankton productivity experiments and nutrient measurements at the edge of the Nova Scotia Continental Shelf between June 28 and July 12, 1976. *FMS, Tech. Rep. 708.*

DENMAN, K. L., VANDALL, P. E., HERMAN, A. W., and JORDAN, F. 1977. Shipboard observations for the chlorophyll remote sensing experiment off Yarmouth, Nova Scotia, August 1975. ***FMS, Tech. Rep. 706.***

HARGRAVE, B. T. (Editor) 1978. Geochemical and biological observations in intertidal sediments from Cobequid Bay, Bay of Fundy, Nova Scotia. ***FMS, Tech. Rep. 782.***

IRWIN, B., EVANS, P., and PLATT, T. 1978. Phytoplankton productivity experiments and nutrient measurements in the Labrador Sea from 15 October to 31 October 1977. ***FMS, Data Rep. 83.***

IRWIN, B., EVANS, P., and PLATT, T. 1978. Phytoplankton productivity experiments and nutrient measurements in the Labrador Sea from 11 February to 28 February 1978. ***FMS, Data Rep. 114.***

IRWIN, B., HARRISON, W. G., DENMAN, K. L., and PLATT, T. 1978. Phytoplankton productivity and nutrient measurements at the edge of the continental shelf off Nova Scotia between April 28 and May 11, 1977. ***FMS, Data Rep. 62.***

IRWIN, B., HODGSON, M., DICKIE, P., and PLATT, T. 1978. Phytoplankton productivity experiments in Baffin Bay and adjacent inlets 22 August to 18 September 1977. ***FMS, Data Rep. 82.***

IRWIN, B. and PLATT, T. 1978. Phytoplankton productivity experiments and nutrient measurements in Bedford Basin, Nova Scotia, from September 1975 to December 1976. ***FMS, Tech. Rep. 762.***

IRWIN, B. and PLATT, T. 1978. Phytoplankton productivity experiments and nutrient measurements in Bedford Basin, Nova Scotia, from January 1977 to July 1977. ***FMS, Data Rep. 93.***

KEIZER, P. D., DALE, J., STADLER, D., and ZIEBARTH, U. 1978. Trace hydrocarbon analysis of sub-surface waters - a comparison of two samplers. ***FMS, Tech. Rep. 776.***

LORING, D. H. and RANTALA, R. T. T. 1977. Geochemical analyses of marine sediments and suspended particulate matter. ***FMS, Tech. Rep. 700.***

MOYSE, C. M. 1978. Bay of Fundy environmental tidal power bibliography. ***FMS, Tech. Rep. 822.***

PLATT, T. 1977. Population ecology of marine cladocera in St. Margaret's Bay, Nova Scotia. ***FMS, Tech. Rep. 698.***

PROUSE, N. J. and HARGRAVE, B. T. 1977. Chlorophyll, carbon and nitrogen in suspended and sedimented particulate matter in St. Georges Bay, Nova Scotia. ***FMS, Tech. Rep. 721.***

SAMEOTO, D. D. 1977. Zooplankton biomass, density and their association with phytoplankton on the southwest area of the Nova Scotian shelf. ***FMS, Tech. Rep. 742.***

SUTCLIFFE, W. H., JR., and BRODIE, P. F. 1977. Whale distributions in Nova Scotia waters. ***FMS, Tech. Rep. 722.***

TAGUCHI, S. and PLATT, T. 1978. Phytoplankton biomass in Bedford Basin: volume, surface area, carbon content and size distribution. ***FMS, Data Rep. 55.***

TAGUCHI, S. and PLATT, T. 1978. Size distribution and chemical composition of particulate matter in Bedford Basin, 1973 and 1974. ***FMS, Data Rep. 56.***

THERRIAULT, J. C., DICKIE, P., HODGSON, M., and PLAIT, T. 1978. Spatial variability of phytoplankton productivity and biomass, and of nutrient measurements in the near-surface waters of St. Margaret's Bay in 1975. ***FMS, Data Rep. 87.***

