Bedford Institute of Oceanography

2002 in Review

ToC

40th Anniversary Edition

Canada

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The cover image is the CSS Hudson *in the Canadian Arctic in the late 1980s.*

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INTRODUCTION

Anniversaries, in this case our 40th, are an opportunity for both celebration and reflection. We very much enjoyed our year of celebrations. *Open House 2002*, the special lecture by David Suzuki, the *Symposium on the Future of Marine Science*, and the Symphony Nova Scotia concert all contributed to the sense of community that is a strong characteristic of the Institute. The lectures by Dale Buckley (during the opening ceremonies for open house) and by Bosko Loncaravic (the first lecture of our symposium) provided rich memories of research highlights over four decades. Both talks emphasized the key role of scientific advice to the government of Canada (such as input to the Gulf of Maine boundary dispute decided upon at the World Court in The Hague and the *Arrow* oil spill in Chedabucto Bay). These are examples of the key role the Institute has played in enhancing the economic strength of Atlantic Canada.

Other lectures at the BIO 40th anniversary symposium looked towards the challenges that may face the Institute in its next 40 years. Specifically, in the closing remarks of the symposium, Robert Fournier of Dalhousie University, focussed on population pressures and their impacts as the key challenge for the future fate of the oceans. Moreover, the oceans are a global system and events taking place far away from Canadian shores will affect us. Solutions to these future challenges will require a multi-disciplinary, integrated approach, on both a national and international scale. Given the experience over the last 40 years, BIO is very well positioned to provide a leadership role in tackling these future challenges.

BIO is perhaps somewhat unique when compared to other marine science institutes such as Scripps, Woods Hole, and Southampton; we are a federal government facility rather than an academic one. As such, one of our strengths has been the applied focus of research, monitoring, and advisory activities. This is a strength that will continue to be enhanced during the next few years as the role of science within government evolves. BIO is a splendid example of 'public science' for the good of Canadians.

Jacob Verhoef, Director
Geological Survey of Canada (Atlantic)
Natural Resources Canada

M Sinclair

Michael Sinclair, Director,
Bedford Institute of Oceanography
and Regional Director, Science
Fisheries and Oceans Canada

Carol Ann Rose
A/Regional Director
Oceans and Environment
Fisheries and Oceans Canada

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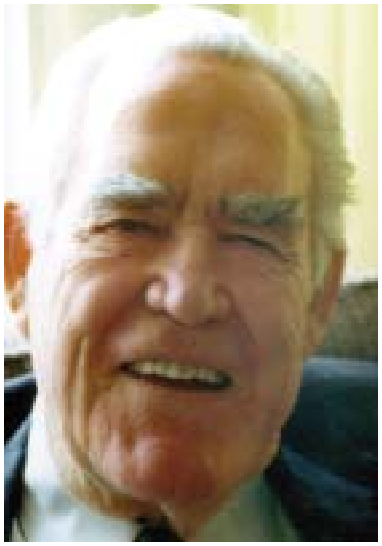
DEDICATION

This anniversary issue of our annual report is dedicated to the four Bills instrumental in founding and bringing BIO to the forefront as a world-class scientific Institute. In the opening address for BIO's 40th Anniversary Symposium in October 2002, Dr. Bosko Loncarevic adroitly summarized their contributions to the Institute. He indicated that, "These men are the giants of Canadian science to whom our science and nation owe much. Canada's marine scientific community is fortunate that the four Bills were there at the right time and in the right place because without them this would be a different, and in my opinion, much diminished Institute." Dr. Loncarevic's tribute to these four remarkable individuals is highlighted in italics at the beginning of each summary.

Dr. Bill van Steenburgh.

*"**Bill van Steenburgh,** the Director-General of DMTS, who convinced the government that Marine Sciences are a national priority".* Dr. van Steenburgh was instrumental in promoting the concept of an oceanographic institute on the Atlantic Coast of Canada and bringing it to fruition. He and his colleagues on the Canadian Committee for Oceanography had a vision of multidisciplinary research teams with the necessary vessel and laboratory support to acquire knowledge for ocean management. As a result of his efforts, the creation of BIO and the construction of the scientific research vessel *Hudson* were celebrated in 1962. The original wing of BIO is named in honour of Dr. van Steenburgh.



Dr. Bill Cameron.

*"**Bill Cameron**, the Director of Marine Sciences Branch, who fought day-to-day battles for us in Ottawa*." Dr. Cameron was an internationally known oceanographer, author, and lecturer who worked behind the scenes in the Department of Mines and Technical Surveys (DMTS) in Ottawa to support BIO. As one of the early professors of oceanography at the University of British Columbia, he was instrumental in the establishment and organization of the Institute of Oceanography. He brought young scientists into this emerging field and inspired the direction of oceanography in Canada during the 1950s and 1960s. Dr. Cameron was a specialist in theoretical oceanography, in particular the theory of circulation of estuaries, and was best known for his Arctic studies and as a member of the joint Canada-United States Beaufort Sea

Expeditions. As a science administrator, he understood the need for interaction between all disciplines involved in marine research and the establishment of common facilities and services. Dr. Cameron brought to the Institute his vision of how BIO was to function and this was the management model used until the mid-1980s.

Dr. Bill English.

***"Bill English,** the first Director, who had to create the first concept for an institute on the shores of Bedford Basin".* Dr. English was a dynamic leader who brought to BIO his extensive experience in planning and directing elaborate sea-going operations, his impressive scholastic record, and an outstanding naval career in the Second World War. His vision for BIO was for an institute with a substantive measure of regional autonomy, which he considered essential to its success. In his address at the opening of BIO in 1962, he indicated that oceanography in the title of BIO was used in the widest sense to mean the science of the sea, from the most abstract mathematical description to the most down to earth technical survey. Dr. English described the Institute as a place where the oceanographic background of the Fisheries Research Board would collaborate with the expertise of the Marine Sciences Branch of the Department of Mines and Technical Surveys in a fundamental oceanographic research program that would benefit both organizations. During his two years as director, it became a personal mission to facilitate the autonomy of the Institute despite various challenges. The Institute as an autonomous unit was the creation of Dr. English.

Dr. Bill Ford.

***"Bill Ford**, who developed the concept of the campus and with skill made it the foundation of the BIO."* Dr. Ford was the second Director of BIO and was at the helm between 1965 and 1978, a period of unparalleled expansion of the Institute. His concept for the Institute was based on a community of experts seeking to understand the marine environment and he had a talent for ensuring that the programs developed at BIO were balanced among the various scientific disciplines. He instilled a spirit of goodwill and cooperation among the various research teams and fostered multidisciplinary research. It was through his skills in negotiating with Treasury Board, that two major building expansions occurred on the BIO campus. Dr. Ford was instrumental in building BIO into the world-renowned institution that it is today and developing the Institute as a national Canadian resource. Scientifically, Dr. Ford was perhaps best known for his leadership of Operation Cabot in the 1950s, which was the first Canada-USA multi-ship study of the Gulf Stream.

RETROSPECTIVE 2002

In 2002, the Bedford Institute of Oceanography celebrated 40 years of scientific excellence and continued to support geological, biological, and oceanographic research as well as management activities mandated by Fisheries and Oceans Canada, Natural Resources Canada, the Department of National Defence, and Environment Canada.

Highlights of the anniversary celebrations are recorded in this report along with historical articles, features on research initiatives, and activities undertaken to support emerging priorities in 2002.

NEW INITIATIVES

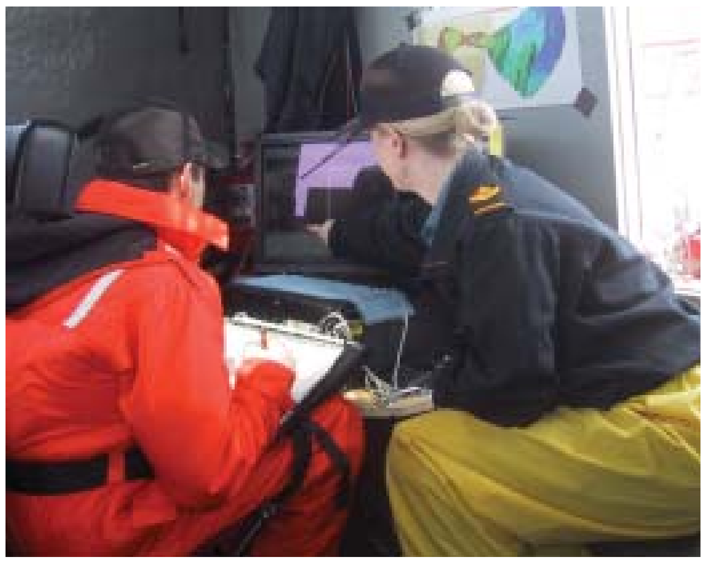
Natural Resources Canada (NRCan) established the office of the **Climate Change Impacts and Adaptation Research Network Coastal Node** at BIO in January 2002. The office supports coastal research in Atlantic Canada that contributes to Canada's climate change program. Primary objectives are to:

- contribute to the coordination and interaction of climate change research and to provide greater visibility and understanding of the issues;
- provide a source of information to communities, governments, business, and industry;
- involve a broad range of researchers to increase the research on climate change impacts and adaptation capacity in Canada; and
- assist in the coordination of climate change vulnerability assessments.

In March 2002, the **Route Survey Office**, part of a larger organization within the Canadian Navy called TRINITY, acquired a Klein System 5500 side scan sonar and used it, with excellent results, to survey a portion of Halifax Harbour.

DFO's **Aquaculture Policy Framework** (APF) was announced in June, 2002. This framework orients DFO around a common vision for marine and freshwater aquaculture in Canada and provides guidance to employees in their daily regulatory and program decisions. The Aquaculture Coordination Office is leading a multi-disciplinary exercise to implement the principles of the APF within the Maritimes Region that is expected to be finalized in March 2003.

BIO scientists participated in a major **international expedition in the Nordic Seas** on board the Swedish icebreaker IB *Oden* as part of a major two-ship survey in the general region where major deep water masses are formed, and a region crucial to the thermohaline circulation system. IB *Oden* surveyed the ice-covered areas while the US ship RV *Knorr* surveyed ice-free areas in the same region.



Kenny Ingram (left) and Krista Ryan (right) collecting data using the Klein System.

The Honourable Robert G. Thibault and the Honourable Ernest Fage signed a renewed Canada/Nova Scotia **Memorandum of Understanding (MOU) on aquaculture development** on June 18, 2002. The renewed MOU enables both the federal and provincial governments to continue working together on the environmental management of the aquaculture industry in Nova Scotia.

In June, a new field study began to take **multi-year moored measurements of the Labrador Current** and other currents in Flemish Pass off the northeast Grand Bank. This work is part of the Ocean Climate and Variability Research Program and is jointly funded through the federal Panel on Energy Research and Development (PERD) and collaborative agreements with three oil companies.

July 12, 2002 marked the release of **Canada's Oceans Strategy (COS)**, the federal government's policy statement for ocean management in Canada. Based on the authority and direction set out in the *Oceans Act*, COS defines the vision, principles, and policy objectives for the future management of Canada's estuarine, coastal, and marine ecosystems. It calls for ocean governance that

emphasizes collaboration with all levels of government; shared responsibilities for common objectives; and, engaging Canadians in oceans-related decisions. The article on COS in the *Resource Management Highlights*, provides an overview of the implementation of the strategy at a regional level.

An **Oyster Spat Experimental Project** in the Bras d'Or Lakes, N.S. began in late summer 2002. The project involves the collection and harvesting of American oyster spat/seed from a contaminated/closed area. The objectives are to determine the success of such a collection area, and the volume and size of the seed from a closed/contaminated area. The experience and contacts developed under this project are expected to be invaluable in the efforts to respond to the oyster disease MSX. The development of MSX-resistant strains for the aquaculture industry and rehabilitation of wild oyster beds are especially important socio-economically in Cape Breton. Oysters also provide an important food fishery for the five Unama'ki First Nations.

The "Grand Opening" of the **Unama'ki Institute of Natural**

Abandoned and partly collapsed foundations attest to rapid erosion of low cliffs at Cap Lumière, NB. Other homes and businesses along this coast, including those in the background, are at risk from accelerated coastal erosion resulting from rising sea levels and other impacts of climate warming.

Resources took place in Eskasoni, Cape Breton, on September 6. Dr. Peter Harrison, Deputy Minister of Fisheries and Oceans Canada, announced a Unama'ki-DFO scholarship to be awarded by Dalhousie University to a graduate student in the spring of 2003. The student will conduct research in Cape Breton on a priority issue of the First Nations and will mentor Aboriginal high school students during the period of research. This scholarship is part of BIO/Dalhousie efforts to enhance research and mentoring at the new First Nations Institute.

In October, DFO announced a project to create a detailed **atlas of fish-spawning areas** on the Scotian Shelf off the Atlantic coast of Nova Scotia. Through this project, DFO will indicate the time of year when spawning occurs, and map spawning areas, key nursery areas, and locations of larval concentrations of commercial finfish and shellfish. The project stems from increased petroleum exploration activity off Nova Scotia and will be useful to scientists, managers, regulators, industry, consultants, and fishermen in identifying potentially harmful environmental effects from exploration activities. This is a joint industry/government initiative and is managed by a 12-member advisory board. It is expected that the atlas will be completed by early 2004.

In November 2002, the **DFO National Centre for Offshore Oil and Gas Environmental Research** (COOGER) was established to facilitate the development of coordinated research programs in areas of marine environmental and oceanographic research related to oil and gas activities and DFO mandates. The secretariat for the Centre is located at BIO and Dr. Ken Lee has been appointed executive director. The Centre will provide a focus for research activities on offshore oil and gas in DFO and it will also provide a single point of contact for external agencies and the industry.

On November 12, George Iwama, Director-General of the **Institute of Marine Biosciences** of the National Research Council of Canada, and Paul Keizer of BIO signed an MOU between the two institutes. The memorandum includes the DFO laboratories in New Brunswick (the Gulf Fisheries Centre in Moncton and the Biological Station in St. Andrews). This MOU will enhance collaborative research among the four laboratories, in particular on mariculture and biotechnology.

The Honourable Robert G. Thibault (left), Minister of Fisheries and Oceans Canada, and Dr. Kenneth Lee (right), Executive Director of the Centre for Offshore Oil and Gas Environmental Research (COOGER), at COOGER's opening event.

Diana Munro and Matt Dill processing samples at the new Environment Canada mobile microbiology lab.

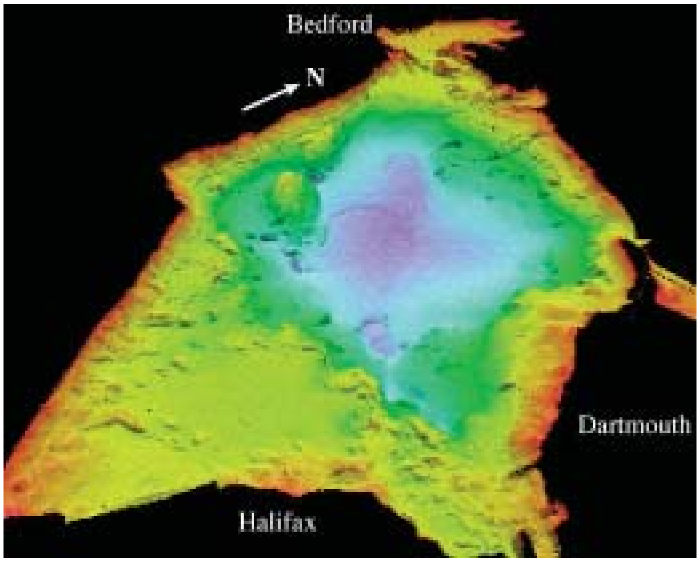
In 2002, Environment Canada obtained a new **mobile microbiology lab** for the Shellfish Section at BIO. This lab, used throughout the Maritime Provinces, enables Environment Canada to sample the water quality for aquaculture and shellfish harvesting sites along coastal waters. The mobile lab complements the work conducted by the fixed labs at the Bedford Institute of Oceanography and the Environment Canada laboratory at the Environmental Science Centre on the University of Moncton campus, New Brunswick.

The **BIO history project** began in 2002 to record the recollections of early staff in an attempt to capture the flavour of the BIO experience and document contributions of the Institute to science and to Canadian society. Interviews are ongoing and are being conducted in preparation for the 50th anniversary of the Institute in 2012. Transcripts will be prepared, archived, and made available to future researchers and the public.

WORKSHOPS AND INTERNATIONAL MEETINGS

Barry Hargrave chaired the workshop on **Environmental Studies for Sustainable Aquaculture** (ESSA), held on January 16-18, 2002 at BIO between ESSA science staff and members of the National Habitat Management Working Group on Aquaculture. Physical circulation models, new chemical and biological methods, environmental data, and habitat management questions relevant to predicting potential far-field environmental effects of salmon aquaculture were reviewed. Near-field impacts and recovery and evaluation of potential effects of toxic chemicals used in the aquaculture industry were also presented. Research conducted during ESSA studies in Bay d'Espoir (Newfoundland), Letang Estuary, southwestern Bay of Fundy (New Brunswick), and Broughton Archipelago (south-central British Columbia) were reviewed.

On January 29, 2002 Gordon Fader, Natural Resources Canada (NRCan), gave a public presentation titled ***Bedford Basin Drained*** at the Maritime Museum of the Atlantic in Halifax. The presenta-



Three dimensional perspective view of Bedford Basin from southeast to northwest.

tion was an interpretation of the geology, evolution, and the natural and anthropogenic features of Bedford Basin at the head of Halifax Harbour. A tour of the basin was given based on multibeam bathymetry recently collected by NRCan and the Canadian Hydrographic Service. Highlights of the talk focused on the presence of former islands in the basin; archaeological sites of interest; the discovery of the *Erg* shipwreck - a wartime sinking in the basin with the loss of 19 lives; the discovery of the barge that caused the 1945 magazine explosion; 32 Volvo automobiles on the bottom; and many other fascinating aspects of the seabed. Over 300 people were in attendance and others were turned away for lack of space. As a result of public interest in the presentation, the Museum requested a repeat performance for their 20th year celebration in May.

The **Atlantic Science and Technology (S&T) Steering Committee**, chaired by Jacob Verhoef, NRCan, organized the first ever Atlantic S&T Forum in Halifax in February. The Steering Committee's members represent the four Atlantic Provinces. The forum brought together science managers and scientists to talk about common issues, with the 75-80 participants representing fourteen departments. Speakers came from government, university, and private industry. The interactive conference offered a mix of practical and conceptual sessions in various subjects and formats relating to important science issues - including what we are dealing with now and what we expect to confront over the next few years.

Norman A. Cochrane chaired the second session of the **4th Annual Northwest Atlantic Herring Acoustic Workshop** at BIO February 12-13, 2002. This international workshop brought together fisheries researchers and industry representatives with an ongoing involvement in the application of hydroacoustic techniques to herring stock assessment and management on the east coasts of Canada and the USA. The workshop allowed Canadian and American researchers to compare techniques and experiences in hydroacoustic assessment at a detailed technical level. It also afforded useful information exchanges between hydroacoustic equipment manufacturers and end-users.

The first workshop on the **Eastern Scotian Shelf Integrated Management (ESSIM) Forum** took place at Mount St. Vincent University, Halifax, Nova Scotia on February 20-21, 2002. This meeting was organized by DFO's Oceans and Coastal Management Division, for the purpose of initiating multi-stakeholder dialogue on integrated oceans management. The workshop objectives were: (i) to promote sectoral and cross-sectoral dialogue and capacity-building for integrated oceans management and planning; and (ii) to discuss key elements of the initiative, including: vision, objectives, and outcomes; a collaborative management and planning process; and the future integrated oceans management plan. Initial assessment of workshop outcomes by DFO highlights the following points:

- There was strong support from workshop participants to proceed in the general direction proposed for the development of the ESSIM Forum and the oceans management plan.
- The workshop succeeded in highlighting to the broader community the ongoing efforts for government engagement and coordination.
- There is now an emphasis on individual sectors and communities of interest to organize themselves in order to participate effectively in the process.

The Centre for Marine Biodiversity (CMB) held a workshop on **Canadian Marine Biodiversity** at White Point Beach Lodge, Nova Scotia from February 25 to March 1, 2002. The workshop was co-funded by DFO and the Census of Marine Life. Conveners were Kees Zwanenburg and Ken Frank of BIO; experts gathered from across Canada, the United States, and Europe to discuss current state of knowledge of marine biodiversity in Canada's three oceans. The deliberations were comprehensive and ranged from the manner in which historical patterns set the marine biodiversity stage in Canadian waters, the extent to which we know and do not know the true biological diversity of our oceans, to modern forces and processes affecting present day diversity. The workshop also discussed the urgent need to develop and implement effective plans for the conservation of Canada's marine biodiversity. Additional details are in the CMB article in the *Other Programs* section of this report.

R. O'Boyle chaired two Canada/US **Transboundary Resources Assessment Committee** (TRAC) meetings in 2002. The February meeting was convened in Woods Hole, Massachusetts to review the assessment models used for Georges Bank cod, and the April meeting took place in St. Andrew's, NB to consider status of the stock.

On March 25-26, 2002, Environment Canada (EC) hosted the **Ecological Risk Assessment Workshop** at BIO. This two-day event was open to all Environment Canada staff in the Atlantic Region and staff of the Disposal at Sea Program of EC across Canada. Case studies of how risk assessment has been applied to situations in the Atlantic Region were reviewed and a member of the US Army Corps of Engineers discussed how environmental risk assessment (ERA) is being applied to the ocean disposal of dredged materials. A representative from the Royal Military College in Kingston, Ontario, also presented recent ERA work conducted in Saglek, Labrador.

A **Gulf of Maine Sewage Workshop** took place at BIO, 11-12 April 2002, chaired by Ms. Pat Hinch from the Nova Scotia Department of Environment and Labour. More than 110 individuals from nine jurisdictions attended the two-day meeting that focused on funding mechanisms, public education, regulation and enforcement, and ecosystem health. Jocelyne Hellou, from BIO chaired the session on ecosystem health.

Natural Resources Canada and DFO organized a **European Union Seminar** at BIO in June. Participants included other federal government departments, provincial departments, private industry, and universities. The objective of the seminar was to inform Canadian technology companies and researchers about opportunities for partnering with counterparts in the European Union for:

- participation in the European Commission's 2002-2006 Sixth Framework Program on Research and Technological Development;
- participation in the pan-European Cooperation in Science & Technology (COST) Research Networks; and
- participation with Europeans in Canadian government research and development.

On June 24 and 25, Natural Resources Canada held a workshop to outline directions for the new **Geoscience for Ocean Management Program**. Staff from NRCan across Canada, as well as clients from other federal departments, the private sector, universities, and the provinces attended. The workshop was considered to have successfully met its four objectives of:

- outlining and refining the program principles and objectives;
- hearing from key stakeholders on their needs for marine geoscience information;
- conducting round table discussions of stakeholder priorities and gaps; and
- initiating discussions on program content.

The Centre for Marine Environmental Prediction (CMEP) hosted a **Global Workshop for Assessing Operational Global Marine Environmental Prediction for Canada** at Dalhousie University, Halifax NS, August 26-27, 2002. Dr. Dan Wright was on the organizing committee for this national workshop sponsored by the Meteorological Service of Canada (with Hal Ritchie, Keith Thompson, and Francis Swiers). Major outcomes included the initiation of programs to conduct marine environmental prediction on a global scale.

The **American Geophysical Union (AGU) Chapman Conference** series consists of topical symposia to discuss current issues and to present recent results in ocean, earth, and atmospheric research. The 2002 Chapman Conference on *High-latitude Ocean Processes*, held in l'Estérel, Quebec from August 26 to 29, 2002 focused on physical processes in the Arctic and sub-Arctic oceans. Four scientists from BIO, Peter Jones, Allyn Clarke, Ewa Dunlap, and Charles Tang were among the 60 participants from Canada, USA, Norway, Germany, France, and China. Charles Tang was the lead convener and Peter Jones was an invited speaker of the conference.

The joint meeting of the **Association of Earth Science Editors (AESE)** and the **European Association of Science Editors (EASE)** was held in Halifax in September 2002. Members of the organizing committee included NRCan employees Jennifer Bates, Evelyn Inglis, Nelly Koziel, and Graham Williams. The meeting provided an opportunity for scientific editors from both sides of the Atlantic Ocean to share their experiences. A one-day field trip included a stop at Joggins to examine the exceptional Carboniferous fossil record of the coal age environment. At the banquet, the popular geology book, *The Last Billion Years,* was awarded the AESE award for outstanding publication.

Rob Fensome and Jennifer Bates receiving the AESE Outstanding Publication Award for The Last Billion Years *from past-President Evelyn Inglis - photo by Bob Davie.*

A two-day professional development workshop on ***Communicating Science*** was held in November at BIO. Science, public relations, and journalism students from Dalhousie University, Mount St. Vincent University, University of Kings College, and the College of the North Atlantic attended.

The **Regional Advisory Process** (RAP) conducted ten meetings in 2002 to peer review scientific analyses in support of the fisheries and oceans management in Gulf and Maritimes regions.

Over the last two years the Guysborough County Regional Development Authority (GCRDA) has been coordinating the development of a comprehensive information support tool for the purpose of enhancing aquaculture development in Guysborough County, N.S. The **Aquaculture Coordination Office** has been an active participant on the steering committee of this initiative.

Natural Resources Canada staff attended the annual Report of Activities meetings of the Nova Scotia, New Brunswick, and Newfoundland Geological Surveys. These meetings provide a forum for provincial and federal researchers and managers to exchange ideas on science issues of the day, and potential opportunities for collaborative projects between the provincial and federal departments.

AWARDS, HONOURS, AND TRIBUTES

Allyn Clarke was awarded the J.P. Tully Medal in Oceanography in May 2002 by the Canadian Meteorological and Oceanographic Society for "Outstanding commitment to Canadian oceanography, his pioneering work on deep convection in the Labrador Sea, and his national and international leadership in ocean and climate scientific research". Dr. Clarke has played a central role in the development and implementation of the World Ocean Circulation Experiment (WOCE) and Climate Variability and Prediction Experiment

(CLIVAR) both at the national and international levels. In support of his vision for the future of ocean exploration and development, he has been an active member of the Joint Scientific and Technical Committee for the Global Ocean Observing System (GOOS) and has been instrumental in preparing the ocean component of the Global Climate Observing System (GCOS). More recently, as a member of the Steering Committee for GOOS, he has been charged with helping provide scientific oversight for this program which arose from the Rio Environmental Summit.

Allyn Clarke received an *Editor's Citation for Excellence in Reviewing* by the American Geophysical Union at their spring meeting in 2002. This award was presented on behalf of the editorial board of the Journal of Geophysical Research-Oceans.

René Lavoie, Manager of the Invertebrates Fisheries Division received the Honorary Lifetime Achievement Award from the Aquaculture Association of Canada (AAC). The award was presented at the AAC Annual General Meeting in Charlottetown, P.E.I. on September 19, 2002. The AAC's Board of Directors presents the award to recognize individuals for their outstanding contributions to the Association and to the aquaculture sector in Canada. Dr Lavoie was chosen for his work towards environmentally responsible aquaculture development, especially shellfish, in Atlantic Canada and internationally.

The International Council for the Exploration of the Seas (ICES) celebrated its 100th anniversary at the 2002 Annual Science Conference in Copenhagen in early October. Noteworthy was the award for the best scientific paper of the conference, awarded to DFO scientist, **Trevor Platt** and his collaborators for their paper titled, *Ecosystem variation and fisheries: Operational test of the Match-Mismatch Hypothesis*. Dr. Platt's research associate, Dr. César Fuentes-Yaco, presented the paper.

The BIO Oceans Association Beluga Award was presented to **Peter Vass** of DFO's Marine Environmental Sciences Division on May 9, 2002 in recognition of his outstanding ability in the development of experimental scientific research equipment used for benthic studies in areas ranging from St. Georges Bay to the High Arctic. Currently, Peter is conducting field research on methylmercury biomagnification in the Bay of Fundy and continues to be part of the deep-sea trawling impact study, which has evolved to include deep-sea coral research and habitat mapping.

The winner of the 2002 A.G. Huntsman Award was **Dr. Donald W. Forsyth**, Professor of Geological Sciences at Brown University in Providence, Rhode Island. He was educated at Grinnell College (B.A. in physics), the Massachusetts Institute of Technology, and Woods Hole Oceanographic Institution (PhD in marine geophysics). He holds a number of awards from the American Geophysical Union and Geological Society of America. Dr. Forsyth is one of the world's outstanding marine geophysicists. With over 90 refereed publications, his research has had a broad impact on the marine geosciences in areas ranging from oceanic crustal structure to mantle dynamics, and in studies that combine both theoretical and observational methods. In the 1970s, he made the first detailed analysis of upper mantle velocity structure as a function of the cooling and thickening of the oceanic lithosphere and, in a separate study, was responsible for the first quantitative analysis of plate tectonic driving forces. In the 1980s, Dr. Forsyth pioneered early work on modeling the geodynamics of mantle flow and melting beneath mid-ocean ridges, and began to develop models to explain the variation in ridge crest topography with spreading rate. He invented a new type of gravity anomaly, the Mantle Bouguer Anomaly, which has been widely used to map crustal thickness variations in the oceans. Dr. Forsyth was one of founding members of the Ridge InterDisciplinary Global Experiments (RIDGE) program, and in the 1990s led the highly successful Mantel ELectromagnetic and Tomography Experiment (MELT), the largest marine seismic experiment ever attempted. Most recently, Dr. Forsyth is leading the development of the Oceanic Mantle Dynamics Initiative, a decade-long program that is intended to expand the use of broadband seismic techniques. Dr. Forsyth is known as an excellent educator, an outstanding colleague to a large number of scientific collaborators, is a model of integrity, and has been unselfish in the service that he has given to the scientific and university communities. The 2002 award was presented by Dr. Howard Alper, President of the Academy of Science, Royal Society of Canada at a ceremony at BIO on January 15, 2003.

Dr. Donald W. Forsyth (left) receiving the Huntsman Award from Dr. Howard Alper (right), President of the Academy of Science, Royal Society of Canada.

A **Commemorative Medal** was created to mark the 50th anniversary of the accession to the Throne of Her Majesty Queen Elizabeth II on February 6, 1952. This medal was awarded to individuals who have made a significant contribution to Canada, their community, or to their fellow Canadians. The Commemorative Medal is part of the jubilee year celebrations and was organized by the Department of Canadian Heritage. BIO recipients of the awards were:

- **Ralph Halliday** for exemplifying scientific and service excellence. He established the marine fish research program at BIO in 1977. His leadership and vision generated an outstanding monitoring program and a state-of-the-art advisory process.

- **Phil Hubley** is an engineer working on fresh water hatchery and habitat issues. He exemplifies high standards of technical excellence/service to clients, and is innovative in finding solutions to complex problems.

- **Heather Joyce** for producing excellent quality work as a hydrographer and chart maker. She volunteered for an extended assignment in Newfoundland and participated in an exchange program with the USA in 2002.

- During his long career, **Robert Lively** provided vital seagoing experience to major expeditions, led cruises, and supported software systems both onshore and at sea. He is a dedicated and versatile worker whose contributions are invaluable.

- **Pat Williams** provided essential service, corporate knowledge, and continuity to five managers at DFO's Ocean Science Division. She is quick and efficient in her work, and dedicated to providing outstanding service to her colleagues and to the public.

- **Steve Blasco** played a pivotal role in promoting the transfer of technology from government and university researchers to the exploration industry. A renowned marine geophysicist with the federal Department of Natural Resources, he has designed innovative equipment for the harvesting of ocean resources. Relating his experience as a member of the production team for the IMAX film Titanica, he uses his excellent communication skills to educate Canadians and share with them his passion for science.

The DFO Deputy Minister's Prix d'Excellence and the Commendation Award of the ADM Science were presented to **Lenore Bajona** (Informatics) and **David McKeown** (Ocean Sciences) for their innovation and initiative in developing an Internet site to manage vessel requests.

Dr. Peter Harrison, DFO Deputy Minister, Lenore Bajona, David McKeown and Donna Petrachenko during the presentation of the DFO Deputy Minister's Prix d'Excellence DFO - photo by Wolf Studios.

In June 2002, DFO presented the 2001 Regional Merit Awards to staff who have made outstanding contributions to the department:

- **Mike Collins** of the Canadian Hydrographic Service (CHS) received an award for his efficient, effective, and timely delivery of products and services to clients and his interpersonal skills that contributed to a better working environment.

- **Paul Dickie** received an award for his dedication to the *Bedford Basin Plankton Monitoring Program*, a project that he initiated in 1991. Mr. Dickie realized the scientific value of long-term time series data collected at regular and frequent intervals using consistent methods. He has also mentored more than 110 students from universities, high schools, and elementary schools and has been a great spokesperson and positive role model for DFO.

- **Paul McKiel** received an award for his involvement in the relocation of the Dartmouth Technical Workshop to BIO in September 2000. He ensured that the construction of the new workshop met the needs of the technical workshop staff.

- A Team Merit Award was presented to **Maureen Butler**, **Mark Lundy**, and **Dale Roddick** of the Invertebrate Fisheries Division, and **Kohila Thana** of Informatics for design and development of three major databases for the Bay of Fundy scallop fishery. The team assembled, verified, and entered all of the data into state-of-the-art databases that they designed and made the information available on the Virtual Data Centre at BIO. This represents an invaluable scientific asset for the people of Canada.

The following staff received NRCan Division Merit awards:

- **Austin Boyce** for dedicated support to the acquisition of the highest quality sidescan sonar data in cooperative research projects;

- **Claudia Currie** for dedicated efforts in organizing symposia, workshops, and other events;

- **Nellie Koziel** for tireless efforts in organizing special events for staff; and

- **Bill MacKinnon** for efforts in coordinating office and staff moves designed to facilitate team work among staff.

The former Ocean Sciences Division boardroom was renamed the George Needler Boardroom in honour of the contributions of the late **Dr. George Needler** to oceanography and international science during a career that spanned 40 years. The dedication ceremony took place on October 23, 2002. This recently expanded and refurbished room has the dual function of a boardroom with seating capacity of about 30 or a seminar room with capacity of over 70.

VISITORS

Dr. Wendy Watson-Wright, ADM Science, DFO visited BIO on February 5. Following a meeting with Jacob Verhoef to discuss NRCan/DFO joint priorities, Dr. Watson-Wright gave a speech to staff summarizing the view from Ottawa. Subsequently, three smaller meetings took place with staff of Ocean Sciences Division, Canadian Hydrographic Service, and the Centre for Marine Biodiversity. Research priorities and new results were the focus of the sessions.

In March, the **Indonesian Ambassador to Canada** and an Indonesian delegation of senior officials visited BIO for a discus-

The Needler family during the dedication of the Needler Boardroom. Left to right: Ian Needler, Kirstie Hawkey, Mary Kate Needler, and Peter Needler.

sion on Canada's ocean management systems and related industries. The visit included a tour of BIO. The delegation was interested in Canadian technology, our expertise in seabed mapping, and the application of mapping to ocean management issues.

The **Honourable David Anderson**, Minister of the Environment, visited BIO on April 2, 2002. His address to staff and visitors provided background information on the science of climate change, social, and environmental information about predicted impacts of climate change in Atlantic Canada, and a summary of the Government of Canada's strategy for meeting the climate change challenges.

On May 3, 2002 a 14-member Chinese delegation led by **Mr. Wang Yanliang,** President of the Chinese Academy of Fishery Science toured BIO. The delegation and BIO staff discussed aquaculture planning and development and environmental protection relating to aquaculture regulatory regimes.

Dr. Peter Harrison, Deputy Minister of Fisheries and Oceans Canada, visited BIO on May 16. Bob O'Boyle provided a tour followed by a lunch with the management team. Discussion focussed on the peer review process of scientific advice at the Institute, as well as the manner in which horizontal research issues among departments are managed.

The **Honourable Herb Dhaliwal**, Minister of Natural Resources Canada, visited BIO in May to officially open the Climate Change Impacts and Adaptation Research Network office, administered by NRCan at BIO. After the ceremony, he responded to staff and media questions.

Mr. George Anderson, NRCan's newly appointed Deputy Minister, visited BIO in June. Jacob Verhoef provided a tour of the facility, which was followed by a meeting with staff to discuss contributions to priority issues of the department and also provided Mr. Anderson with an overview of the working of the Institute, and the interactions among departments located at BIO.

The President of the Institut français de recherche pour l'exploitation de la mer (IFREMER) in France, **Dr. Jean-Francois Minster**, visited BIO on October 30-31, 2002. He was part of an IFREMER team of senior management, including Hugues de Longevialle, Gerard Riou, and Elie Jamarche. Dr. Minster presented a seminar on European marine research of relevance to climate change. The visit provided an excellent opportunity for BIO staff to reflect on our program management and prioritization process.

Mr. Jean-Claude Bouchard, the new Associate Deputy Minster of Fisheries and Oceans Canada, visited BIO on November 7. Mike Sinclair provided Mr. Bouchard an overview of the status of the fisheries resources and the research activities in support of stock assessment at a meeting the previous day, and René Lavoie conducted the tour of the Institute.

The **Honourable Robert G. Thibault**, Minister of Fisheries and Oceans Canada, visited BIO on November 12. His speech highlighted the extensive renovations that are underway and planned for the next several years at BIO. He congratulated the Institute on its 40^{th} anniversary and the collaboration undertaken by staff with the private sector on fisheries and oil and gas issues. A short tour highlighted research on grey seals, Atlantic salmon, and ocean instrumentation.

NRCan hosted **Dr. Oddvar Longva** of Norway, as a Visiting Scientist under the auspices of a Letter of Agreement between the Geological Survey of Canada (Natural Resources Canada) and the Geological Survey of Norway. The agreement was developed as a framework to facilitate collaborative research in marine geoscience. Dr. Longva worked in partnership with NRCan scientists on a new ocean-mapping program in Canada, similar to a program being developed in Norway.

THE FIRST 40 YEARS AT BIO

A Short History of the Bedford Insitute of Oceanography

- Brian Nicholls

The Bedford Institute of Oceanography (BIO) was officially opened on October 25, 1962 by the Hon. Paul Martineau, Minister of Mines and Technical Surveys. Among those present was Dr. W. E. van Steenburgh of the same department, and the person primarily responsible for the founding of the new federal institute. Later that year, in his foreword to the first annual report, the Director, Dr. W. (Bill) English, stated that the Bedford Institute of Oceanography was established as a result of a government decision that oceanography in Canada be expanded to meet growing national needs (fisheries, navigation, maritime defence, natural resources, and weather forecasting). He added that the new Institute would be "...Canada's centre for hydrography, oceanography, geophysics, chemistry, and geology for the Atlantic and most of the Canadian Arctic."

One of the unique features of the new Institute was the bringing together of oceanographers and hydrographers (surveyors responsible for charting the sea) within the same organization. Cruises involving these two activities started in 1964 and were highly successful. Over the years, scientists from other fields, such as marine fisheries and seabird conservation joined the Institute. Together with on-site support services, including engineering support, and a fleet of research and survey vessels based at the same location, BIO developed into a recognized centre for interdisciplinary studies in the marine sciences and technology field. A short account of its development from 1962 to the present is given below, together with a selection of programs and projects that are representative of the types of work undertaken.

Construction at the BIO site, May 1961 – photo by John Lazier.