WARE, D. M. and HENRIKSEN, B. L. 1978. On the dynamics and structure of the southern Gulf of St. Lawrence herring stocks. ***FMS, Tech. Rep. 800.***

Marine Fish Division Publications

CLARK, S. H., BURNS, T. S., and HALLIDAY, R. G. 1977. Assessment of the pollock fishery in ICNAF Divisions 4VWX and Subarea 5. *ICNAF, Selected Pap. 2; 15-32.*

CLAY, J. D. 1977. Preliminary observations on survival of *Clarias lazera* from Israel in saline waters. *Bamidgeh* (Bull. Fish Culture in Israel) 29 (3): 102-109.

CLAY, J. D. 1978. Sexual maturity and fecundity of the African catfish *(Clarias gariepinus)* with an observation on the spawning behaviour of the Nile catfish *(Clarias lazera).* J. Linn. *Soc. London,* Zoo/. *66 (2).*

ELLISON. L. N, and CLEARY, L. 1978. Effect of human disturbance on breeding of double-crested cormorants. *Auk 95:* 510-517.

MANSFIELD, A. W. and BECK. B. 1977. The grey seal in eastern Canada. *Fisheries and Marine Service, Tech. Rep. 704.*

MOHN, R. K. 1978. Modelling the natural pacemaker of the heart as a pulse-frequency modulator. *Med. Biol. Eng. 16; 90-97.*

SINCLAIR, M. 1978. Summer phytoplankton variability in the lower St. Lawrence estuary. *J. Fish. Res. Board Can. 35:* 1171-1185.

CWS Seabird Research Unit Publications

BROWN, R. G. B. 1977. Atlas of eastern Canadian seabirds. Supplement I: Halifax-Bermuda transects. *Canadian Wildlife Service, Ottawa; 24* pp.

BROWN, R. G. B. 1977. The Senegal Survey biological programme, February-March 1976. *CSS Baffin* Offshore Survey, Senegal and The Gambia. Vol. 1. DFE, *Fisheries and Marine Service, Ottawa:* 119-127.

BROWN, R. G. B. 1978. Atlas of eastern Canadian seabirds. Supplement II: Labrador. *Canadian Wildlife Service, Ottawa, manuscript report.*

BROWN, R. G. B. 1978. Atlas of eastern Canadian seabirds. Supplement Ill: Baffin Bay and adjacent Sounds. *Canadian Wildlife Service, Ottawa, manuscript report.*

BROWN, R. G. B. 1978. Birds at sea: western Atlantic. *Ibis 120;* 116-117.

BROWN, R. G. B., BOURNE, W. R. P., and WAHL, T. R. 1978. Diving by shear-waters. *Condor 80:* 123-125.

GASTON, A. J. 1978. Seasonal and diurnal variations in numbers of Brunnich's Guillemots on Prince Leopold Island, Canada. *Ibis. 120;* 111.

GASTON, A. J. and NETTLESHIP, D. N. 1978. Population reduction of Thick-billed Murres *Uria lomvia* at Cape Hay, Bylot Island, Lancaster Sound, N.W.T. *Canadian Wildlife Service, Ottawa, manuscript report:* 15 pp.

LINTON, A. 1978. The food and feeding habits of Leach's Storm-petrel *(Oceanodroma leucorhoa)* at Pearl Island, Nova Scotia and Middle Lawn Island, Newfoundland. M.Sc. thesis, Dalhousie University, Halifax, N.S.: 112 pp.

LINTON, A., and NETTLESHIP, D. N. 1977. Biological investigation of Northern Fulmars *(Fulmarus glacialis)* at Prince Leopold Island, N.W.T., summer *1976. Canadian Wildlife Service, Ottawa, manuscript report:* 152 pp.

LOCK, A. R. 1978. A study of abundance and movements of gulls attracted to dumps located near Prince Edward Island airports. Canadian *Wildlife Service, Ottawa, manuscript report: 47* pp.