THE FIRST DECADE (1962 TO 1972)

Staff moved into the Bedford Institute of Oceanography in mid-1962. They came from the Department of Mines and Technical Surveys, with its marine interests in tidal studies and hydrographic surveys, and from the Fisheries Research Board of Canada. The first vessels associated with the Institute were the CSS *Baffin, Kapuskasing, Acadia* and *Maxwell*; these were supplemented with the use of charter vessels and work undertaken on board Canadian Coast Guard icebreakers. Often referred to at this stage as a modest research facility, it had, by the end of its first decade, grown to an establishment of 525 scientific and support staff (excluding ships crews), with an annual budget approaching $15 million. While various government reorganizations occurred during this period (and subse-

The Honourable Joe Green, Minister of the Department of Energy Mines and Technical Surveys congratulating Captain Butler at the ceremony marking the end of Hudson *'70, October 16, 1970. Cedric Mann, who played a leading role in the planning and organization of the cruise, is seated on the right.*

quently), which affected reporting relationships, the overall program of the Institute remained remarkably viable. At the end of this decade, it comprised three main organizational units, each of which was to make its mark over the years: the Atlantic Oceanographic Laboratory (part of a succession of departments including, most recently, Fisheries and Oceans Canada {DFO}); the Marine Ecology Laboratory of the Fisheries Research Board of Canada; and the Atlantic Geoscience Centre of the Geological Survey of Canada.

The initial program of the new Institute comprised work carried over from projects initiated elsewhere, and included both hydrographic surveys and oceanographic research in Arctic and Atlantic regions, but very quickly new programs were planned and implemented. New ships were added to the BIO fleet, including the research vessels *Hudson* and *Dawson*. During this decade, Institute ships worked in eastern and northern Canadian coastal waters, and in the Atlantic, Pacific and Arctic oceans. In the Atlantic, for example, physical oceanographic investigations of Gulf Stream branching off the Tail of the Grand Bank were undertaken, while deep-sea geophysical explorations focussed on the underwater mountain range, the Mid-Atlantic Ridge, at 45º N. Of particular interest during the latter part of the decade was the 1970 circumnavigation of the Americas by CSS *Hudson*, the first vessel to achieve this distinction. The geological and geophysical investigations undertaken during this cruise in the Northwest Passage contributed to an awakening interest in the hydrocarbon potential of this region. The cruise also provided a unique opportunity for testing hypotheses about biological production rates by comparing conditions over a variety of temperate and tropical water masses. A new program specializing in the ecology of plankton, both phytoplankton and zooplankton was established at the Institute to better understand the food webs supporting marine fisheries. Also in

CSS Hudson *in Arctic ice taken during the* Hudson *'70 voyage. The cruise track is in the foreground with the commemorative medallion on the top right.*

1970, a serious oil spill resulting from the grounding of the tanker *Arrow* off Nova Scotia required a major scientific effort to tackle the many resulting environmental problems, both immediate and long term.

THE SECOND DECADE (1972 TO 1982)

BIO ships continued to support Canadian participation in national and international projects in distant waters. For example, CSS *Baffin* undertook cruises to both the Atlantic and Pacific coasts of South America: off Guyana in 1974 on a hydrographic production/training cruise, and off Peru in 1977 on a fishery project. Both cruises were sponsored by the Canadian International Development Agency (CIDA). CSS *Hudson* participated in several international programs, including the International Commission for the Exploration of the Seas (ICES) Denmark Strait Overflow project in 1973, which involved 13 ships in the waters between Greenland and Iceland. A third vessel, CSS *Dawson*, participated in the Lesser Antilles Deep Lithosphere Experiment (LADLE) in the region south of Bermuda in 1980. Several interdisciplinary cruises were made to the eastern Arctic during this period to acquire knowledge in support of northern development.

Closer to home, two major interdisciplinary projects got underway in Nova Scotia in 1973: a larval fish studies program in St Georges Bay, and an investigation of anthropogenic impacts on the marine environment in Canso Strait and Chedabucto Bay. In view of the potential construction of a tidal power plant in the upper reaches of the Bay of Fundy, a program to describe and understand the ecology of this body of water got underway in 1977. Also with respect to the Bay of Fundy, a program was established to monitor the pre-operational and operational phases of the Point Lepreau, New Brunswick nuclear power station. As a result of the expertise developed in this program, BIO scientists would subsequently undertake investigations of radioactivity in other geographic locations, including the Arctic Ocean. Research and development on new methods of measurement in the ocean is an important activity at the Institute that complements the research and survey programs. This decade saw instrument engineers working on a variety of systems and devices including: an underwater rock-core drill, instrument mooring methods and materials, baseline acoustic positioning systems, oceanographic sensors, and seismic profilers. A major ongoing initiative is the determination of the regional geology of the sedimentary basins of offshore eastern Canada, the eastern Arctic, and the North Atlantic in order to obtain estimates of the oil and gas resources of these basins. Appraisals of these resources were conducted during this period for the Labrador and south Baffin Island shelves, the east Newfoundland Shelf (including the Hibernia field), eastern Georges Bank, and the Scotian Shelf.

The federal department responsible for environmental issues, Environment Canada, opened facilities at the Institute during this decade. A microbiology laboratory was established in 1972 in support of the Canadian Shellfish Sanitation Program, and toxicology and chemistry laboratories were also opened in the 1970s. In 1976, the Seabird Research Unit of the Canadian Wildlife Service moved from Ottawa to BIO. With a program focussed on marine ornithology, the staff of this unit developed close working relationships with BIO oceanographers.

On January 1, 1977, Canada extended its fisheries jurisdiction to 200 nautical miles. As a result, shifts in the direction of several Institute programs were made towards fisheries issues. The Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) was established, and its secretariat located at BIO. Scientific staff of the

Huntec Deep-Towed Seismic Reflection System (DTS™) was developed in an industry-BIO partnership in the 1970s, and used throughout the world for deep seismic profiling.

Studies on production of salt marsh grass in 1981, taken in Cumberland Basin, Bay of Fundy, New Brunswick. Wallace Ross (standing) and Don Gordon.

Marine Fish Division relocated to the Institute, and initiated major new research and advisory activities on the production and productivity of marine groundfish and marine mammals. Collaboration with existing BIO staff resulted in investigations of interactions between fish and their environment. In 1980, several new buildings were officially opened at BIO, including a unique auditorium that would serve the Institute well over the years. Also in 1980, a major international award for excellence in the marine sciences, the Huntsman Award, was instituted, and has been awarded every year since.

THE THIRD DECADE (1982 TO 1992)

Midway through this decade, the twenty-fifth anniversary of BIO occurred. This was recognized in a variety of ways, including a 1986 special "Anniversary Issue" of the Institute's annual report. The foreword to this issue is entitled "On helping to make a revolution", and states, with respect to these first twenty-five years, that "... the contributions of BIO to the global activity have been novel and significant: like all major oceanographic research institutes during this period, we have done our share of leading, and our share of filling-in behind."

CSS F.C.G. Smith *conducting sweep surveys in Lunenburg Harbour in 1986.*

In 1986, CSS *F.C.G. Smith*, an acoustic sweep vessel for inshore and harbour hydrographic surveys, was added to the BIO fleet. CSS *Baffin* and *Dawson* both retired from active service in 1991, the latter being replaced by CSS *Parizeau* from DFO's Pacific Region. The fleet now comprised 10 ships, including three fishery research vessels. Compared with earlier years, this decade represented a change in the geographic focus of the major programs of the Institute; during 1982-1992, and subsequently, BIO was to undertake fewer research and survey cruises beyond Canadian contiguous areas.

Among cooperative programs undertaken by BIO staff during this decade were:

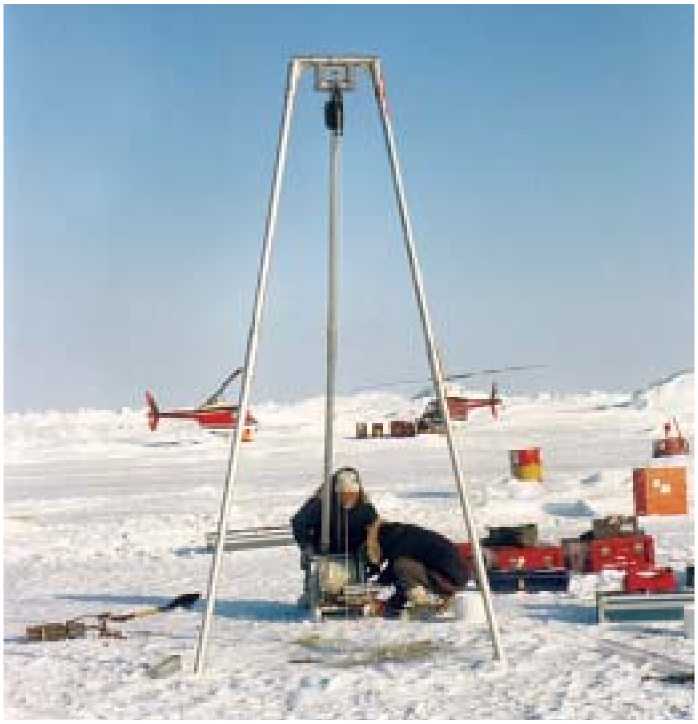
- the Canadian Atlantic Storms Project (CASP), an initiative involving meteorologists and oceanographers to investigate winter storms over the Maritime Provinces and their effects on the ocean;

- environmental studies of the polar margin north of Canada's Arctic Islands (conducted over a period of several years from a floating body of ice);

- investigation of the processes that control the survival, growth, reproduction, and distribution of Atlantic cod and sea scallops in cooperation with other agencies as part of the Ocean Production Enhancement Network, a newly established Canadian centre of excellence;

- water transport and biological primary production studies in the North Atlantic as part of the international World Ocean Circulation Experiment (WOCE) and Joint Global Ocean Flux Study (JGOFS) programs;

- participation in the Canadian Frontier Geoscience Program in offshore and Arctic oil and gas frontier regions (during this decade the Grand Banks received significant attention); and



Collection of Vanveen grab samples, mini-gravity cores, and heat flow measurements of the Arctic Ocean seafloor from Hobson's Choice Ice Island (circa 1987) - photo by David Mosher.

- continued participation in the international Ocean Drilling Project (in 1987, for example, in Legs 112 and 115 to the Peruvian continental shelf and the Indian Ocean, respectively).

Engineering research in support of safe navigation focussed on the development of the electronic chart, and included participation in international evaluation trials in the North Sea. Also with respect to hydrographic charting, the development of the remote-controlled vehicle DOLPHIN as a means of improving survey productivity, was part of BIO's support to industry and a successful example of technology transfer. BIO staff contributed towards the successful resolution of the Gulf of Maine boundary dispute, preparing a range of technical documentation and advice for the Department of External Affairs, and subsequently participating in the oral hearings at the International Court of Justice of The Hague.

THE FOURTH DECADE (1992-2002)

In 1997, Canada's new *Oceans Act* was enacted. This legislation had major implications for oceans and coastal management, and resulted in the priorities of the Institute being revised, with increased emphasis on ecosystem-based management, marine conservation, and marine environmental quality. One of the first initiatives arising from the act was the Eastern Scotian Shelf Integrated Management (ESSIM) project, involving both scientific and management staff. During the decade, a number of new groups moved into the Institute. In particular, there was a major influx of fisheries scientists as a result of the closing of DFO's Halifax Fisheries Laboratory at the end of 1995. In 1999, DFO's new regional Oceans Branch, a direct result of the new act, was established at the Institute.

Over the years, BIO has been home to several non-governmental organizations in oceans-related fields. During this period, the following organizations established a presence: Fishermen and Scientists Research Society; Ocean Colour Coordinating Office of the Scientific Committee on Oceanic Research; Partnership for Observation of the Global Oceans; and Centre for Marine Biodiversity. In addition, the Department of National Defence's Route Survey Office opened at the Institute. Among special events held at BIO during the period was an ocean industry day focussing on ocean technology development and transfer, which attracted over fifty exhibitors. At the end of this fourth decade, program spending, including funds allocated for the operation and maintenance of vessels, amounted to $44 million; the staff complement amounted to 600 (excluding ships crews).

During the 1992-2002 decade, less work was undertaken in the Arctic. On the other hand, Atlantic continental shelf and coastal regions received increased attention. In particular, emphasis on coastal issues and the provision of scientific support to integrated coastal zone management emerged as a priority for all units, much of the work involving interdisciplinary collaboration within the Institute and with external agencies. The following examples illustrate the types of the work undertaken. Experiments were designed and implemented to quantify the impacts of mobile fishing gear on the benthic habitat of fishing banks on the Scotian Shelf and the Grand Banks. New technologies were developed to facilitate the work, including tools for imaging and sampling the seabed. This equipment was also used in studies examining the effects of hydrocarbon drilling wastes on continental shelf benthic ecosystems. Climate change and variability became a coordinating theme for a number of Institute programs, and increased in emphasis during the decade. For example, oceanographic data, collected over the waters of Atlantic Canada since the late nineteenth century, were brought together under a regional ocean climate database, which provides a tool for exploring the climatology of the northwest Atlantic. Studies of coastal impacts of climate change in Prince Edward Island involved Institute geoscientists and hydrographers, as well as staff from Environment Canada and Dalhousie University. The Institute responded to a fast-growing demand for marine geoscience research related to hydrocarbon exploration and development off the east coast. One result was a better understanding of seabed constraints to the installation of offshore production facilities.

Fisheries research continued to be a high priority as exemplified by the following projects: invertebrate aquaculture investigations focusing on sea scallops, bay scallops, oysters, and mussels; ongoing

Capturing an adult female grey seal during the breeding season on Sable Island in the early 1990s. Jim McMillan is netting the seal with Brian Beck in the background and Don Bowen on the right.

Videograb equipment developed at BIO being deployed on CCGS Hudson, *June 2000. Videograb was used in research investigations on the impacts of mobile fishing gear on bottom habitat.*

monitoring of the grey seal population on Sable Island with respect to foraging ecology and reproduction, important with respect to the management of this resource; and a new cooperative program in support of the integrated management of the Bras d'Or Lakes, Nova Scotia, in partnership with Cape Breton First Nations.

CLOSING REMARKS

The *History of Oceanography Newsletter*, published by the Commission of Oceanography, International Union of the History and Philosophy of Science, has noted more than once that publications on the history of marine science in Canada are scarce, and that there has been little attempt to take a synthetic look at the development of these sciences despite Canada's impressive record of accomplishment, with limited resources. In the case of BIO, special issues of the Institute's annual report, such as this one and the 1986 issue, provide selected factual information; while recent activity in establishing Institute archives is an encouraging development. It may not be too soon to start planning for a first comprehensive history of the origins and early development of the Institute, perhaps to be published, say, on its fiftieth anniversary, one that would also provide a contribution to the study of science and government in Canada. The need for such a history was recently reinforced for me upon reading parts of Arthur Lee's 1992 book, *The Directorate of Fisheries Research: Its Origins and Development*. Dr. Lee was the Director of Fisheries Research for England and Wales from 1974 to 1980. In the preface to his book he makes the following pertinent comment: "...delving into old files and reports brought home to me the depth of my ignorance, in my early years in fisheries research, of what had gone on before and even of what was happening at the time. This ignorance did not decrease as the years went by and now, looking back, I see how much more satisfactory it would have been at all stages of my career had I known more fully how things had come about."

Geoscience at BIO: The First Forty Years

- Gordon Fader and Graham Williams

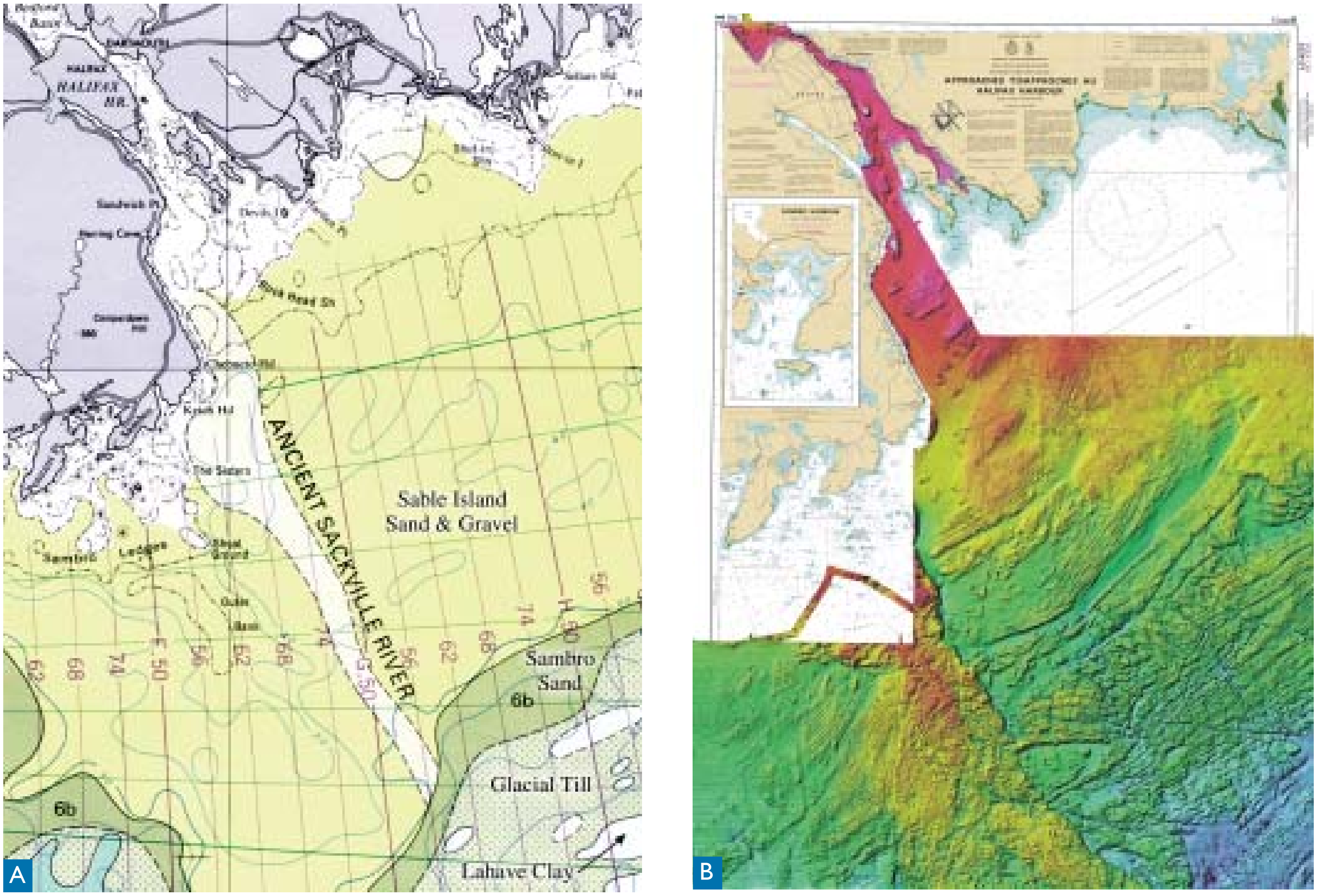
INTRODUCTION

This is a brief summary of forty years of the Geological Survey of Canada's geoscientific research at the Bedford Institute of Oceanography, which includes geology, geophysics, geochemistry, and related disciplines. It has been an important component of the marine research carried out at BIO since its opening in 1962. In such a review it is difficult to be inclusive of all-important contributions by many scientists. Because of space restrictions, we have focussed on the major programs and discoveries and the evolutionary stages in marine geoscience without citing individuals or providing references. For a chronological history of geoscience events, we recommend a summary produced by M. J. Keen in Keen (1990).

We recognize three phases in the conduct of geoscience at the Bedford Institute of Oceanography. The first phase, in some ways the most exciting, because it covered the pioneering days, was one of exploration and discovery. This lasted from the opening of the Institute in 1962 until the late 1970s and early 1980s. It was a time to learn the intricacies of marine as opposed to land-based geology and to build up a regional understanding of the vast area that is our offshore Canadian domain. During this phase, teams of geologists and geophysicists conducted numerous scientific cruises mapping and collecting baseline reconnaissance data.

In Phase II, extending from the 1980s until the early 1990s, the focus was on detailed and process studies and the birth of modelling. There was a need to know how structures and features were formed and their long-term implications. An even more important question, however, was how to make predictions.

Phase III, from the mid-1990s until the new millennium, has seen the generation of more sophisticated models and continued integration with other disciplines, a time of transgressing some of the old boundaries and expanding our horizons. A new need for precision, accuracy, and even higher resolution images resulted in



A) A portion of a surficial geology map of the inner Scotian Shelf off Halifax, Nova Scotia, interpreted in 1970, showing the distribution of sediments at the seafloor and a few bathymetric contours. B) A multibeam bathymetric map of the same region showing the true morphology and complexity of the seabed. Multibeam bathymetric maps like this will provide the future basis for sediment and bedrock mapping, seabed engineering, habitat assessments, and overall management.

detailed surveys and models. Much of the impetus for this was a requirement to manage the offshore and to have input on policy and direction. This was carried out with reduced resources, both in staff and facilities, as geoscience agencies around the world began to shrink in response to reduced budgets and changing priorities.

Now BIO geoscience is entering uncharted seas, with the emphasis on issue-driven and applied programs. Long-term research has been reduced and fewer projects are undertaken. The release of older data and interpretations in digital format has taken on a new priority.

Two other important issues in the geoscience story were the invention and application of instrumentation and the development of databases. Since it is usually impossible or impractical to see or sample seabed rocks directly, BIO geoscientists have utilized an impressive array of equipment. Sometimes this development has been in collaboration with industry as with the Huntec Deep-Towed Seismic Reflection System (DTS™), sometimes alone as with the BIO drill, Ocean Bottom Seismometers, and RALPH (an instrumented tripod to monitor sediment transport rate and direction). Additional information on the development of instrumentation at BIO is contained in the article with that title later in this section of the report.

PHASE I

With the opening of Bedford Institute of Oceanography, the federal government established a major presence in marine scientific research for the east coast offshore. Previously, this had been the domain of the universities (both in Canada and the USA) and industry. The federal presence meant the initiation of major ship-based studies, and especially the introduction of multiparameter cruises. The collection of potential field data (gravity and magnetic) on all hydrographic cruises started in 1965 and was pursued for almost thirty years. It provided BIO scientists with the most comprehensive potential field data, later supplemented with seismic data, for any continental margin in the world. This, coupled with the presence of a magnificent field laboratory stretching from about 44º N latitude to beyond the Arctic Circle, led to some dramatic discoveries.

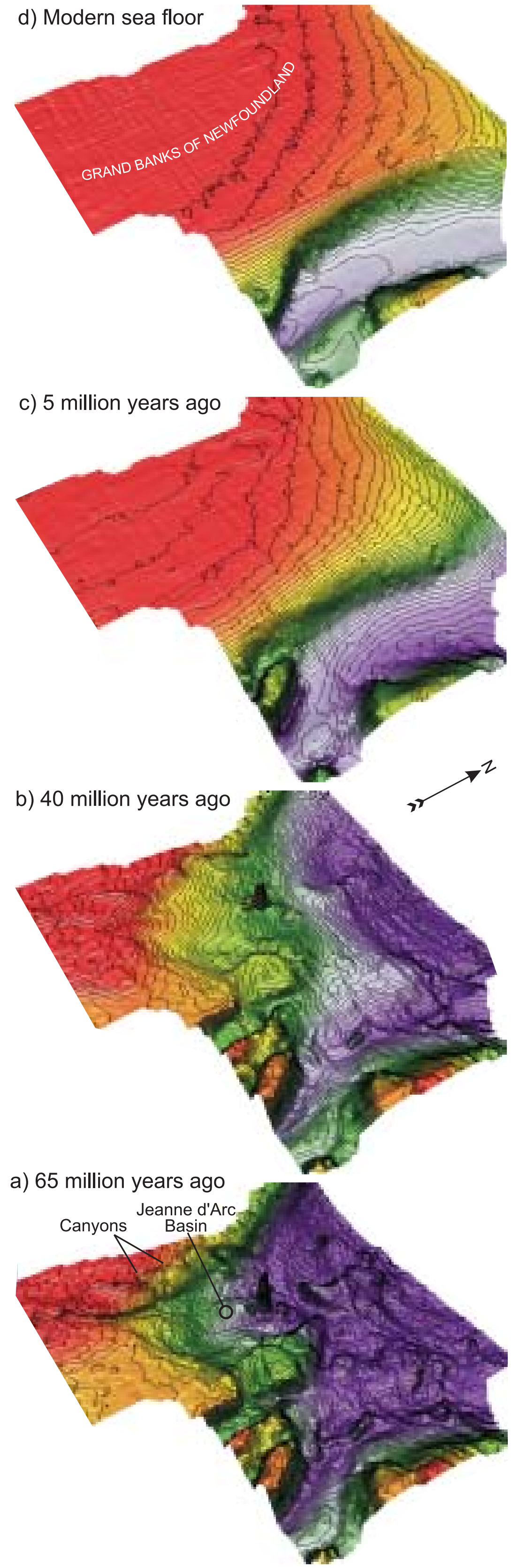
Prior to the first multiparameter cruise, tests were being carried out on the use of potential field and seismic instrumentation on ships and on the seabed. In 1963, a geophysical survey in Baffin Bay and Nares Strait indicated that the Tertiary basalts of western Greenland extended offshore. Subsequent acquisition of single-channel seismic capability in 1965 confirmed the presence of sedimentary as well as basement rocks on the Labrador Shelf. This was of major significance to oil companies leading to petroleum exploration and discoveries.

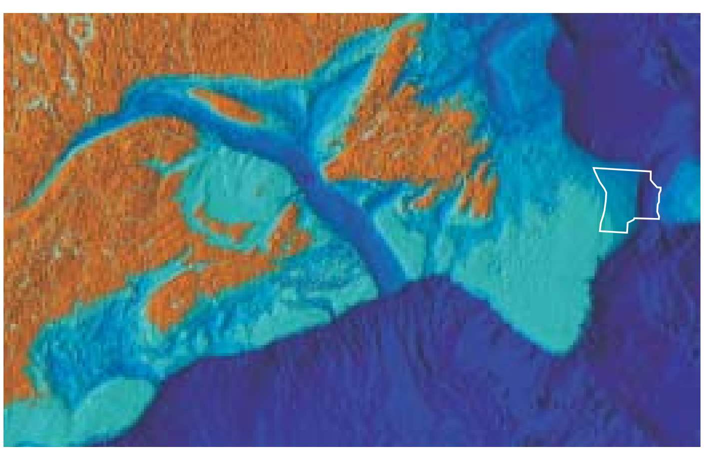
In the more liberal days of the 1960s, scientists conducted research throughout the Atlantic in such places as the Mid-Atlantic Ridge, Iceland, Bermuda, and the Azores. A major incentive was to test the newly developed model of plate tectonics and sea floor spreading. The results were new insights into the opening of the North Atlantic and the structure of the Mid-Atlantic Ridge, the recognition of magnetic delineations, and the honing of expertise invaluable to the Deep Sea Drilling Project (DSDP) and its offspring, the Ocean Drilling Program (ODP). Consequently, several BIO geoscientists have served on DSDP and ODP cruises, sometimes as chief scientist, or have been involved in post-cruise studies. Highlights have included recognition of Orphan Knoll as a fragment of continental crust, the determination of the time of opening of the Labrador Sea, and the definition of the onset of glaciation in Baffin Bay.

Regional mapping was a high priority in the early days and led to some exciting finds. A major breakthrough in seabed geological mapping was the realization that acoustic reflection characteristics from echosounders, boomers, and airgun systems differentiated surficial sedimentary facies. The importance of this finding is confirmed by the continuing and extensive reliance on acoustic technology in seabed mapping. Surficial features on the sea floor that were first recognized and named included: pockmarks (gas escape craters), end moraines (glacial ridges), and iceberg furrows (large depressions from moving grounded icebergs) to name a few. Subsequently, pockmarks have been found on shelves all over the world and are an important indicator of hydrocarbons as well as playing an as yet undefined role in global climate change. The first in a series of regional surficial geology maps, the Halifax-Sable Island area, was published in 1970 followed by six more. In 1976, the first bedrock geology map of any Canadian offshore area was produced. The Huntec Deep-Towed Seismic Reflection System played an important role in studies of east coast offshore surficial sediments and continues to this day to be a superior sediment mapping system.

BIO scientists were not constrained to the East Coast. Sidescan sonar records from Arctic cruises in the early days identified seafloor ice scour and pingos (dangerous shallow ice-cored mounds) in the Beaufort Sea. Canada and the USA mounted major expeditions to investigate the Arctic Ocean in the 1970s and 1980s. These included the Fram series (named after the ship of the Arctic explorer, Fridtjof Nansen), LOREX (the Lomonosov Ridge Expedition), and CESAR (the Canadian Expedition to study the Alpha Ridge). Results revealed that the Arctic mid-oceanic ridge is spreading slowly with cyclical sedimentation in the Cretaceous (142 to 65 million years ago).

An understanding of the regional tectonic framework of the continental margins of eastern Canada developed through the





Four perspective surfaces illustrating the Cenozoic evolution of the northeastern corner of the Grand Banks of Newfoundland (white outline on the map). These ancient sea floor images were interpreted from seismic data provided to the Geological Survey of Canada Atlantic by the Ex-Parex Group. Red is shallow and purple is deep. Each surface shows how the sea floor morphology has changed as sediment was deposited on the margin. a) 65 million years (m.y.) ago the area formed a shallow sea with canyons eroding into the western margin of what was the Jeanne d'Arc Basin. b) By 40 m.y. ago, the relief of the Jeanne d'Arc Basin had filled in. c) By 5 m.y. ago, enough sediment accumulated to form a broad shelf that began to resemble the modern Grand Banks of Newfoundland as we know them today shown in d) - image courtesy of Mark Deptuck and map courtesy of John Shaw.

multiparameter surveys of the 1970s and 1980. The bathymetric, magnetic, gravity, and reflection and refraction seismic data gathered on such cruises were published in a series of maps in 1988.

Environmental impact studies became of paramount importance, focussed by the grounding of the tanker *Arrow* in Chedabucto Bay, 4th February 1970. The resulting multidisciplinary assessment of the oil spill and its impact on the surrounding habitats and beaches was the forerunner of investigations in the Strait of Canso and Miramichi Estuary.

The increased exploration for offshore oil and gas led to the decision for BIO to develop expertise in the offshore sedimentary basins. The studies, with the emphasis on lithostratigraphy, biostratigraphy, and deep reflection seismic data, commenced in 1971. Some of the resulting publications focussed on estimates of the hydrocarbon resources and reserves of offshore eastern Canada, and were important in determining federal government policy.

Technological innovations continued throughout the 1970s and early 1980s. The BIO drill, originally with 20' capability but subsequently extended to 30', revealed the nature of bedrock in previously unexplored areas.

PHASE II

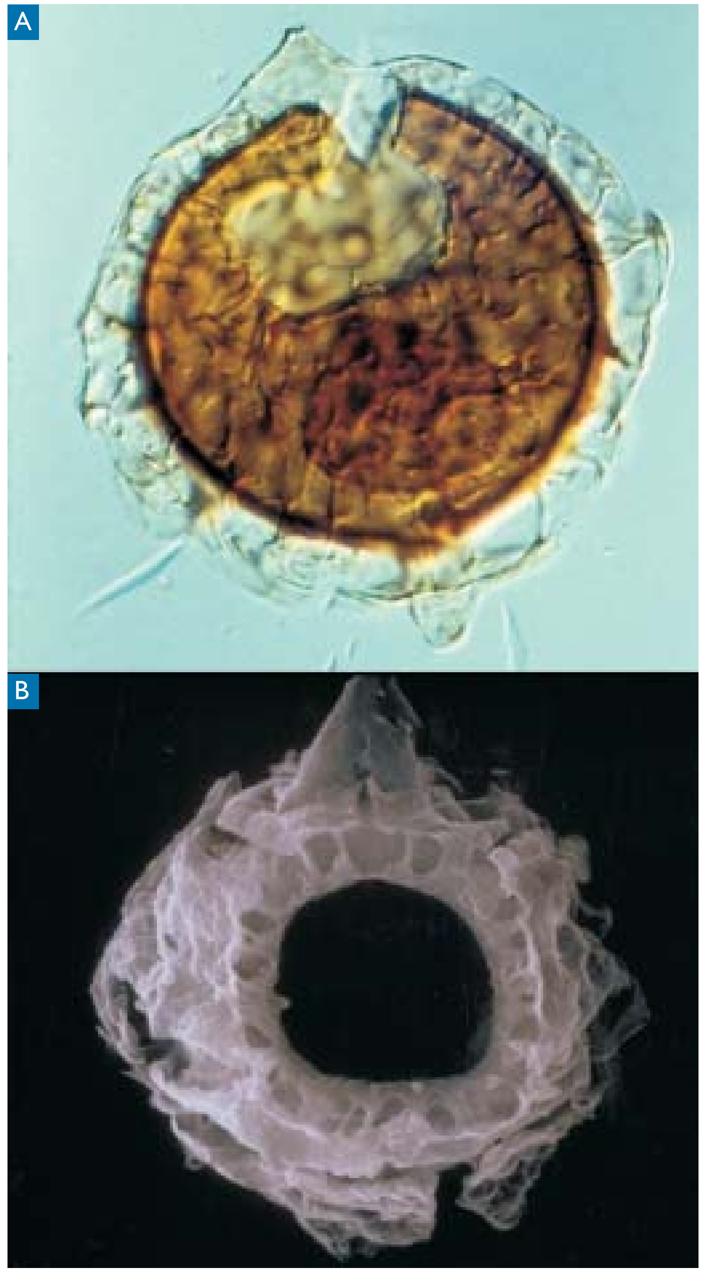
Interest in processes, as opposed to regional surveys, developed in the 1970s as BIO geoscientists tried to explain how some of the Quaternary seabed and subsurface features had formed, and define when and how glaciation occurred. The earth's maturation history could be used to predict promising exploration areas and targets, and provide a better understanding of the deep crust.

The glacial history of the East Coast offshore was little understood until studied by BIO scientists. For example, the onset of deglaciation on the Labrador Shelf was originally believed to be only a few thousand years ago, but is now known to have happened much earlier. Following the application of AMS dating (accurate dating method using accelerator mass spectrometry) and extensive regional mapping, syntheses of the Quaternary (1.8 million years to the present) geology of this and other continental shelves appeared in the late 1980s.

Concern over damage resulting from oil spills led to geological studies of coastal regimes and modern processes such as barrier-island systems and strand plain deposits. All the coastlines of New Brunswick, Nova Scotia, and Prince Edward Island have been video taped and the tapes made available to the public. Similar footage is also available for the Arctic. A systematic multidisciplinary evaluation of Baffin Island fjords, many of which have glaciers at tide water, allowed comparison with river-dominated fjords of British Columbia and wave-dominated fjords of Nova Scotia.

In the 1980s, sedimentary processes were studied both on the shelf and in deeper water, from the slope to the abyssal plain. A major change to the surficial mapping program shifted emphasis to the nearshore, an area largely neglected during Phase 1. Detailed sidescan sonar imaging provided a more precise delineation of variations in facies of deeper waters and revealed much about turbidites, especially those resulting from the Grand Banks earthquake of 1929. Another discovery showed that the continental slope of offshore eastern Canada was molded by the most recent glaciation about 20,000 years ago. The glacial and sea level history of the Quaternary has had a dominant impact on the land and sea boundaries in the Maritimes.

The integration of maturation studies of organic material and



Comparison of a light micrograph image (A) and scanning electron microscope (SEM) image (B) of the fossil dinoflagellate Samlandia chlamydophora *(about 35 million years old). The SEM image shows the relationship of the two wall layers and that the outer membrane is arranged into distinct areas or plates.*

modelling in the late 1970s and early 1980s led to some impressive predictions. Visual kerogen (fossilized insoluble organic material) studies pinpointed the oil and natural gas potential of the Jeanne d'Arc Basin two years before the first Hibernia discovery well. This was followed by the first modelling of the margins of Eastern Canada, using lithospheric stretching. The results yielded predictions of the thermal maturation of the sediments and substantiated the visual kerogen data. The first thermo-mechanical models of the East Coast offshore predicted the mechanical properties of the lithosphere and its response to loading of sediments and water.

Since BIO is located on the margin of the North Atlantic, this has been a major stimulus for studies of the rift-drift history of this imposing ocean. Comparative studies of the formation of sedimentary basins, formed as the super-continent Pangea broke up (about 200 million years ago) have provided insights into the spreading history and comparable geological evolution on both sides of the

Atlantic Ocean. Few people realize that we are also located close to Earth's largest igneous province, the Central Atlantic Magmatic Province (CAMP), which includes basalts on both the African and North American margins of the Atlantic Ocean. Outpourings of basaltic lava of the CAMP ring the Bay of Fundy and coincide with the initial stages of rifting before the onset of drifting.

During the Phase II era, analyses of offshore wells also revealed the existence of younger basalts and confirmed the occurrence on the Scotian Shelf of Meguma basement. One of the most dramatic discoveries was the first identified submarine impact crater, the Montagnais, which is on the southern margin of the Scotian Shelf. The meteor that formed this crater hurtled to Earth several million years after the extinction of the dinosaurs.

An important stimulus to research during Phase II was the Frontier Geoscience Program, introduced in 1984. This program provided extensive funding for geoscientific studies of the Arctic Islands, the Western Arctic, the East Coast, and the West Coast. It led to some impressive compilations, including atlases of the Labrador Sea and Scotian Shelf, and the seismic atlas of the Scotian Basin. Parallelling these developments was the publication in 1990 of "Geology of the Continental Margin of Eastern Canada", published as part of the *Geology of Canada* series and *Decade of North American Geology*. This provided a synthesis of the knowledge of geology, surficial and bedrock, and geophysics of offshore eastern Canada. Perhaps now is the time to plan a sequel to include advances made in the last decade.

PHASE III

Geological modelling of new data marked the development of this phase. A good example of this is provided by the Lithoprobe Project and Frontier Geoscience Program (FGP), which saw the collection of deep, marine, multichannel seismic reflection data across the continental margins and adjacent continental regions. These data provided a means of profiling the structure of Earth's crust and upper mantle, using techniques pioneered by industry and adapted by academic and government groups to penetrate to deeper regions. At BIO these surveys, conducted between 1984 and 1990, established the nature of the crust beneath the Appalachians, northeast of Newfoundland, in the Gulf of St. Lawrence, and below the continental margins and sedimentary basins off Nova Scotia, the Grand Banks, and in the region of the Labrador Sea. There was a multidisciplinary aspect, however, which did not end with the collection and interpretation of the seismic data. These data were combined with other datasets and with numerical models of the subsidence and thermal history of the region, to determine the tectonic history and the nature of the forces driving continental break-up. Some of the questions addressed were: the nature and extent of continental crustal thinning near the margins; the role of volcanism during break-up; and the character of the ocean-continental transition. Thus, the combination of several kinds of data with predictive quantitative modelling has enhanced predictability.

Incredible advances have taken place since the digitization of data and the continual development of more sophisticated personal computers. Nowhere is this more apparent than in the seabed mapping program. Bathymetric data are now collected with multibeam survey techniques developed by the Canadian Hydrographic Service in partnership with the Geological Survey of Canada (GSC). This has revolutionized the collection and display of these data and revealed previously unknown sea-floor features such as relict river channels from former episodes of lowered sea level and new moraines and bedrock features. Through the combined use of sidescan sonar and multibeam backscatter systems, it is possible to produce high resolution imagery covering 100% of the sea floor. This highlights shipwrecks, pipelines, and cables and yields priceless information on sediment distribution and processes. This technology has provided some surprising insights into, for example, Halifax Harbour, in which abandoned cars are clearly visible. The technology has played a major role in an analysis of the degree of contamination of sediments lying on the floor of the harbour and provided essential information for the siting of wastewater marine outfalls. It has greatly assisted surveys for potential pipeline sites for oil and natural gas development, such as the Sable and Hibernia fields.

Geological work on the slope became a higher priority during the 1980s, when the oil companies became interested in the area and drilled five wells in water depths of 1000-1500 metres on the Scotian Slope. Although detailed studies were restricted to those areas in the immediate vicinity of the wells, major field programs were completed in 1999 and 2000, utilizing the Global Positioning System (GPS) and multibeam bathymetry. These and subsequent studies have highlighted the complex nature of the slope, with deep canyons in some areas, and build-up of sediments in others. Surveys in The Gully, the largest offshore submarine canyon, have provided information on geological characteristics and marine habitats for rare coral that have led to a proposal for declaration of the area as a Marine Protected Area (MPA).