NETTLESHIP, D. N. 1977a. Seabird resources of eastern Canada: status, problems and prospects. *In* Canada's Threatened Species and Habitats, *eds.* T. Mosquin and C. Suchal. Proceedings of the Symposium, May 20-24, 1976. *Canadian Nature Federation, Ottawa, Spec. Publ. 6:* 96-108.

NETTLESHIP, D. N. 1977b. Studies of seabirds at Prince Leopold Island and vicinity, Northwest Territories: preliminary report of biological investigations. *Canadian Wildlife Service, Ottawa, Progress Note Number 73:* 11 pp.

NETTLESHIP, D. N. 1977. Resume of current research on seabirds in northern Canada, *1976. Canadian Wildlife Service, Ottawa, manuscript report:* 3 pp.

NETTLESHIP, D. N. 1978. Population analysis of colonial nesting seabirds from photography. *Ibis 120:* 119.

NETTLESHIP, D. N. 1978. Seabird research in northern Canada. *Canadian Wildlife Service, Ottawa, manuscript report:* 3 pp.

NETTLESHIP, D. N. 1978. The potential for recovery of marine organisms following an oil spill in Lancaster Sound and vicinity. FEARO Public Hearings: Lancaster Sound Drilling Proposal, Pond Inlet, N.W.T.: 9 pp.

NETTLESHIP, D. N., and GASTON, A. J. 1978. Pelagic distribution of seabirds - western Lancaster Sound and Barrow Strait, Preliminary Report 1977. Environmental Social Program Northern Pipelines, ESCOM Report No. *AI-09; 73* pp.

NETTLESHIP, D. N., and GASTON, A. J. 1978. Patterns of pelagic distribution of seabirds in western Lancaster Sound and Barrow Strait, Northwest Territories, in August and September, 1976. *Canadian Wildlife Service, Ottawa, Occasional Pap. 39: 40 pp.*

PEAKALL, D. B., NETTLESHIP, D. N., and PEARCE, P. A. 1978. Chemical pollution: western Atlantic. *Ibis 120;* 106.

Major Cruises of **1977/78**

1977 Cruises Operated by Ships Division, Institute Facilities

Cruise No. & Vessel	Cruise Dates	Officer in Charge	Area	Objectives
77-001 *Dawson*	March 9-13	R. O. Fournier, Dalhousie Univ.	NS Shelf and Slope	Plankton studies
77-002 Dawson	March 16-25	D. Bidgood, NSRF	NS Shelf and Shelf Edge	Core sampling; seismic profiling; water and suspended sediment sampling; equipment testing
77-003 Dawson	March 28-April 6	B. D. Petrie, AOL	Scotian Shelf Shelf Break and Slope, NS	Shelf Break Dynamics Program - see Coastal Oceanography, AOL
77-004 Dawson	April 12. 24	D. D. Sameoto, MEL	Coast of Gaspé PQ	Testing BIONESS and plankton studies - see Biological Oceanography, MEL
77-005 Hudson	April 13-22	D. L. McKeown, AOL	Emerald Basin, Shelf Break; Roseway Bank, NS	Equipment testing and evaluation
77-006 Dawson	April 25 May 4	M. I. El-Sabh, UQAR	Gulf and estuary of St. Lawrence	CTD profiling; zooplankton and fish larvae sampling; current meter moorings; etc.
77-007 Hudson	April 28-May 11	A. W. Herman, AOL	NS Shelf	CTD profiling; water sampling; plankton studies; equipment testing
77-008 *Baffin*				
Phase I	May 2-July 15	J. M. R. Pilote, AOL	Jacques Cartier Passage, St. Lawrence Estuary, PQ	Hydrographic charting; magnetic profiling; and surface water sampling for oil particle analysis