Closer to shore, multidisciplinary studies of climate-change impact on coastal regions have evaluated changing sea level, storm-surge flooding, changes in sea ice, and coastal erosion. A goal of the studies is to identify critical factors associated with climate change and sea-level rise so that coastal communities will be able to react to concerns.

Contrary to popular belief, issue-driven science is not a new concept. An example is the impact of the 1982 United Nations Law of the Sea Convention on the BIO program. Although this convention is not as yet ratified by Canada, it highlighted how little we knew about the area beyond the 200 mile limit, and even much of the continental margin within that boundary. Concurrent with these concerns were boundary issues in the Gulf of Maine and on the Grand Banks, both important fishing grounds and potential areas for hydrocarbon exploration. These issues galvanized mapping studies of the sea floor and the underlying sediments and basement. Such motivation resulted in the Geological Survey of Canada covering the cost of a multichannel seismic survey of the St. Pierre Bank. The data collected demonstrated the lateral extent of the Scotian Basin and proved of considerable interest to the oil companies.

The 1990s and the new millenium have witnessed dramatic strides in website development and digitization. This has transformed management of the databases now available to aid research at BIO. Notable examples are *BASIN* and the Expedition Database, colloquially known as *ED*. *BASIN* provides geological data on all the offshore wells in a format that can be readily manipulated. For example, it is extremely easy to plot logarithmic data against lithology, biostratigraphy, and maturation data whatever the source. Several companies have purchased *BASIN* and it is being extensively used by staff and students of universities throughout Canada. *ED* contains all the data related to cruises on which geoscientific data has been collected by GSC Atlantic or GSC Pacific, or their precursors. Besides accessing the data, one can also obtain a "Trackplot" of the survey or seismic lines together with location of samples.

Merging and digitization of magnetic data from various organizations and covering the Arctic, Labrador Sea, and Atlantic Ocean north of the 30ºN latitude began at GSC Atlantic in 1988. This has provided an unparalleled database, which has and is still being used to produce a superb series of maps such as the new series of detailed magnetic anomaly maps for Atlantic Canada.

Studies of sedimentary basins have been revitalized with the increasingly detailed multichannel and 3D seismic profiles now available. The multichannel data shows that salt under the Scotian Margin does not simply form the classic diapirs but often occurs as detached bodies. Use of 3D data has led to some spectacular time structure maps of specific horizons, showing erosional features such as submarine canyons and faults. To better understand the maturation history in basins such as the Scotian and Jeanne d'Arc, the Tertiary is being studied in greater detail.

FUTURE

A severe handicap to progress during Phase III was a major cutback in staff in 1995, when many of the experienced staff left the Geological Survey of Canada and certain programs, such as paleoceanography and deepwater geophysics were curtailed. This affected progress in many disciplines. However, it is apparent that the reconnaissance survey phase of research is over and that the new direction will be more issues-driven and applied. This could mean greater emphasis on the Canadian North, the Law of the Sea, the SeaMap project (systematic multibeam bathymetric studies), climate change, habitat characterization, high resolution mapping, and the environment. It will also result in efforts to make all data, past and present, readily available in digital format.

Such an applied agenda will also mean rapidly changing priorities, shorter-term research projects, and targeted research on fewer issues. As a priority, we will need to replace staff as they retire. Whatever the future holds, it is obvious that over the past 40 years Canada has had an extremely creative and productive geoscience team on the cutting edge of research and representing an excellent investment in marine geoscience studies. Through regional reconnaissance studies, we now have some understanding of most Canadian offshore regions. In so many fields, marine geoscientists at BIO have provided leadership on global issues, marine geoscience technology, and applied local and international projects. They have, and continue to contribute, critical information to the understanding of the offshore so that both development of resources and protection of ecosystems can proceed in a framework of knowledge and sustainability.

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Ocean Sciences - Looking Back at 40 Years

- Allyn Clarke, John Lazier, Brian Petrie, Trevor Platt, Peter Smith, and Jim Elliott

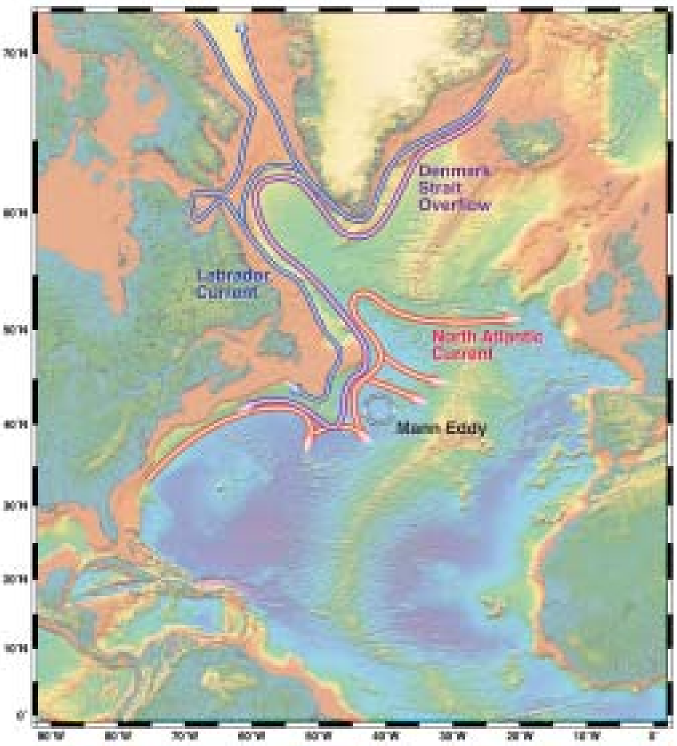
The establishment of BIO in 1962 marked the beginning of a new era in Canadian oceanography. With modern vessels, a modern laboratory, and significant new resources, our marine scientists had the opportunity to take on bigger challenges involved in understanding the dynamics and ecology of the vast oceanic and coastal regions of the East Coast and Arctic Canada. Over the past four decades BIO scientists, with international collaborators, have significantly advanced our knowledge of this oceanographically complex region.

During the first half of the 20th century, physical oceanography was largely associated with local fisheries and included studies of the circulation in the Gulf of St. Lawrence and on the continental shelves of Nova Scotia and Newfoundland as well as a number of expeditions to the Arctic. In the 'blue waters' beyond the shelves, the main features of the circulation and water masses were being explored by Americans and Europeans. Through contact with these scientists and their work, the new generation of BIO oceanographers increased their appreciation of the physical processes in the region and of important research that could be pursued as the world was becoming more aware of the significance of the oceans in our lives.

DEEP OCEAN STUDIES

The North Atlantic Current that originates in the Newfoundland Basin as a branch of the Gulf Stream is one such area of interest. This current flows eastward across the North Atlantic into the Norwegian Sea. The heat it carries north is responsible for Europe being 10ºC above the average for its latitude. Between 1962 and 1966, CSS *Baffin* and CNAV *Sackville* carried out a number of cruises south of Nova Scotia and Newfoundland and east of the Grand Banks. These studies mapped the structure and circulation in the Slope Water and the Gulf Stream extension as it encounters the Southeast Newfoundland Ridge. Here the Stream splits into two branches as it encounters shoaling depths. The northern branch flows northward past Flemish Cap as the North Atlantic Current. This work also discovered an intense clockwise eddy within the Newfoundland Basin, now known as the Mann Eddy after its discoverer Cedric Mann.

A second region of interest is the Labrador Sea where, in severe winters, the mixed layer can deepen to 2000 m thereby creating a unique water mass that 'ventilates' the deeper layers of the ocean by spreading through the North Atlantic at intermediate depths. BIO's principal ship, the CSS *Hudson*, along with the CCGS



Schematic of water circulation in the northwest Atlantic.

Labrador, spent 200 days (1965-1967), mostly in winter, mapping the waters from Davis Strait through the Labrador Sea and Irminger Sea and into Denmark Strait. These surveys created a valuable dataset that is still regularly used to define the conditions existing at the time and provide a reference point for current studies. The Labrador Sea work was aimed at examining the deep convection process but the winter of 1966 was exceptionally mild and calm so convection in the Labrador Sea was weak and shallow. Subsequent analyses of the time series of data collected at Ocean Weather Ship Bravo showed that 1966 was in the middle of a mild period when a large low salinity water mass appeared. This later became known as the 'Great Salinity Anomaly'; it was carried out of the Labrador Sea by the circulation and was tracked in the North Atlantic for 10 years. This work demonstrated firmly how variable the properties in this region were compared to other regions of the ocean.

Cedric Mann collecting water samples during the Arctic section of the Hudson *70 voyage.*

A third phenomenon of interest is the overflow of dense water into the North Atlantic from the Iceland Sea over the sill in Denmark Strait. This flow is thought to be the main driving force behind the circulation that brings the warm water of the North Atlantic Current north into the Norwegian Sea. The work was carried out with scientists from the Woods Hole Oceanographic Institution (USA) and the National Institute of Oceanography (UK). The expedition obtained a complete mapping of the water masses in the Irminger Sea and the first direct measurement of the flow over the sill in Denmark Strait. The transition between the 1960s and 1970s was celebrated by conducting, with CSS *Hudson*, the first circumnavigation of North and South America accompanied by scientific studies of many types in all the oceans along the way.

Work in the 1970s and 1980s was strongly influenced by our new capacity to moor current meters in the deep sea. Current meter arrays in the Newfoundland Basin provided the first direct measurements of the transport of mass and heat in the Gulf Stream and North Atlantic Current at the Tail of the Bank. A long series of current meter measurements in the Labrador Current led to a better understanding of its structure as well as the annual and longer-term fluctuations of the current and its total transport. BIO also participated in 'Overflow 73', an eight-nation investigation of the flow into the Atlantic across the sills between Greenland and Scotland, sponsored by the International Council for the Exploration of the Sea. This was the first large-scale direct measurement of these flows and allowed a more accurate estimation of the total volume of overflow water. Current meter measurements along with conductivity/temperature/depth (CTD) surveys were also conducted in Davis Strait and Baffin Bay and in the northwest corner of the North Atlantic Current where it turns sharply from north to east, just northeast of Flemish Cap. This was the first time current meters had been used in this flow and showed the current to be intermittent.

Continuous profiles of temperature and salinity along with some of the first mid-depth floats were used in the late 1970s to re-examine deep convection during winter in the Labrador Sea. Severe weather led to convection to a depth of 1500 m. These measurements provided the first description and analyses of the flow and water mass transformation in a region of active deep convection.

In the 1990s, most of the work has been associated with Canada's contribution to the World Ocean Circulation Experiment; a program of the World Meteorological Organization aimed at gaining a better understanding of the global climate system. A large mooring program in the Newfoundland Basin in cooperation with USA scientists led to new descriptions of flow details and better determinations of the fluxes of various parameters throughout the region. In the Labrador Sea, a CTD section across the entire basin from Labrador to Greenland was repeated at least

Clean-up on the CCGS Hudson *after a winter storm in the Northwest Atlantic off Newfoundland - December 2002.*

once a year. The winters of the early 1990s were abnormally severe and deep convection was observed to greater depths than ever before. This 'new' water is now being traced as it moves to other regions of the ocean.

COASTAL STUDIES

Studies in the coastal regions through these past four decades have been varied and broad ranging. Initially, during the 1960s, they were a continuation of work underway by the Fisheries Research Board and the new Marine Sciences Branch. Scientific activity has since expanded, ranging from process studies to habitat assessments to forecast models in support of marine safety.

In the mid to late 1970s, environmental and economic concerns of harnessing tidal power in the upper Bay of Fundy were addressed using a model which predicted the changes in tidal range, currents, and sediment distribution for the entire Gulf of Maine. Oil spills in 1970 (*Arrow*) and 1979 (*Kurdistan*), were tracked and monitored in the effort to minimize damage to coastlines and marine life. The Shelf Break Experiment (1975-78), a three-year program of moored measurements, studied dynamic processes at the edge of the Scotian Shelf. Two major discoveries were: 1) the role of topographic Rossby waves generated by Gulf Stream rings in propagating low-frequency current variability across the continental slope to the shelf edge, and 2) the importance of wind-driven shelf break upwelling in "flushing" the deep inner shelf basins. In the Gulf of St. Lawrence, the Gaspé Current Study (1978-80) investigated the structure and variability of this prominent flow, and the Strait of Belle Isle Study (1980-82) quantified the contribution of the Labrador inflow to the mass budget of the Gulf of St. Lawrence.

The Fisheries Ecology Program (1983-85), a collaboration among physical oceanographers, marine ecologists, and fisheries scientists, produced new insights into the biophysical interactions among trophic levels of the marine ecosystem. Focussing on Browns Bank haddock, the investigators were able to observe, quantify, and model the role of the mean, seasonal, and higher frequency currents off southwest Nova Scotia in the transport and survival of haddock eggs and larvae and their impact on stock recruitment. Recent efforts modelling early life stages of haddock, sponsored by GLOBEC Canada, have demonstrable skill in predicting interannual variability of survival and recruitment of the Browns Bank stock.

There have been numerous studies in the nearshore region; many of these have been associated with environmental and search and rescue concerns. One example is the multidisciplinary study of Halifax Harbour in the late 1980s that established the extent of contamination from anthropogenic sources and the benefits of harbour clean up. Another is the circulation model used to track debris from the September 1998 Swissair disaster off Peggy's Cove.

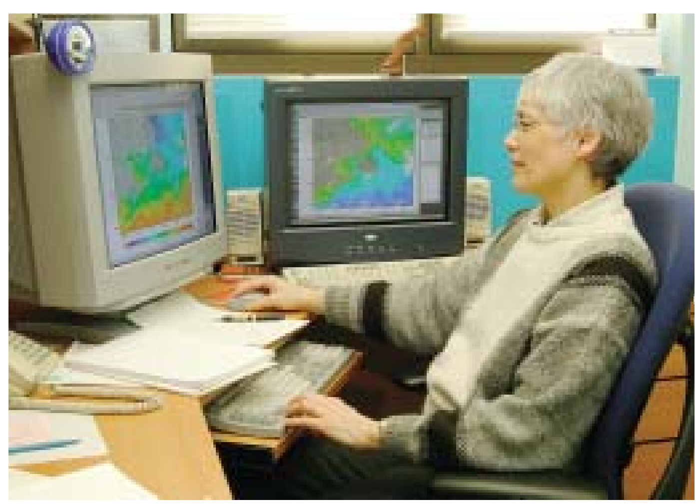
BIO has also contributed significantly to the understanding of cod, haddock, and zooplankton ecology in the US GLOBEC Georges Bank Study (1990-99). Long-term moored measurements in Northeast Channel and off Cape Sable defined the interannual variability of the inflow to the Gulf of Maine, and hence to Georges Bank. Significant progress was made in modelling the tidal and mean circulation.

PHYTOPLANKTON STUDIES

Ecological studies over the past 40 years have involved many groups and collaborators. Understanding the variability at the base of the food chain, the phytoplankton in our surface waters, is just one example and has been a significant challenge.

Early phytoplankton studies in the Marine Ecology Laboratory, of the then Fisheries Research Board, were concerned with the seasonal variability of coastal inlets of Nova Scotia, principally Bedford Basin, St. Margarets Bay, and Petpeswick Inlet. Much of the methodology used in later years was being developed, including techniques for measuring water column primary production and chlorophyll concentration. A research program was also begun in the late 1960s to strengthen the theoretical basis for the studies. This program, which has continued to this day, has contributed to the development of the fundamental concepts and principles of the field of pelagic ecology. A close relationship between theoretical developments and observations in the field has greatly facilitated the success of the program.

The legacies of the research on coastal inlets include procedures for assessing the seasonal dynamics of the autotrophic communities; procedures for synthesizing and interpreting data on pelagic ecology; and a recognition of the vital importance of the physical oceanographic context of biological oceanographic measurements — that is to say, a recognition of the essential role of physical



Linda Payzant at the image analysis terminal of the Remote Sensing Group.

forcing in shaping the dynamics of phytoplankton.

An example of physical-biological coupling arose from the desire to establish the representativeness of individual samples of chlorophyll concentration. This led to a study of the already known phenomenon of patchiness in phytoplankton. Chlorophyll concentrations, measured by underway fluorometry, were collected at closely-spaced intervals. The results were expressed as a variance spectrum and found to conform to the expectations under Kolmogorov's representation of the inertial turbulence spectrum at high wave numbers. This led to the hypothesis that local phytoplankton abundance is under turbulent control, a view that has persisted with the advent of synoptic fields of chlorophyll concentration measured by remote sensing.

One of the procedures used for synthesis is that for reducing the data from field and laboratory experiments and establishing the relation between photosynthesis and light in phytoplankton. Here, the data from some sixty samples are fitted to mathematical models and two parameters extracted. These two numbers summarize the photosynthetic performance of the phytoplankton at the time and place of the experiment. The general approach developed at BIO is now in use by oceanographic laboratories the world over.

Our analysis of the photosynthesis parameters is useful in the treatment of data on ocean colour collected by instruments carried on satellites. One of the major applications of these data is in the calculation of primary production at large spatial scales. This calculation requires first a model of the photosynthetic response to light, such as those developed at BIO, and second a protocol for assignment of the necessary parameters. For the assignment protocol, a procedure was established that involved the partition of the ocean into a suite of biogeochemical provinces within which the phytoplankton could be said to be subject to common physical forcing.

This basic idea was implemented by Dr. Alan Longhurst, a former director of BIO, in the book *Ecological Geography of the Sea,* that has received universal acclaim. The entire theoretical apparatus, developed over a period of more than 25 years, from the photosynthesis-light experiments to the mathematical modelling and the ocean partition was applied to the first calculation of global marine primary production using remotely sensed data. In this calculation, the BIO archive of results from more than 2000 photosynthesis-light experiments, accumulated over 25 years in the North Atlantic, proved to be especially useful.

This is but a glimpse at four decades of progress!

Marine Environmental Research at BIO - A Brief History

- Don Gordon, Barry Hargrave, Paul Keizer, Ken Lee, and Phil Yeats

In its capacity for protecting fish and fish habitat, Fisheries and Oceans Canada conducts research and provides advice on the impact of human activities on fish and fish habitat. Studies of the impact of human activities were a part of the early research initiatives in the chemical oceanography and marine environmental quality programs at BIO and are now the primary focus of research in the Marine Environmental Sciences Division (MESD).

THE EARLY YEARS (1962-1987)

CHEMICAL OCEANOGRAPHY

Chemical oceanography was part of the research program at BIO in the very beginning. In the first decade, the focus was on salinity, oxygen, nutrients, and alkalinity measurements in support of physical oceanographic research. Sensitive analytical techniques were developed for measurement of these parameters and other chemicals that could serve as tracers. One highlight of these early years was the *Hudson '70* expedition that included one of the earliest applications of nutrients as chemical tracers of water mass structure. Later, trace metals, stable oxygen and carbon isotopes, freons, and radionuclides were used as tracers and their application was extended to fishery science and geology.

In the 1970s and 1980s, research initiatives addressed growing concerns about the distribution and fate of natural and anthropogenic trace chemical constituents in the ocean, and environmental impacts of chemical contamination of the marine environment. During this period, work focussed on the Gulf of St. Lawrence. Data were collected to describe the distribution and chemistry of suspended particulate matter, nutrients, oxygen, organic matter, oxygen and carbon isotopes, trace metals, petroleum hydrocarbons, and radionuclides. Knowledge of the sources, distribution, and fate of these chemicals and the techniques that were developed form the basis for the on going research efforts in east coast marine waters. Between 1977 and 1983 there was a substantial effort to investigate contaminants in the eastern Arctic.

The chemical oceanography program expanded onto the international stage with contributions to the programs of the International Council for the Exploration of the Seas (ICES), the International Atomic Energy Association, and the International Oceanographic Commission (IOC). Contributions were made to various international exercises to intercalibrate methods for sampling and analyses and the IOC Atlantic Ocean contaminant baseline study.

MARINE ENVIRONMENTAL QUALITY

In 1965, the Marine Ecology Laboratory (MEL) was established at BIO to conduct research on ecosystem energetics and food web dynamics. The Environmental Quality Unit (EQ) was established in 1970 within MEL to study the ecological effects of contaminants. Early studies included the fate and biological effects of oil spills, the distribution of mercury in marine food webs, bioaccumulation and biological effects of chlorinated hydrocarbons such as PCBs, and chlorinated pesticides across trophic levels (from plankton to seals). Research showed that pathways and effects of these contaminants on marine biota depended on how contaminants entered the ocean, either as accidental spills, direct discharge, or by river or atmospheric input.

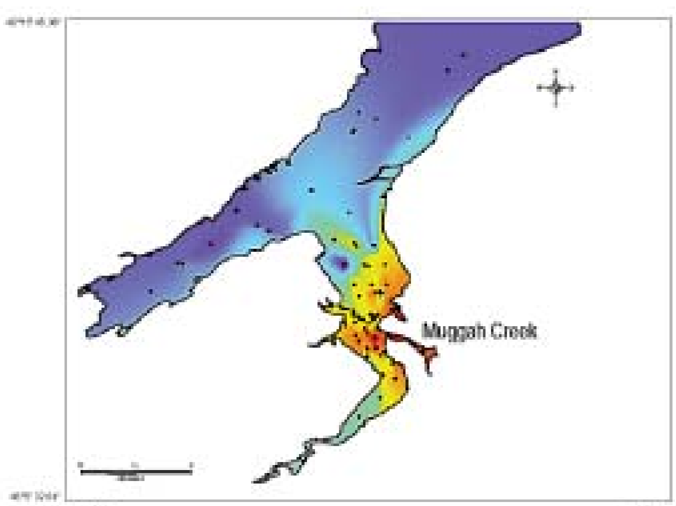
Ecosystem-based studies by multi-disciplinary research teams were used to describe and model effects of human impacts on the ocean. Throughout the late 1970s and 1980s, these included observational and modelling studies to document potential effects of tidal power development in the Bay of Fundy and food web dynamics of persistent chlorinated compounds in coastal waters of the southern Gulf of St. Lawrence. Observations of organochlorines in St. Georges Bay were first made in the mid-1970s and have been repeated every five years to the present day. This time series provides a valuable record of the response of the marine food web to changing concentrations of these atmospherically-transported contaminants.

MARINE ENVIRONMENTAL SCIENCES (1987-2002)

Research on human impacts on marine ecosystems became the responsibility of the Marine Environmental Sciences Division at BIO in 1987. Major projects over the past 15 years and those currently underway cover a broad range of issues. These include the distribution and effects of harbour contaminants, environmental effects of a coastal aquaculture industry, impacts on offshore benthic habitat due to trawling, and ecosystem responses to oil and gas development.

DISTRIBUTION AND EFFECTS OF HARBOUR CONTAMINANTS

Are toxic chemicals affecting the marine habitat of the region's two most heavily populated and industrialized harbours? This question is being addressed in studies of the sources, fate, and effects of contaminants in Sydney and Halifax harbours. A detailed assessment has been made of the impacts of industrial contaminants and sewage on contaminant distributions and biological effects. The conclusions of the two studies are surprisingly similar. The history of contaminant inputs in both harbours, as recorded in sediment cores, shows maximum inputs of industrial contaminants such as polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and heavy metals 30 to 50 years ago and declining inputs over the past couple of decades. However, contaminant levels in the sediments of the central parts of both harbours remain high and living organisms still accumulate certain contaminants. Experiments have been conducted to identify the specific compounds in the contaminant mixtures responsible for toxic effects. Studies on linkages between contaminant exposure and biological effects have resulted in the identification of biological variables (at the community, population, and cellular level) and development of methodologies that can be used to assess marine environmental quality in the harbours. These studies have also contributed knowledge on the significance of natural microbial processes that break down many persistent contaminants. The results of these studies are being used in predictive models that will influence the extent and type of remedial action programs required for the clean up of the harbours.

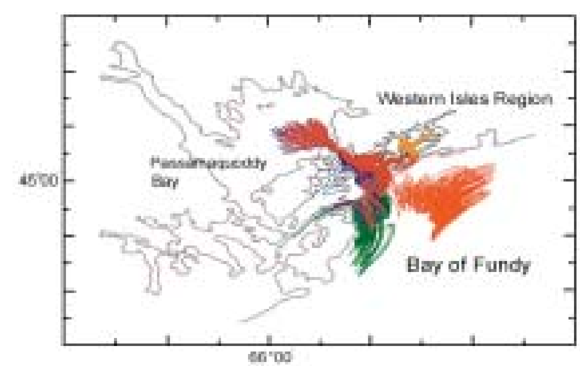


The distribution of PCBs in the surface sediments of Sydney Harbour in 2002. Highest concentrations are red, lowest are blue.

ENVIRONMENTAL INTERACTIONS OF AQUACULTURE

Paul Keizer preparing to deploy a benthic chamber to measure the impacts of organic enrichment under a salmon cage.

Salmon net-pen aquaculture in the Western Isles Region of southwestern New Brunswick expanded rapidly during the 1980s. Growth of the industry has been limited by diseases such as infectious salmon anemia, infections of parasitic crustaceans, and the general increase in outbreaks of harmful algal blooms in coastal waters associated with widespread nutrient enrichment. Nutrient enrichment and oxygen depletion has become a problem in some areas. Ecosystem studies led by research teams from BIO and St. Andrews Biological Station, have developed models and methods for measuring both local and far field environmental effects of salmon aquaculture. Dispersion models tracking water column and sediment variables show that locating several salmon farms in an area with restricted circulation



Modelling the dispersion of particulate wastes in the Western Isles Region of southwestern New Brunswick. Each colour track represents the path of particles released in different parts of the area.

can lead to cumulative impacts. Increases in dissolved nutrients and sediment organic matter have occurred in some areas. Trace metals such as copper and zinc have been found to be good tracers to indicate the area over which dissolved substances and particulate matter released from farm sites are dispersed.

The mussel aquaculture industry in the Maritime Provinces has expanded rapidly, particularly in Prince Edward Island since the early 1980s. The cause of decreasing growth rates of mussels in several locations where aquaculture is most concentrated in PEI has been studied by modelling effects of mussel feeding and biodeposition. Observable effects on water column and sediment variables have recently been documented in bays where flushing rates are low. Current research is focused on estimating optimal carrying capacity for sustainable growth while minimizing changes in pelagic and benthic ecosystem components.

IMPACTS ON OFFSHORE BENTHIC HABITAT DUE TO TRAWLING

DFO has been challenged as a result of various international agreements to develop an ecosystem approach to fisheries management. Two examples are the FAO Responsible Fisheries Agreement and Convention on Marine Biodiversity. An important first step is to understand the effects of fishing gear on seabed habitat and communities. In 1990, Marine Environmental Sciences Division began to apply its expertise in benthic ecology to this issue and developed a major research program conducted in collaboration with other DFO divisions at BIO, the Geological Survey of Canada (Atlantic), the Newfoundland Region, several universities, and the fishing industry. New video and photographic instrumentation was developed for sampling and imaging benthic habitat and communities on the continental shelf.

Major experiments have been conducted using a variety of gear types in different marine habitats. These include otter trawling in the intertidal zone of the Bay of Fundy (1990-1991), on a sandy bottom on the Grand Banks of Newfoundland (1993-1995), on a gravel bottom on Western Bank (1997-1999), and hydraulic clam dredging on a sandy bottom on Banquereau (1998-2001). Observations on immediate impacts and recovery periods were made using a variety of acoustic, imaging, and sampling tools operating over a wide spatial scale (mm to km). The results indicate that the impacts of fishing gear are variable and depend upon numerous factors including the kind of gear, bottom type, and benthic organisms present.

Now that the effects of mobile fishing gear on benthic habitat and communities are better understood, attention is turning to studying how demersal fish (e.g. haddock, cod, and flounders) utilize the seabed. This includes determining the kind and distribution of benthic habitat that demersal fish require to carry out their life processes in a sustainable manner. A wide variety of benthic habitats occurs on the continental shelf off Atlantic Canada and they are very patchy in their distribution. Managing fisheries in an ecological framework requires that these benthic habitats be mapped in detail.

Scientific team at sea on the CCGS Parizeau *off the Grand Banks collecting data and samples for the study on the effects of otter trawling on the banks. Left to right are: Don Gordon, Peter Vass, Dwight Reimer, Tim Milligan, Mark Hawryluk, Kee Muschenheim, David McKeown, Terry Rowell, Karen Saunders, Kevin MacIsaac, and André Ducharme.*

OIL AND GAS RESEARCH

Research on the potential impacts of hydrocarbons on the marine environment started at BIO in 1970 to support the emergency response effort following the grounding of the tanker, *Arrow*. Initial studies focussed on the formation and dynamics of oil-in-water emulsions and the development of analytical techniques to track the spilled oil in the ocean. These studies led to an interest in global oil pollution including the management of an international program to map tarball distributions across the North Atlantic and the assessment of baseline levels of contaminants in the western North Atlantic.

Site of an oil spill bioremediation field experiment in Pepteswick Inlet. The red rectangles are the location of oiled and control plots. Booms to prevent the escape of oil are also visible.

Research was conducted to identify both short and long-term impacts of petroleum hydrocarbons on phytoplankton, zooplankton, benthic organisms (such as worms and clams), and commercial fish species (for example, lobster larvae). Numerous studies on the environmental fate and persistence of contaminant hydrocarbons have been conducted. These include studies of natural oil seeps in the Arctic, the processes controlling the dispersion rates of oil spilled at sea, and the persistence of oil stranded on beaches. The understanding of these processes has facilitated research programs on the development and evaluation of oil spill clean-up procedures based on the application of natural recovery, chemical dispersants, bioremediation, and surf-washing.

Potential impacts of the activities of the offshore oil and gas industry have been studied to facilitate the protection of the fisheries and fish habitat. Biological and chemical studies have characterized contaminants in operational discharges and identified potential impacts to biota, including commercial fish species (such as scallops) and species at risk (for example, corals). Study results are applied to risk assessment models, developed with colleagues from Ocean Sciences Division, to provide guidance to resource managers responsible for regulatory approvals, such as exploration on Georges Bank. Initial studies focused on the potential impacts of drilling muds and well cuttings associated with drilling operations. With the onset of production, greater emphasis is placed on the assessment of cumulative effects of produced water discharges. The results of these studies will be used to improve regulatory guidelines for operational waste discharges.

FORTY YEARS OF CHANGE

The changes in the oil and gas research program over a period of 32 years illustrate the evolution from independent, but complementary, chemical oceanographic and environmental quality programs to the present-day integrated Environmental Science Program. Similar changes in research capacity, direction, and application have occurred in other areas of environmental science. Technological advances have increased our ability to collect and process information. Requests for scientific advice have increased dramatically. Environmental science and natural sciences in general, are being challenged to provide advice on the impacts of human activities, taking into account all potential interactions in the ecosystem. This is a truly daunting challenge but an exciting one for the next 40 years of Environmental Science at BIO.

Research in Support of Fisheries (1962–2002)

- Michael Sinclair, Wayne Stobo, René Lavoie, Bob O'Boyle, and Larry Marshall

The groups conducting research and monitoring in support of fisheries on both marine and diadromous species arrived at BIO at different times. The Marine Fish Division was established at the Institute in 1976 under the leadership of Ralph Halliday. In 1999, the Invertebrate Fisheries Division arrived after the closure of the Fisheries Research Laboratory in Halifax where it had been resident for a number of years. The Diadromous Fisheries Division also relocated to BIO in 1999. This was the first opportunity for consolidation of the research programs into one location. All three divisions have staff located at other sites (such as St. Andrews Biological Station, the Gulf Fisheries Center, biodiversity facilities at Mersey, Coldbrook, and Mactaquac, and various fisheries management offices in Nova Scotia and New Brunswick). Research highlights for the last 40 years are addressed here.

THE 1960s

During the 1960s, to better characterize the size and age composition of the landings from commercial fisheries, the collection of biological information at diverse ports from Cape Breton, Nova Scotia to St. Andrews, New Brunswick was increased. This was the decade when fish stock management was first carried out in support of the International Commission on North Atlantic Fisheries (ICNAF). The key regulatory tools at the time were controls on effort and mesh size. Research was focused on size at maturity, the selectivity features of fishing gear, and stock structure through tagging and life history studies since that information was critical to the definition of management area. During this period, the distant water fleets from Western Europe, the East Bloc countries, and Asia expanded their activities onto the Scotian Shelf and the Gulf of Maine area.

At this time a high priority was placed on Atlantic salmon research, due in part to the impact of forest spraying using DDT and fenitrothion. Two world-class hatcheries were constructed (Mactaquac and Mersey) to enhance the production of smolts. Mactaquac was the largest Atlantic salmon hatchery in the world at that time. An 8-year smolt-tagging program was initiated in 1968 to evaluate the contribution of the federal government's Atlantic salmon hatcheries to the fisheries. The tagging studies

Construction of the water aeration tower and headtank at the Mactaquac Fish Culture Station in the mid 1960s - photo by Phil Hubley.

René Lavoie retrieving experimental oyster seed collectors in Caraquet Bay, 1973.

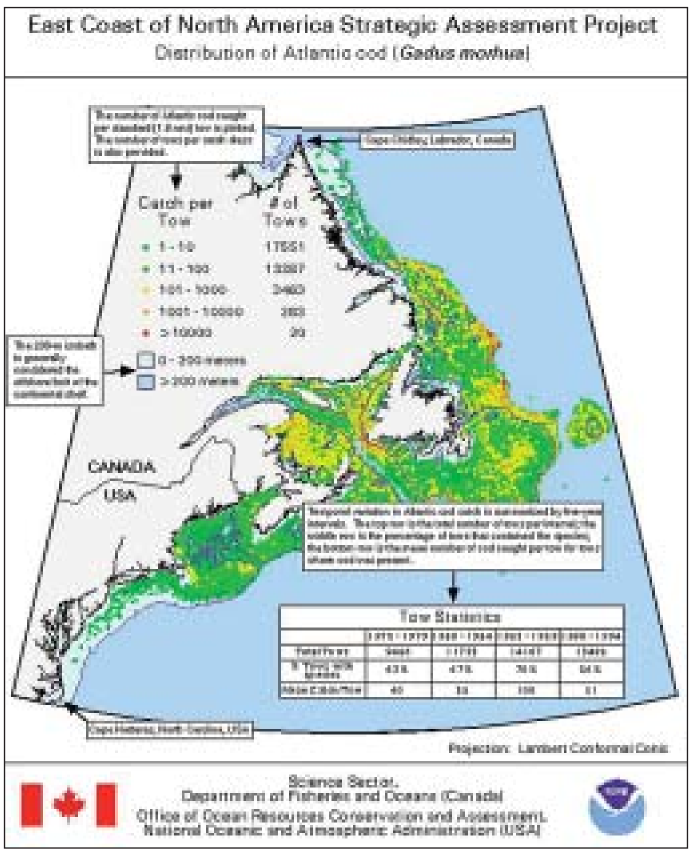
themselves dramatically altered our understanding of salmon migration patterns.

In addition to life history work on lobster and scallops, oyster culture research was conducted at the Ellerslie Oyster Culture Station and at several field stations including Neguac and Shippegan, New Brunswick, and Malagash and Gillis Cove (Bras d'Or Lakes), Nova Scotia.

THE 1970s

Beginning in the early 1970s, investigations focused on the feasibility of raising salmon under cage culture. Both the hatchery techniques and the cage culture experiments would later lead Canada into the billion-dollar salmon aquaculture industry, now especially prominent on both the east and west coasts of Canada, Norway, Scotland, and Chile.

Based on the Woods Hole initiative of 1963, Ralph Halliday established the "ecosystem trawl survey" on the Scotian Shelf in 1970. A similar survey was established in the southern Gulf of St. Lawrence in 1971. This initiative would eventually lead to the establishment of a unique time series of synoptic annual surveys for fish and invertebrates from Cape Hatteras to Cape Chidley.



An example of the information available on Atlantic cod as a result of the ecosystem trawl survey initiated in the 1960s (USA) and 1970s (Canada).

The Law of the Sea developments, culminating in the extension of maritime jurisdiction in 1976, was the dominant driver of research priorities in fisheries in the 1970s. The optimism of an expanded Canadian presence in the offshore fisheries led to the growth of the research teams, the establishment of the Marine Fish Division finfish assessment and research group at BIO, and in 1977, the establishment of the Canadian Atlantic Fisheries Advisory Committee (CAFSAC), with its secretariat at BIO.

The Scotian Shelf Ichthyoplankton Program (SSIP) was undertaken in the 1970s, and was based in part on the success of the plankton surveys off the coast of California by the California Cooperative Fisheries Investigation (CalCOFI) which extended from Baha, California to British Columbia. SSIP resulted in new understanding of the spawning areas of a wide range of fish species, illustrating the importance of re-circulation of currents on banks for life history migrations of marine species. Staff hired at the end of the decade, brought strong quantitative skills including capability in the computer programming language APL that fostered innovative developments in stock assessment modelling methodology. Indeed the adaptive framework (ADAPT) program in use in many research labs was written in a programming language (APL) and was called ADAPT because it was so easy to change to particular situations or was "adaptable". It is now used in many DFO research facilities across Canada as well as by fisheries researchers in international research facilities.

The results of the tagging studies on Atlantic salmon revealed migration from rivers in the Maritime Provinces to West Greenland, and the impact of those fisheries on local stocks. River specific advisory committees were established, which led to a moratorium on commercial fishing in the Saint John River in 1972. This was the beginning of a long process that led to the eventual elimination of all commercial fishing for Atlantic salmon in the Maritimes in 1984 and in Atlantic Canada in the late 1990s.

The diadromous research program was expanded at this time to include gaspereau, shad, and striped bass. There was a strong focus on engineering to construct/enhance fishways at dams and improve culvert designs. A finding that was to prove dramatic was the research linking juvenile salmon mortality at the Mersey Fish Culture Station to increasing acidity of rivers in the Southern Upland area of Nova Scotia. This was the first hint of the devastation to Nova Scotian rivers due to acid rain.

In the early 1970s, a comprehensive oyster spatfall monitoring program on the Gulf shores of New Brunswick and Nova Scotia, and in Prince Edward Island, identified estuaries where oyster spat could be collected predictably and reliably. In years that followed,

Wayne Stobo tagging a four-week old grey seal pup on Sable Island in the late 1970s.

an oyster seed production industry was born in New Brunswick. After some difficult years, the industry now provides the seed for the production of quality cultivated oysters for the high-end half-shell trade.

The Sable Island research program on grey and harbour seals was also initiated in this decade. This program for monitoring the abundance of these apex predators off Nova Scotia led to the remarkable finding of explosive exponential growth over three decades (from several thousand individuals of grey seals in the 1970s to over 300,000 today).

Grey seal pupping grounds on Sable Island January 2000 - photo by Jim McMillan.

A major fire occurred at BIO in April 1979. This destroyed the offices of the Marine Fish Division and many of the research data and administrative files that were located in the area. The group was housed in the adjacent Core Building until new facilities were available in the early 1980s.

Area claimed by the USA and Canada relating to the extension of jurisdiction. The red and black lines represent respectively, the initial claim in the Gulf of Maine area by Canada (1978) and the USA (1976). These limits were subsequently extended prior to the decision made by the International Court of Justice in 1984.

THE 1980s

A high priority horizontal issue in the early 1980s was the preparation of the scientific background information for the Canadian arguments presented at the International Court of Justice in The Hague in support of Canada's claim to parts of Georges Bank and the Gulf of Maine area. The United States based their case primarily on oceanographic and ecological arguments supporting the conclusion that their boundary delineation claim was coincidental with a natural ocean boundary separating discrete ecosystems in the Gulf of Maine area. Along with geological, bottom topography, and oceanographic information prepared by other components of BIO, research findings on commercially important fish and invertebrate distributions and migrations were prepared for the legal team. The scientific arguments put forward by the United States were ultimately put aside by the judges, and the 1984 decision resulting in the Hague Line across Georges Bank proved to be very favourable to Canadian fisheries interests. The research investment of the two previous decades at BIO had borne fruit.