Phase II	July 25- September 26	R. K. Williams, AOL	Labrador Coast; Victoria Strait NWT, and Cambridge Bay to Cape Bexley, NWT	Hydrographic charting; magnetic profiling; and water sampling for oil particle analysis
77-009 *Maxwell*	May 2- October 28	M. G. Swim, AOL	Atlantic Provinces	Hydrographic charting
77-010 *Dawson*	May 9- 19	R. F. Reiniger, AOL	Gulf Stream	Recovery and placement of current meter moorings; seawater sampling; CTD and XBT profiling
77-011 *Hudson*	May 12- June 2	L. H. King, G. B. Fader. AGC	Eastern Grand Banks; Flemish Cap	Surficial and bedrock geology data collection and sampling; Loran-C calibration and evaluation
77-012 *Meta*	May 11- October 25	S. S. Dunbrack, AOL	NB Coast	Chart revisions; navigational range surveys; miscellaneous hydrographic charting
77-013 *Dawson*	May 30. June 3	R. O. Fournier, Dalhousie Univ.	Halifax Section; NS Shelf and Slope	Plankton studies
77-014 *Hudson*	June 5- *23*	C. E. Keen, AGC	Continental margin northeast of the Grand Banks	Geophysical studies; piston coring; first use of the OBS under operational conditions
77-015 *Dawson*	June 13. *22*	K. R. George, AOL	Gulf of St. Lawrence	Oil sampling of the sunken *Irving Whale*
77-016 *Martin Karlsen*				
Phase I	July 3- August 18	D. D. LeLievre, AOL	Labrador coast from Cape Harrison to Cape Makkovik	Hydrographic charting (inshore route survey)

Phase II	August 19-October 11	D. D. LeLievre, AOL	Northern Labrador Sea	Continuation of the hydrographic/geophysical survey (bathymetry, gravity, and magnetic profiles)
77-017 *Dawson*	July 4-14	B. D. Petrie, AOL	Scotian Shelf, Shelf Break and Slope, NS	Recovery and replacement of shelf break array; CTD profiling; recovery of CODS meteorological data; Batfish towing
77-018 *Hudson*	July 11-15	P. F. Kingston, AOL	Sambro Bank, NS	Equipment testing and evaluation
77-019 *Labrador, d'Iberville*	July 19-September 29	A. L. Adams, AOL (now I.F.)	Eastern arctic	Route surveys; standard charting
77-020 *Dawson*	July 25-29	R. O. Fournier, Dalhousie Univ.	Off southwestern tip of NS	Plankton studies
77-021 *Hudson*	July 25-August 22	R. H. Fillon, AGC	Labrador Shelf and Saglek Bank	Geological studies; determination of glacial history; miscellaneous projects
77-022 *Dawson*	August 1-10	B. Sundby, UQAR	Scotian Shelf; Gulf of St. Lawrence	Collection of undisturbed sediment cores; water sampling
77-023 *Dawson*	August 22-September 2	K. Kranck, AOL	Bay of Fundy	Study of suspended particulate matter
77-024 *Hudson*	August 22-September 17	E. P. Jones, AOL	Eastern arctic and Labrador Sea	Chemical data collection; investigation of oil seep area near Scott Inlet
77-025 *Dawson*	September 6-9	R. O. Fournier, Dalhousie Univ.	Halifax Section; NS Shelf and Slope	Plankton studies
77-026 *Dawson*	September 10-16	N. S. Oakey, AOL	Off NS Shelf at 42°N, 63°45'W	Octuprobe microstructure profiling; CTD profiling; vertical current meter testing

77-027 Hudson	September 18-October 13	B. MacLean, AGC	Baffin Island Shelf, Scott Inlet, and vicinity	Geophysical data collection and profiling; bedrock coring; sediment reconnaissance; miscellaneous studies
77-028 Dawson	September 19-*27*	R. W. Trites, MEL	SW Scotian Shelf; northern Georges Bank	Herring larvae sampling and studies; CTD and current meter profiling; physical oceanography studies
77-029 Hudson	October 13-November 3	J. R. N. Lazier, AOL	Labrador Shelf and Slope	Miscellaneous studies; continued development of Loran-C navigation software
77-030 Baffin	October 17-December 19	L. A. E. Doe, Dalhousie Univ.	NS to Peru (325 stations)	Multidisciplinary studies of problems related to the Peruvian anchovy fishery
77-031 *Dawson*	October 24-November 6	S. Akenhead, Nfld. Biological Station	Flemish Cap and adjacent waters	Hydrographic surveys and biological studies
77-032 Maxwell	November 1-4	M. G. Swim, AOL	NS Shelf south of Halifax; St. Margaret's Bay, NS, and vicinity	Testing of the Hi-Fix 6 Positioning System
77-033 Maxwell	November 7-12	T. R. Foote, AOL	Gulf of St. Lawrence	Ice forecast cruise for AES
77-034 Dawson				
Phases I and II	November 9-18, 20-25	C. T. Schafer, AGC	Eastern Newfoundland Basin and Slope	Marine geology survey
77-035 Maxwell	November 16-25	M. I. El-Sabh, UQAR	Gulf of St. Lawrence	Study variability and dynamics of the Gaspé Current

77-036 *Dawson*	December 3-14	R. F. Reiniger, AOL	Gulf Stream	Recovery and placement of current meter moorings; testing of CTD equipment; XBT profiling
77-050 Various vessels	January-December	Various MEL scientists	St. Margaret's Bay, NS	Biological studies
77-051 Various vessels	January-December	Various MEL scientists	Bedford Basin, NS	Biological studies
77-052 *Navicula*	Late April-end of October	Various MEL scientists	St. Georges Bay, NS	Ecological studies of St. Georges Bay

1978 Cruises Operated by Ships Division, Institute Facilities

Cruise No. & Vessel	Cruise Dates	Officer in Charge	Area	Objectives
78-001 *Dawson*	January 3-*8*	B. D. Petrie, AOL	NS Shelf and Slope	Shelf Break Dynamics Program - see Coastal Oceanography, AOL
78-002 *Hudson*				
Phase I	January 20-February 8	J. R. N. Lazier, AOL	Labrador Shelf and Slope; Labrador Sea; Cape Farewell, Greenland	Recovery and placement of current meter moorings; CTD profiling for studying heat content of the upper layers
Phase II	February 10-March 2	J. R. N. Lazier, AOL	SE Labrador Sea	Study of the offshore flow of the Labrador Current and influence of the Atlantic current

Phase III	March 7-March 31	R. A. Clarke, AOL	Labrador Sea	Recovery and placement of current meter moorings; CTD profiling; testing BIONAV system
Phase IV	April 2-14	R. A. Clarke, AOL	Cape Farewell, Greenland	CTD profiling; recovery of current meter moorings
Phase V	July 14-20	J. R. N. Lazier, AOL	Labrador Shelf and Slope	Recovery of current meter moorings
78-003 Dawson	February 27-March 3	R. O. Fournier, Dalhousie Univ.	NS Shelf	Plankton studies
78-004 *Dawson*	March 6-11	D. A. Huntley, Dalhousie Univ.	Mouth of Chignecto Bay, Bay of Fundy	Study of turbulence in the bottom boundary layer in tidal flow
78-005 *Dawson*	March 14-31	D. Bidgood, NSRF	NS Shelf and Slope	Core sampling; seismic profiling; water and suspended sediment sampling; equipment testing
78-006 *Dawson*	April 10-12	P. A. Yeats, AOL	Halifax Section	Sea water sampling for use in the ICES trace metal intercalibration exercise; particulate matter sampling
78-007 *Dawson*	April 24-28	B. T. Hargrave, MEL	Emerald Bank; Scotian Shelf	Study of benthic communities in regions of steep bottom gradients; measurement of gas and nutrient exchange at the sediment surface
78-008 *Hudson*	April 27-May 11	D. L. McKeown, AOL	Continental Shelf areas, NS and Nfld.	Equipment testing and evaluation
78-009 *Maxwell*	May 1-October 26	R. K. Williams, M. G. Swim, AOL	NB, NS, and Nfld.	Standard hydrographic charting
78-010 *Baffin*	July 12-September 29	R. K. Williams, AOL	Brig Bay, Nfld.; N Labrador Coast: and Ungava Bay	Hydrographic charting; magnetic profiling and bottom sampling