A second driver of the research advisory focus of the 1980s was the extreme growth in capacity of the fishing fleets in the Scotia-Fundy area. This led to the 1980 Kirby and the 1989 Haché task forces. The Kirby Task Force addressed the viability of the offshore fleets leading to a paradigm shift in fisheries management, from competitive fisheries characterized by the "Tragedy of the Commons" to a property rights approach with specific shares being owned by companies and individual fishers. The Kirby Report led to enterprise allocations for offshore scallops, and this generated the need for an enhanced scallop stock assessment and research program. A new type of government/industry partnership in research on fisheries was generated which has proven to be a model for others.

The Haché Task Force addressed the fleet overcapacity of the small groundfish trawlers and resulted in:

- Imposition of Individual Transferable Quotas (ITQs) for groundfish trawlers < 65 feet, and a new partnership with scientists at BIO and St. Andrews which involved enhanced port sampling and an annual late summer survey off southwest Nova Scotia using small fishing trawlers provided and funded by industry.

- The initiation of programs to improve communications between scientists and the fishing industry led to the establishment of the Fishermen and Scientists Research Society (FSRS). The Society chose to avoid involvement in fisheries management issues, has major collaborations with scientists working on fish, invertebrates, and oceanographic studies, and is now well established and receiving international recognition.

- Enhanced research on the population dynamics and food habits of Sable Island grey seals, and on methods of population control.

Assessment methodologies also advanced during this period. At the beginning of the 1980s, assessment procedures were relatively *ad hoc*. Procedures were developed based on more formal non-linear optimization algorithms. Nevertheless, problems in the models were being observed in the mid-1980s. These ultimately led to a workshop in 1989 that formalized the diagnostic tool now known as the Retrospective Analysis (a tool that revealed systematic overestimation of stock biomass and underestimation of fishing mortality).

Funding for fisheries research was relatively rich during the 1980s. Several multi-disciplinary field studies were undertaken to investigate the role of oceanographic processes in the definition of population patterns and recruitment variability for lobsters, scallops, haddock, and herring. The concept of larval retention areas associated with geographically predictable recirculation features, provided an attractive interpretation of herring population patterns and their temporal variability. The application of the concept to haddock was studied during the Fisheries Ecology Project which determined that there was a 'leaky" gyre on Browns Bank. In seasons where the gyre was stable, haddock larvae were retained on Browns, but when it was not, they drifted inshore off southwestern Nova Scotia. However, when applied to research on lobster, the results indicated that late stage lobster larvae are dispersed broadly by the wind-driven surface layer circulation that was not in agreement with the herring and haddock observations. An otolith program was established, and used the characteristics of the fish earbone to unravel a range of complex ecological problems from aging studies to recruitment dynamics of a number of species, for example, haddock.

Several large-scale surveys were undertaken to evaluate the distribution and abundance of invertebrate species, such as ocean quahogs and squid. The quahog surveys covered the Scotian Shelf from the Laurentian to the Northeast channels. The results provided the background information for the development of a lucrative fishery on these resources in the 1990s. In the inshore, mapping of the productivity of the marine plant resources in the area off southwest Nova Scotia, formed the basis of a sustainable harvesting regime. The dramatic observation of the increase in abundance of sea urchins from Cape Breton to Shelburne, concomitant with the reduction in kelp biomass, led to a large-scale study. During the study there was an outbreak of a disease which decimated large parts of the sea urchin population. By good fortune, the study captured the dynamics of complex distributional changes at large scales, and resulted in new understanding of benthic ecosystem dynamics in the coastal zone.

A major multi-disciplinary study was initiated on the impacts of acid rain on the rivers and lakes of Nova Scotia, with particular emphasis on the Atlantic salmon. The results were far reaching, including the changes in the insects and invertebrates at Kejimkujik National Park, the opportunities for mitigation using lime, and the physiological responses of young salmon to changes in pH. As a result of increasing acidity in the rivers of the Southern Upland from Yarmouth to Guysborough counties, many of these waters became unsuitable habitat for salmon. In parallel with the research on habitat, there was an enhanced focus on the development of assessment and forecasting methods. The dim prospects led to final closures of the commercial salmon fisheries of New Brunswick and Nova Scotia by 1984 and subsequent license buy-backs.

Irish moss harvesting in southwest Nova Scotia, near Pubnico in the early 1980s - photo by Bob Semple.

THE 1990s AND BEYOND

In the early 1990s, the rapid decline of the cod and other groundfish stocks was observed, in particular on the eastern Scotian Shelf. Overly optimistic stock assessments, overfishing, and unexplained increases in natural mortality during the late 1980s to mid 1990s, led to a resource collapse and a moratorium, which is still in place today. Considerable attention was directed towards a thorough review of the causes of the collapse and identification of changes required in the management system. For the first time, stock assessments included partitioning of the natural mortality component, with the development of a model that estimated the predation effect of seals on the eastern Scotian Shelf cod. The deliberations on the reasons for the "cod collapses" led to a new impetus on research on fisheries management systems, and a multi-disciplinary program on Comparative Dynamics of Exploited Ecosystems in the Northwest Atlantic (CDEENA).

Research collaboration with USA scientists led to an analysis of the biogeographic shifts (1974–1994) in fish community structure. The results indicated the strong dependence of the fish distributions on bottom temperature variability at decadal time scales. The distributional information on over 100 species was made available on the Internet. Increased research activity on fish communities and biodiversity associated with the Centre for Marine Biodiversity (CMB) have resulted in new appreciation for fishery impacts and the need for broader consideration of ecosystem elements in finfish assessments. Further details on CMB are in the article on the centre under the *Other Programs* section of this report. The overall process of peer review was made more open to the fishing industry, and an enhanced monitoring program of oceanographic conditions was put in place for the Atlantic Zone, from Northern Labrador to the Gulf of Maine.

Another significant development as a result of the groundfish collapse was the disbandment of the CAFSAC and establishment of the Regional Advisory Process (RAP). CAFSAC was seen as a closed scientific peer review forum that allowed input from only DFO scientists. In 1993, consultations were held in the Maritimes on an alternate to CAFSAC, coordinated out of Ottawa. These discussions led to adoption of a very different peer review structure that was ultimately adopted elsewhere in the Atlantic Zone.

The collapse of the groundfish stocks led to more emphasis on non-traditional species, both fish and invertebrates, and a resultant shift in research towards these poorly understood resources. Much of the work has been carried out in partnership with the fishing industry. This broadening of scope in the fisheries was coincident with the *Oceans Act* (1997), a new emphasis on ecosystem impacts of fisheries, and a concern for biodiversity at the community, species, and genetic levels. A regime shift in management of ocean activities (from single species/single issue concerns with relatively

One of the endangered Inner Bay of Fundy one sea-winter salmon from the Big Salmon River, New Brunswick. The fish was sampled for DNA tissue analysis for the live gene bank program at Mactaquac. Greg Perley is assisted by Krissy Atwin, of the Kingsclear First Nation in New Brunswick with Dave Longard in the background.

narrow conservation considerations to integrated management with broader ecosystem objectives) had a major impact on the research programs in the harvest fisheries divisions at BIO.

The collapse of several fish stocks and the disappearance of others ushered in a new concern, and ultimately some species came under the "species at risk" mandate. To support the recovery plan for inner Bay of Fundy salmon populations (which were listed as endangered), a live gene-banking program was initiated at the Mersey, Coldbrook, and Mactaquac biodiversity facilities. Genetic studies were initiated on the Atlantic whitefish of Petite Rivière, Nova Scotia (the only population in the world) to determine the linkages with other species in the same genus. The shark program was enhanced because of new concerns for these species, which have low fecundity and thus are susceptible to overfishing. A new focus was directed towards by catch of leatherback turtles and the role of The Gully as critical habitat for bottlenose whale.

The exciting new technologies that emerged at the turn of the century have allowed innovative questions to be addressed. With the use of multibeam and sidescan sonar, the offshore scallop industry improved the efficiency of fishing operations by about 300%. The increased understanding of scallop habitat preference modified the scallop research surveys. The use of acoustic telemetry allowed the tracking of individual Sydney Bight cod from their summer feeding area to a cod mixing area for overwintering on the Laurentian Channel. The new data management capabilities resulted in the development of the "Virtual Data Centre" that has led to remarkable savings in research time to generate data products for stock assessments.

The beginning of our fifth decade is a period of transition for research in harvest fisheries. The evolution from research, monitoring, and advice in single species to support for ecosystem-based management has begun.

The Canadian Hydrographic Service at BIO

- Gary Rockwell, Steve Grant, and Bob Burke

INTRODUCTION

The Canadian Hydrographic Service (CHS) has been an integral part of the Bedford Institute of Oceanography (BIO) since its opening in October 1962. The four ships at the wharf on opening day were all involved in hydrographic surveys during the 1962 season.

CHS staff, originally based in Ottawa, opened an office in the Ralston Building in Halifax in 1958. The CHS survey ships all berthed at Purdy's Wharf on the Halifax waterfront except for the CSS *Acadia*, which returned to Pictou each fall. This all changed with the opening of BIO. Field hydrographers from CHS moved to BIO from their office in downtown Halifax, bringing their equipment and their archives of survey data.

BIO was well suited to CHS, the ships were tied up adjacent to the offices and the survey launches and equipment were maintained in the BIO shops. The ships left from Purdy's Wharf in the spring of 1962 and returned to BIO in the autumn. The return of the CSS *Maxwell* was timed to coincide with the opening ceremonies on October 25th. The BIO location led to cooperation with other groups at the Institute and the CSS *Baffin* carried out multidisciplinary surveys during most seasons from 1964 until 1990. The CHS Navigation Group was set up in the early 1970s to address the navigation needs of all groups at BIO. Collaborative work has increased in recent years with the broad application of multibeam technology in science and resource management.

The sixties were in many ways the glory days of hydrography in Canada. The *Baffin* had joined the fleet in 1957, the *Maxwell* was added in 1961, and the *Acadia* was still active. CHS had the CNAV *Kapuskasing* on permanent loan from the navy and survey teams were also deployed on shore-based surveys, on various chartered ships, and on Coast Guard vessels working in the Arctic. Every year, at the beginning of May, survey teams spread out across the East Coast of Canada and the Arctic. Most did not return until the end of October, happy to be back home with family and friends and working in the comfort of BIO. The data collected were diligently processed and "Field Sheets" prepared for use in the making of hydrographic charts. As spring arrived, it was time to begin the cycle again. Preparations were made for new surveys, the ships were loaded, and a new survey season was underway.

The structure of CHS changed in 1977 with the arrival of the cartographic unit from Ottawa. The actual move took place over three years from 1977 to 1979. Twenty cartographers were transferred from Ottawa and three additional cartographers were hired locally. CHS Atlantic was no longer just a field survey group, it was

CSS *Baffin* in loose Arctic pack ice in Foxe Basin (circa 1981).

now a full-fledged hydrographic office with the capability to collect data and create products for mariners. This was a national initiative with cartographic staff also moving to Sidney, British Columbia; Burlington, Ontario; and Québec City, Québec. The benefits of having hydrographers and cartographers working closely together, while not appreciated initially, have proven valuable. The work of the hydrographer and cartographer increasingly overlapped and by the mid-1990s, most staff were designated multidisciplinary hydrographers.

HYDROGRAPHIC TECHNOLOGY

CHS has been a world leader in the advancement of hydrography and hydrographic technology. The latest developments in electronic positioning systems were tested and put to work on hydrographic surveys. A data plotter was tested on the *Baffin* in 1962 but did not meet expectations. The first general-purpose minicomputer, a Digital Equipment Corporation (DEC) PDP-8 with 4K memory was installed on *Baffin* in 1967.

Navigation and positioning are fundamental requirements for sea-going research and were factors behind the creation of the Navigation Group in July 1970. Among its many contributions over the years was the introduction of Loran-C and a special ranging version called rho-rho Loran-C that eventually replaced an earlier hydrographic positioning system called Decca LAMBDA. Other initiatives of the Navigation Group were: the development of an integrated navigation system called BIONAV, early research and evaluation of Global Positioning System (GPS) receivers, and extensive development and testing of early Electronic Chart Display and Information Systems (ECDIS) that are now officially recognized by the International Maritime Organization as legal replacements for paper charts.

CHS experimented with multi-transducer sounding systems in the 1970s and installed early versions of digital data collection systems. The hard work eventually paid off, with fully operational multi-transducer systems and digital data-handling systems operational by the mid-1980s. The CSS *Matthew* was fitted with a multibeam acoustic system in 1991; considerable testing and research took place to develop software and procedures to properly use the massive amounts of data generated by the system. The work at BIO led to the development of a high precision motion sensor for multibeam systems. Commercial application led to an instrument that is now the world standard.

During the 1980s, CHS had two major initiatives utilizing robotic vehicles. The Autonomous Remote Controlled Submersible (ARCS) Program utilized a 'torpedo' like vehicle that contained an acoustic positioning system, echo sounder, data logging system, and acoustic telemetric control link. Conducting surveys in ice-covered areas presented a serious challenge for CHS. ARCS was specifically designed to be deployed in the Arctic for under-ice surveys. A prototype unit was tested successfully in southern waters; however, funding cuts and changing survey priorities prevented its operational Arctic deployment.

Dolphin trials with CSS *Baffin* off southwestern Nova Scotia (circa 1984).

The Deep Ocean Logging Platform with Hydrographic Instrumentation and Navigation (DOLPHIN) was an unmanned semi-submersible survey vehicle. It was designed to increase efficiencies on offshore surveys. A number of DOLPHINs could be deployed from a mother vessel and operated in parallel to gather bathymetric data. The design was such that the vehicles could operate in rough weather 24 hours a day. Three prototypes were built along with a specialized handling crane. The program was transferred to the private sector in 1992 and terminated in 1997, as offshore surveys were no longer a priority.

CHS began work on computer-assisted drafting in 1967 and BIO staff played a critical role in the development of a Geographic Information System (GIS) for use in marine cartography. The early systems were used to calculate and create chart borders and positioning lattices, but cartographers still needed their scribe tools and ink pens. The hard work eventually led to the development of fully automated systems. CHS worked closely with the University of New Brunswick and Universal Systems Limited in the development of the CARIS geographic information system. CARIS is now widely used by hydrographic offices around the world.

The implementation of GIS for cartography led to the concept and development of the electronic chart, and CHS at BIO was again in the forefront. Once the charts were in a digital format, the next step was to put them on a screen for the mariner. CHS

Dolphin deployment at BIO wharf (circa 1984).

The CSL Tudlik testing the new acoustic sweep system at Grise Fiord, NWT, 1984.

Navigation Group at BIO pioneered and promoted the electronic chart idea. Electronic charts are now standard equipment on most commercial vessels.

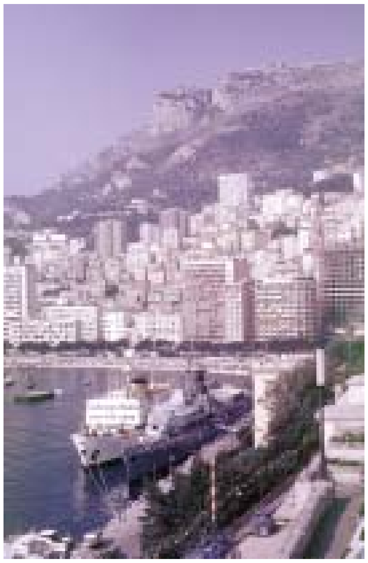
HYDROGRAPHIC SURVEY VESSELS

A number of survey ships have been used by CHS over the past 40 years. The CSS *Acadia*, launched in 1913, was active until 1969. It was designated a national historic site in 1976 and was moved to the Maritime Museum of the Atlantic in 1981 where it is their premiere display. *Acadia* remains a classic example of the best that British builders had to offer. Built during the Edwardian era, the splendid lines of the vessel run uninterrupted from the straight bow to a graceful counter stern. With two masts and single funnel, the ship resembled a small steam yacht more than the hard-working survey vessel. Unconfirmed stories indicate that *Acadia* was refused wharf space at BIO following the opening in 1962. The ship was notorious for the trail of black smoke billowing from coal-fired boilers and rumours suggest that the new occupants of BIO did not want their fine view of Bedford Basin obscured by soot on their windows. Fact or fiction?

The CNAV *Kapuskasing*, a converted World War II minesweeper, served CHS until 1972 when the vessel was returned to the navy for disposal. The CSS *Maxwell* joined the fleet in 1962 and did yeoman service on the East Coast until 1990. This was a highly mobile vessel, small enough to work in the many small ports and harbours in Eastern Canada. *Maxwell* was transferred to the Newfoundland office in 1987 and continued to serve CHS. The CSS *Matthew* replaced the *Maxwell* in 1991 and has carried on the tradition of the hard-working coastal survey ship. CHS took possession of the *F.C.G Smith* in 1986, a unique catamaran style ship built to operate a multi-transducer acoustic sweep system. This pioneering vessel gave CHS the capability to obtain 100% bottom coverage in critical navigation channels and harbours. The *Smith* was deployed to Transport Canada in 1994 for use on the St. Lawrence River. CHS also made use of Coast Guard ships for work in the Arctic. Such vessels as the CCGS *Labrador*, CCGS *Sir John A. MacDonald*, and CCGS *d'Iberville* were the summer homes to survey teams from BIO.

CSS *Baffin* joined the CHS fleet in 1956. This was the most modern survey vessel in the world at that time and was a major component of CHS until retirement in 1991. The *Baffin* was the flagship of the Canadian Hydrographic Service and supported the expansion of Canada's hydrographic and scientific knowledge for 34 years. The vessel was eminently suited to the task of collecting data in all areas of Canada from the High Arctic to the offshore. Hydrographers and scientists on the *Baffin* were leaders in the use of the latest technology with such innovations as radio positioning systems, computer-based data acquisition and processing systems, satellite positioning, and integrated navigation systems. The volume of information collected by the *Baffin* was indeed remarkable and included surveys of Lancaster and Jones sounds, the Labrador coast, the Newfoundland coast, the Gulf of St. Lawrence, the Bay of Fundy, the Grand Banks, and the Scotian Shelf. An important database of gravity and magnetic records was collected during 21 multidisciplinary cruises.

In addition to this extraordinary body of work, other notable events of the *Baffin* included: the circumnavigation of Baffin Island in 1960, representing Canada at the Ninth International Hydrographic Conference in Monaco in 1967, and circumnavigation of North America in 1970 during which the "Pingo Area" in the Beaufort Sea was surveyed. This major achievement was overshadowed by the *Hudson '70* voyage. *Baffin* also took part in Canadian International Development Agency (CIDA) sponsored surveys in Guyana in 1974 and Senegal in 1976. *Baffin* again demonstrated broad capability in 1989 while taking part in a major oceanographic program in Denmark Strait and enduring the worst conditions the North Atlantic could impose. Although the vessel survived this, unfortunately her capabilities and accomplishments could not save her. In the early hours of December 5, 1990, in a severe storm, *Baffin* bumped against the BIO jetty breaching the hull near the portside fueling door. After this, the *Baffin* berthed for the last time and was never again to sail under her own power. The number of hydrographic surveys on the East Coast of Canada was declining. After 34 years of service for Canada, the *Baffin* was quietly retired in April 1991, without a sail past or a decommissioning, a victim of age and shrinking budgets.



The CSS Baffin *at the hydrographic convention in Monaco in 1967- photo by Don Gordon.*

This loss left a void that has not been filled.

CONCLUSION

CHS has maintained offices in the south wing of BIO, now the Polaris Building, since its arrival. Despite the decline in ships and survey capability, the CHS unit at BIO continues to play an important role in the economic viability of the East Coast by providing the charts and navigation information necessary for safe and efficient navigation, marine commerce, fishing, sovereignty, naval activities, and recreational boating. A new role has also emerged in support of the integrated management of our ocean spaces. CHS has been a leader in the implementation of multibeam acoustic systems and the data collected by CHS has opened a new era in the understanding of seafloor processes. These systems allow us to view the sea floor with a detail not possible only a few years ago. Modern seafloor mapping provides the base upon which all marine activities can build.

The theodolites, drafting tools, and manual records of the hydrographer and cartographer have given way to GPS and GIS systems, massive databases, and high-speed plotters. In 2001, CHS successfully implemented a Quality Management System and was registered as compliant to the International Organization for Standardization ISO 9001:2000 standard.