78-011 *Dawson*	May 4-17	R. F. Reiniger, AOL	Gulf Stream	Recovery and placement of current meter moorings; CTD and XBT profiling
78-012 *Hudson*	May 15-30	G. R. Peters, Memorial Univ.	Placentia Bay, Nfld.	To establish a geotechnical testing area; equipment development
78-013 *Meta*	May 11-October 25	V. S. Gaudet, AOL	Western NS and southern NB coastal areas	Chart revisory and navigational range surveys
78-014 *Dawson*	May 23-28	R. O. Fournier, Dalhousie Univ.	NS Shelf	Plankton studies
78-015 *Dawson*	June 1-7	D. D. Sameoto, MEL	Bedford Basin, NS; Shelf edge	Testing BIONESS sampler; plankton studies - see Biological Oceanography, MEL
78-016 *Hudson*	June 2-21	J. M. Bewers, AOL	Western North Atlantic	Study of chemical anomalies; trace metal measurements; multidisciplinary studies
78-017 *Dawson*	June 12-19	C. L. Tang, AOL	NW Gulf of St. Lawrence	Study of the Gaspé Current; circulation study of the NW Gulf of St. Lawrence
78-018 *Dawson*	June 20-July 5	M. I. El-Sabh, UQAR	Lower St. Lawrence estuary; Gaspé coast; Baie de Chaleur and Magdalen Shallows	Study of variability and dynamics of the Gaspé Current; fish larvae study
78-019 *Martin Karlsen*				
Phase I	June 26-July 19	G. W. Henderson, AOL	Labrador Sea	Hydrographic and geophysical charting (natural resource charts)
Phase II	July 19-October 14	G. W. Henderson, AOL	Cape Harrison to Cape Makkovik, Labrador	Hydrographic charting (inshore route survey)

78-020 *Hudson*	June 27- July 19	C. E. Keen, AGC	NS Margin; Orphan Knoll Basin; and Labrador Shelf	Geophysical surveys; dredging; retrieval of current meter moorings; piston coring
78-021 *d'Iberville, St. Laurent, MacDonald*	July 29- October 27	M. A. Hemphill, AOL	Eastern arctic	Standard hydrographic charting
78-022 *Dawson*	July 17- *27*	D. J. W. Piper, Dalhousie Univ.	Laurentian Fan	Study of the Pleistocene growth pattern of the Laurentian Fan
78-023 *Hudson*	July 20- August 10	R. T. Haworth, AGC	Continental shelf, northeast Nfld.	Rock core drilling for geological mapping
78-024 *Dawson*	July 31- August 4	R. O. Fournier, Dalhousie Univ.	Yarmouth, NS, and vicinity	Plankton studies
78-025 *Dawson*	August 4- *22*	C. L. Amos, AGC	Bay of Fundy	Multidisciplinary data collection as baseline information for tidal power development studies
78-026 *Hudson*	August 25- September 16	E. M. Levy, AOL	Near Scott Inlet, Buchan Gulf, Lancaster Sound, and Melville Bay	Study of potential arctic oil seep areas, their sources and chemical nature, etc.
78-027 *Dawson*	August 28- September 1	A. S. Bennett, AOL	Emerald Basin; Bedford Basin, NS	Equipment evaluation
78-028 *Dawson*	September 11- 21	M. J. Dunbar, McGill Univ.	NE Gulf of St. Lawrence	Chemical and biological studies
78-029 *Hudson*	September 17- October 23	B. MacLean, AGC	Baffin Island Shelf and Baffin Bay	Geophysical and geological studies

78-030 *Dawson*	September 23. October 2	C. L. Tang, AOL	NW Gulf of St. Lawrence	Recovery of moorings; circulation study
78-031 *Dawson*	October 10- November 10	R. W. Trites, MEL	Georges Bank; Gulf of Maine	Herring larvae study
78-032 *Hudson*	October 23- 30	J. R. N. Lazier, AOL	Hamilton Bank, Labrador Shelf	Placement of current meter moorings; CTD profiling
78-033 *Maxwell*	October 30- November 10	R. G. Burke, AOL	NS Shelf - approaches to Halifax Harbour	Equipment evaluation
78-034 *Dawson*	November 16- 22	T. R. Foote, AOL	Gulf of St. Lawrence	Ice forecast cruise for AES
78-035 *Dawson*	November 27- December 7	R. F. Reiniger, AOL	Gulf Stream	Recovery and placement of moorings; equipment testing; etc.
78-036 *Dawson*	December 11- 16	R. O. Fournier, Dalhousie Univ.	SW Nova Scotian Shelf	Plankton studies
78-050 *Navicula*	mid-April- late October	Various MEL and Dalhousie Univ. scientists	St. Georges Bay, NS	Ecological studies
78-051 *Sigma-T*	February- December	Various MEL scientists	Bedford Basin, NS	Primary productivity studies; nutrient recycling studies
78-052 *Gulf Star*	July 20- October 4	P. McLaren, GSC	E Lancaster Sound and Baffin Island	PetroCanada/GSC biological and geological survey

Cruises of the Marine Fish Division, 1977 and 1978

Cruise Number & Vessel	Cruise Dates	Officer in Charge	Area	Objectives
E. E. Prince-783	May 24-June 3, 1977	P. F. Lett	Southern Gulf of St. Lawrence	Mackerel egg survey
E. E. Prince-184	June 17-27, 1977	P. F. Lett	Southern Gulf of St. Lawrence	Mackerel egg survey
E. E. Prince-191	November 15-*24,* 1977	R. N. O'Boyle	Georges Bank	Herring larval patch study
E. E. Prince-205	June 19-30, 1978	P. F. Lett	Southern Gulf of St. Lawrence	Mackerel egg survey
Lady Hammond-1	June 21-29, 1978	D. F. Gray	Southern Gulf of St. Lawrence	Mackerel egg patch study
Lady Hammond-6	September 11-October 11, 1978	D. Clay	Sable Island Bank	Silver hake survey
Lady Hammond-7	October 16-November 10, 1978	R. N. O'Boyle	Georges Bank	Herring larval patch study
Anne Jolene-1	October 24-November 5, 1978	W. D. Smith	Scotian Shelf	Pollock and cod migration studies
Pubnico Libra-1	October 18-19; 1978	A. Sinclair	Northumberland Strait	Herring migration studies

Scotia Point-1	October 23-27, 1978	A. Sinclair	Northumberland Strait	Herring migration studies
Canso Condor-3	October 20-November 10, 1978	K. Waiwood	Georges Bank	Energy flow studies
Canso Condor-4	November 13-20, 1978	L. Cleary	Scotian Shelf	Pollock and cod migration studies

NOTES:

(1) Abbreviations used in both tables and not in the Abbreviations and Acronyms list include: E - Eastern; N - Northern; NSRF - Nova Scotia Research Foundation; NW - Northwest; SE - Southeast; Univ. - University; UQAR - Universite de Quebec à Rimouski; and XBT - Expendable Bathythermograph.

(2) For further information on particular cruises contact: M. P. Latremouille, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, NS, B2Y 4A2.

(3) No cruises corresponding to numbers 77-037 to 77-049 and 78-037 to 78-049 were undertaken.

ToC

Dr. William L. Ford Retires

William L. Ford completed 13 years as leader of the Bedford Institute of Oceanography in November 1978, and was succeeded as Director-General by Dr. Cedric R. Mann. Friends and colleagues celebrated the years of the Ford leadership at a party where Bill received many gifts and accolades. Among them was a special plaque presented by Regional Hydrographer Russ Melanson, below right. Russ himself retired in December after 36 years with the Canadian Hydrographic Service.

BIO Building Expansion

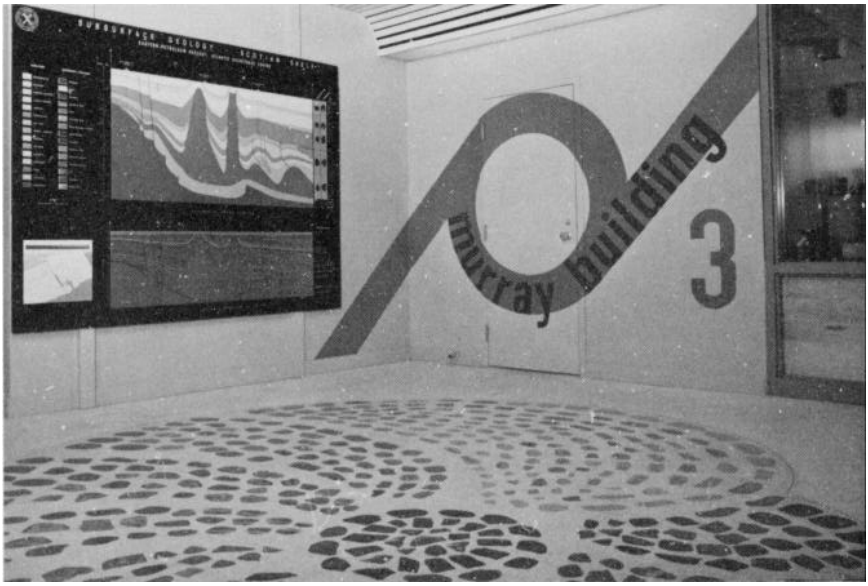
The construction of new buildings at the Institute, begun in February 1975, was mentioned in the last Biennial Review. Steady progress has been made during the past two years; the building program is proceeding within. the budgeted costs, and approximately on schedule. Design for all major buildings is now complete, and construction of the major units is either underway or complete. The major tasks remaining include the completion of all buildings, upgrading and renovations to the original buildings, and landscaping of the site.

When the buildings were planned, some five years ago, a limited growth was predicted for Government staff, and it was anticipated that commercial contractors would require substantial space at the Institute. The growth in the commercial area has been much slower than anticipated - but this has been more than balanced by the transfer of Government staff from Ottawa under the decentralisation program and the increase in staff engaged on work directly associated with the fisheries of the 320 kilometre limit. As a result, the new buildings (when completed) will be comfortably filled by the present staff, although it will be possible to remove the old temporary accommodation at the Institute. Some of the new facilities are shown in the following photographs.

An aerial view looking east of the BIO complex. New facilities include: the Murray Building (4), which houses AGC and RMCB offices; the Holland Building (5), now under construction, that will house common services such as the library, computing Centre,' and cafeteria; and the Strickland Building (7) where some MEL offices and laboratories are located. Older sections of the complex are the fish laboratory (1), Vulcan Building (2), Polaris Building (3), and Van Steenburgh Building (6). (BIO 5115-17)

Geophysicist Dick Haworth moves into his new office in the Holland Building. (BIO 5784)

Ecologist Don Gordon at work in his new Strickland Building laboratory. (BIO 5192)



The chambers of the foraminifera Elphidium clavatum *are depicted in this floor-mosaic by Caroline Wallace at the third-floor entrance to the Murray Building. A photograph of the actual fossil is on page 159. (BIO 5178)*

Technicians of the Environmental Marine Geology group at work in their new laboratory in the Murray Building. (BIO 5201)

Steelwork for the roof of the auditorium of the Holland Building is lowered into place by a crane. This new building will house common services such as the library, computing centre, and cafeteria. (BIO 5204-11)

Errata

(1) The figure caption on page 20 should read 1,200 to 1,500 meters.

(2) The figure caption on page 199 should read: Common Murres (foreground) and Northern Gannets on Funk Island, Newfoundland. Funk Island is location 26 on the map following. (Courtesy of D. N. Nettleship)

Fisheries and Environment Canada **Pêches et Environnement Canada**

Energy, Mines and Resources Canada **Energie, Mines et Ressources Canada**