Throughout the changes, CHS maintains a tradition of pride, hard work, and quality. Our clients depend on us to guide them safely on their way. The CHS motto says it all: Nautical Charts Protect Lives, Property, and the Marine Environment.

History of Instrumentation at BIO

- Allyn Clarke, Dave Heffler, Donald Belliveau, and Timothy Milligan

If the scientists from the 1873-1875 HMS *Challenger* expedition had visited BIO on its opening day in 1962, they would have recognized many of the oceanographic instruments and techniques still in use. The most significant change was the replacement of lead lines with acoustic sounders for mapping ocean depth. In 1962, most ocean instrumentation was mechanical. Physical and chemical oceanographers sampled the temperature, salinity, and chemical properties of the ocean using reversing thermometers and water sampling bottles. The sea floor was still being sampled using mechanical grabs, dredges, and corers.

NAVIGATION

Instruments to sample and map measurements in the ocean are of little use if you do not know where you are. In 1962, radio navigation systems such as Decca operated within a few hundred kilometres of shore, but in the deep sea, vessels still relied on celestial navigation and dead reckoning. For detailed local deep-sea surveys, buoys were moored and the vessel was positioned relative to the buoy using radar. This technique was expensive, time consuming, and restricted to ranges of about 20 miles from the buoy. In 1964,

Observing temperature and salinity using a Knudsen bottle and reversing thermometers.

a radio navigation system called LAMBDA (Low AMBguity DeccA) was installed on CSS *Baffin* to support joint hydrographic and geophysical surveys of the continental shelves. LAMBDA relied on a master station carried on the ship and manned shore stations every few hundred miles along the boundary of the survey area. This system gave much higher accuracy than normal Decca, but it could only be used by one ship and its infrastructure cost was enormous.

In 1968, CSS *Hudson* became the first non-USA and non-military ship in the world to be navigated by satellites. Raytheon Corporation's first non-military Transit Satellite navigation system was installed on *Hudson,* in Bermuda, while on passage to a geophysical survey of the Mid-Atlantic Ridge.

At about the same time, Loran-C became the primary radio navigation system covering the major trans-Atlantic aircraft routes. Loran-C navigation was achieved by comparing the arrival times of signals from three different stations. Since the useful range of these stations was of the order of 2,000 km, Loran-C had limited application in the open ocean far from the continental margins. BIO extended the operating range of Loran-C by carrying a very stable atomic clock on the vessel. This allowed the absolute time of arrival of each Loran-C signal to be determined and a position obtained from only two Loran-C stations. This technique, known as the "rho-rho" mode, provided very precise relative positions since changes in the atmospheric conditions and in the ratio of ocean and land that lay between the vessel and the Loran-C transmitter introduced small timing changes. These timing changes could be determined from Transit Satellite fixes obtained every one to two hours. BIO scientists developed an integrated navigation software system, BIONAV that combined these two datasets in a symbiotic way. The Loran-C relative ship positions during the 10-15 minutes of a satellite overpass allowed the calculation of very accurate vessel positions (better than 1 kilometre). These satellite fixes were then used to calibrate the Loran-C clock and provide Loran-C positions that were accurate, precise, and continuous. The system also displayed these positions in all the working areas of the vessel.

Throughout its history, BIO staff have pushed the capability of available navigation systems. BIO purchased an early Global Position System (GPS) receiver in order to take advantage of the partial GPS coverage available during the 1980s. BIO, in partnership with University of New Brunswick, was involved in the development of differential GPS as a means of allowing non-military users enhanced accuracy.

Since 1962, our navigational ability has greatly improved at BIO. Celestial navigation was done several times daily and required clear skies, a highly skilled observer, a number of minutes to observe the positions of the sun, moon, planets, or stars, and many more minutes with tables, pencil, paper, and charts to obtain a position with an accuracy of a few nautical miles. The first Transit Satellite system required a rack of electronics, a less skilled operator, 10-20 minutes to acquire the data, and 15 minutes to process it to provide a fix accurate to a kilometre every 1-2 hours. The BIONAV system required 3-4 racks of electronics and computers, a full-time skilled operator, and provided real time navigation data with a relative accuracy of 25 metres and an absolute accuracy of less than a kilometre. Today's GPS receivers are the size of a text book, run unattended on the vessel's bridge, and provide real-time positions accurate to 10 metres.

AUTONOMOUS INSTRUMENTATION

In 1962, most ocean observations were made directly by research or survey vessels. Oceanographers read thermometers, drew water samples, did manual chemical titrations, classified and counted organisms from a net haul or bottom grab using a microscope, or read depths from a paper sounder recording. Over the past 40 years, we have developed a wide variety of instruments that can be left to observe the ocean for periods of days to years, either recording this data internally for subsequent recovery, or sending the data back to BIO via satellite communication links.

In the 1960s, hydrographers and oceanographers had inshore current meter mooring systems to measure the currents in important shipping channels. These instruments could be moored in waters as deep as 200 metres and would record their data either on film or printed paper tapes for periods of 1-2 months. Moorings were either marked with surface buoys or set in near shore locations where they could be precisely located by triangulation using reference locations onshore. At this same time, Nick Fofonoff and Ferris Webster, two Canadian-born physical oceanographers at Woods Hole Oceanographic Institution, began an engineering and scien-

Early CTD and rosette system.

Modern CTD rosette system.

tific program to develop the technology to maintain current meter moorings in full ocean depths for periods of six months to two years. Staff of Ocean Circulation began a parallel and collaborative program to develop a similar capacity at BIO. In 1970, BIO was able to deploy and recover the first current meter array across the Drake Passage; this was the first direct measurement of the transport of the Antarctic Circumpolar Current. Throughout the 1970s and 1980s, we explored both stainless steel and kevlar mooring line to extend our capability to stronger currents, deeper depths, and longer lasting moorings. After a number of notable mooring losses, we arrived at mooring designs that have measured the full depth transports of the Gulf Stream and the North Atlantic Current for periods of up to 22 months.

BIO's moorings differed from those of other groups around the world through the development and use of buoyancy packages designed to line up in the current, reduce drag, and to avoid turbulent movement. Recently, we have extended those principles to the in-line buoyancy packages that are used to ensure that we can recover the deeper instruments even if we have a failure of the mooring line higher in the water column. Our new streamlined backup buoyancy packages are improving our mooring performances in high current regimes. While instruments moored in-place on lines provided long-term data, in the 1990s, engineers at BIO developed a platform called SEAHORSE that could profile a portion of the water column. This is a slightly buoyant instrument that uses the mooring motion caused by waves to move itself to the bottom of its profile. SEAHORSE has carried CTDs (with fluorometers), turbulence probes, and current meters, and now uses cell phone technology to send the data to the scientists in near real-time. SEAHORSE has been licensed to Brooke Ocean Technology to produce and sell.

SEAHORSE being deployed at Station 2 off Halifax Harbour. Brian Beanlands on the left and George Fowler on the right.

During the 1970s, in a partnership between France and the USA, a satellite system was developed that allowed a low-powered radio transmitter to be accurately positioned anywhere on the globe and to transfer a small amount of data. The World Meteorological Organization (WMO) was planning a field program to observe the global atmosphere for an entire year to initiate the first global weather forecast models. With more than 70% of the globe being ocean, and with much of that ocean distant from well-travelled ship tracks, autonomous instruments were needed to provide the necessary marine observations. John Brooke, Jim Elliott, and staff at BIO worked with Hermes, a local ocean instrument manufacturer, to develop a surface drifter that was able to measure atmospheric pressure and temperature over periods of a few years. These instruments were deployed in large numbers during the field season to drift with the ocean surface currents and are still used by meteorological agencies.

BIO's first sea ice studies were conducted from icebreakers and from field camps on the pack ice. These studies required a great deal of logistic support and were restricted to a short time window during which the ice was sufficiently thick and stable to be a safe working platform. By the end of the 1970s, we began developing autonomous instruments that could measure ice drift, wind speed and direction, air and ice temperature, ice thickness, and ice pressure over periods of several months. The earlier WMO project had made Halifax/Dartmouth a commercial centre of expertise in this technology. Autonomous ice instruments have been deployed in the Gulf of St. Lawrence, on the Labrador Shelf, and in the Arctic Ocean. They have provided many seasons of atmospheric and ice data used to develop and validate ice/ocean models for these regions.

Ice beacon and surface meteorological instrument.

Geophysicists map the structure of the earth's crust by observing the changes in the sound speed in its different layers, a method known as refraction seismics. BIO originally used large drifting sonar buoys to collect seismic refraction data on the shelf and in the deep ocean. Since the surface ocean is noisy, explosives, some as large as 5,000 pounds, were used as the initial sound sources. In 1975, BIO researchers embarked on a design for an Ocean Bottom Seismometer (OBS) which would operate and remain in the quieter environment on the sea bottom. These were operational by about 1980, and in 1983 a local firm (the Canadian Marconi Company) built 20 units at a total cost of $350,000. The instruments have had many upgrades but are still in service and actively used by scientists from BIO and universities. The lower noise and better signal processing allow us to probe the deep crust using airguns (albeit large ones) instead of explosives.

In 1979, the Atlantic Geoscience Centre, now GSC Atlantic began development on RALPH, an instrument used in the study of seabed dynamics. In these studies, it is very important to continue observations over periods of up to two months in order to capture conditions during which the material on the seabed is moving most vigorously. RALPH is a research instrument, hence it continues to grow and develop at the same time that it is being used. It has been successfully deployed in the nearshore (Nova Scotia, Prince Edward Island, and New Brunswick), in the Arctic, on the shelf, at Hibernia and, for many winters, near Sable Island. It has been used in the Saquenay Fiord and Lake Winnipeg and also in New Zealand. RALPH is currently equipped with a pressure sensor, current meters, sonar technology to measure bedform changes, and a time lapse camera. It also uses both optics and ultrasonics to measure suspended sediment. The original Super 8 movie camera has been replaced by a digital video camcorder. Initially, RALPH's data storage was a state of the art digital cassette tape with a capacity of 250 kilobytes, which seldom operated properly over the entire length of the deployment. Over the years, data capacity has increased markedly and by 2002, it consisted of four 20-gigabyte hard disk drives.

UNDERWAY OBSERVATIONS

BIO scientists also developed a number of instruments to allow oceanographic vessels to collect observations while they were steaming between work areas. *Hudson* was built with a special system that pumped seawater from a near surface input port close to the bow to the forward lab through chemically inert, non-metallic piping. In the early years, this system was primarily used to collect near surface water samples for subsequent laboratory analysis. Slowly, various instruments were incorporated into a system that currently provides a continuous record of temperature, salinity, oxygen content, and chlorophyll as well as collecting regular water samples for subsequent nutrient analysis.

Most physical, chemical, and biological properties of the ocean change significantly within the upper 50 to 200 metres of the water column. In the early 1970s, a system to profile the upper 200 metres of the water column was developed. This system, called BATFISH, could be towed at speeds up to 14 knots and is still being used and marketed today. The system was a little ahead of its time since the sensors, computers, and navigation systems of the 1970s were all somewhat less than adequate to meet its demands. New instruments, developed to observe chlorophyll concentrations and to count plankton particles, were added to the BATFISH. These instruments allowed pioneering work on patchiness of biological systems to be conducted. In the late 1980s, in a working partnership with Brooke Ocean Technology, a Moving Vessel Profiler System was developed. This system is much simpler to operate, has a greater depth range, and can be deployed from research and merchant vessels and from ferries.

Marine geophysics was also an early user and developer of towed instrumentation. In the mid 1960s, one of the first sidescan sonars

BATFISH being deployed.

was used to discover (and name) pockmarks on the Scotia Shelf. Because sidescan sonars were not commercially available, BIO engineers designed and built a system. The tow body came from Defence Research Establishment Atlantic (DREA) designs. The recorder was a modified Alpine recorder, which was originally designed for weather fax, but became the standard depth sounding recorder. One was modified with a double helix as sidescan recorder. These were wet paper recorders and required great care in handling the records.

Later, AGC worked closely with Huntec Ltd. (Toronto) to develop the Huntec Deep Towed Seismic (DTS™) system. These are still in service at BIO and around the world, and continue to produce the best high-resolution seismic records in many settings. The DTS system uses a boomer source for a repeatable pulse and a receiving hydrophone, both of which are towed at depths down to 100 metres to eliminate surface noise. It uses complex analog electronics for both tow body motion compensation and for signal processing. The advent of digital electronics has greatly simplified both these tasks.

INSTRUMENTS FOR STUDYING BENTHIC HABITAT

Throughout the 1960s, scientists sampled the muds, rocks, and organisms by blindly lowering bottom grabs, dredges, and still cameras in pressure cases to the ocean floor. The development of video cameras and remotely operated vehicles through the 1970s provided a means to examine the sea floor in fine detail. During the 1990s, the demand from fisheries habitat managers, the fishing industry, and other interested groups for accurate assessment of environmental impacts of human activities on the continental shelves, led to new studies of marine life on the sea bottom and their habitat. To respond to this demand, scientists needed to both map the benthic habitat in fine detail and to simultaneously study biological processes within their physical, geological, and chemical environment. These required the development of a new suite of instruments.

During the 1970s, a scientist at the Biological Station in St. Andrews, New Brunswick, designed and built a towed camera platform, BRUTIV, to map shallow water lobster habitat. This sled was equipped with video and still cameras and holds to a fixed altitude above the bottom as it is towed behind a research vessel. In the 1990s, it underwent extensive upgrading at BIO to exploit advances in electronic and video equipment. Its usefulness for regional surveying of the seabed, for identification and classification of benthic habitat, has since led to the development of a new video and still camera towed body called TowCam. Both instruments were used extensively in the assessment of the impacts of bottom trawling on benthic environments on offshore banks.

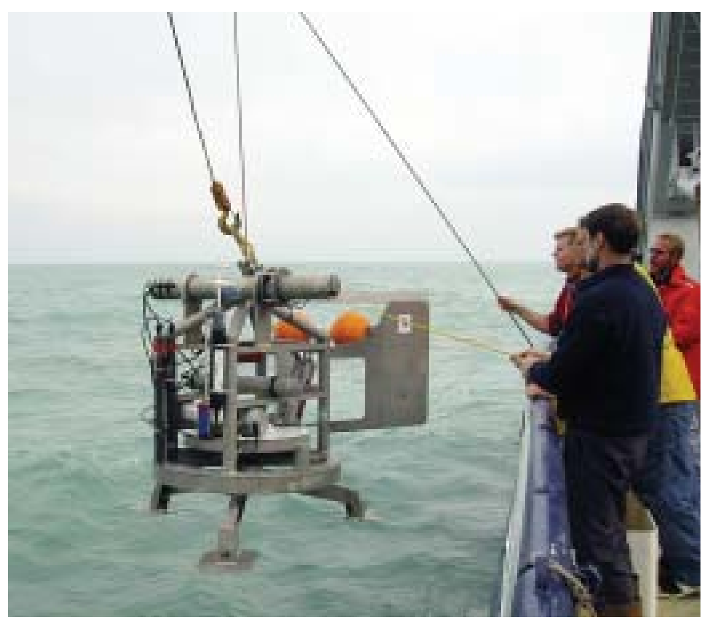
The trawling impact study also required the design and construction of two specialized samplers: a hydraulically activated grab and a modified epibenthic sled. A major design feature of both these samplers was the incorporation of video imaging. High-resolution cameras mounted on the grab allowed the scientists to survey the area prior to selecting the sample. The video image plus the hydraulic activation allowed the scientist to verify the quality of the sample and to resample, if necessary, without retrieving the grab. An epibenthic sled is used to sample organisms in the upper few centimetres of the sediments. The addition of video cameras allowed scientists to observe the bottom during sampling and determine if a representative sample was being collected.

At the same time, a study targeting the fate of drill wastes had observed flocculated drill mud in the water column near the Rowan Gorilla III rig, located on Sable Island Bank. Sea floor images from the Video Grab revealed the presence of a mat of drill mud that could not be sampled by existing instruments. This led to the development of Campod, a lightweight platform consisting of high-resolution video and still cameras with a suction device for sampling the floc layer on the seabed. The sizes of the flocs, created as drilling muds pass through the water column, are an important parameter and to observe this a digital floc camera was created. While originally designed to collect images through the water column, the digital floc camera was modified to monitor drill waste discharges over the longer term. A moored instrument package consisting of the floc camera and other sensors was designed to observe particle behaviour in the near bottom zone close to drilling activity.

It is also critical to understand the biological impact that these wastes could have on benthic organisms. HABITRAP, a biological monitoring system, was developed to observe sublethal effects of drilling wastes *in situ* on suspension feeders such as mussels and scallops. HABITRAP is a sediment trap that collects up to 39 timed samples of the biodeposits produced by bivalves positioned over the mouth of the trap. This allows the calculation of growth rate, reproductive potential, and survival based on biodeposit rates and the concentrations of natural tracers in food and faeces samples.

In 2001-2002, a new instrument was developed which incor-

HABITRAP being deployed near the Hibernia production platform.



INSSECT being deployed as part of a multidisciplinary study of sediment transport in the western Adriatic.

porated aspects of several of these instruments. It is called INSSECT (IN situ Size and SEttling Column Tripod) and uses the digital silhouette camera to monitor suspended particle size, a video system newly developed to measure particle settling rates, and a modified sediment trap system to capture the flocs in gels for post-recovery measurements. An off-the-shelf current meter is mounted on INSSECT. The ability to measure the particle size and settling velocity, as well as the water velocity, provides data required by models used to predict the dispersion of materials from natural phenomena or anthropogenic activities.

CONCLUSION

The development of new instruments is an ongoing process. Advances in technology may enhance instrument capabilities. An instrument designed for one program may be modified for use in another. For example: the Video Grab was used to recover pieces of Swissair Flight 111; the floc camera has been used in studies of river sediment plumes off California and Italy; and TowCam has been used to study pockmarks and scallop beds.

Unique to all these studies is the ability of BIO staff to adapt new and evolving technologies to scientific needs. Instrument development over the years has allowed scientists at BIO to carry out state-of-the-art science in the harsh environments of the North Atlantic and Arctic oceans. The creation of innovative sampling and monitoring equipment has also enabled them to respond to the needs of both industry and management as they work to develop Canada's ocean resources in a safe and sustainable fashion. Many of these projects have been carried out with private sector partners and have resulted in ocean instruments that have been marketed internationally. The development cycle for these instruments was often years, but some have remained in use for decades. One instrument co-developed at BIO, the Guildline Salinometer used to determine the salt content of water samples, has been the international standard salinometer for more than 25 years and is found in every oceanographic laboratory around the world. In spite of the shorter project funding cycles of the last five years, instrument development continues to be part of BIO's ongoing research programs.

Celebrating our Women in Science - Stories of Three Builders of BIO

- Charlotte Keen, Sherry Niven, Tim Milligan, and Rebecca Jamieson

While few in number, women have contributed significantly to the scientific achievements of BIO over the past 40 years. In celebration of that contribution, we have embarked on a project to document the stories of the women scientists of BIO. This article is the beginning. Here we highlight the stories of three of BIO's "builders", women who played key roles in the early development of the Institute.

Vivien Brawn (Srivastava).

"Hands on and personal with her fish"

VIVIEN BRAWN (SRIVASTAVA),

Research Scientist (1965-1972), Fisheries Research Board and Marine Ecology Laboratory.

Vivien Brawn came to Canada from the UK in 1957 to work at the St. Andrews Biological Station. She already had several years experience studying the behaviour of groups of cod in the North Sea, including their movement, aggregation, and habitat. While at St. Andrews, she engaged in a study of herring behaviour and physiology as part of the Passamaquoddy Tidal Project. Following this, she went to the University of British Columbia (UBC) to complete her PhD in zoology on Pacific and Atlantic herring. In 1965, she came to the Bedford Institute of Oceanography as a research scientist with the Fisheries Research Board (FRB), which later became the Marine Ecology Lab. Vivien achieved many "firsts" as a woman in science. She was the first woman scientist hired by the FRB, the first woman to achieve a PhD in zoology at UBC, and the first woman hired at BIO as a research scientist (then called Scientific Officer).

At BIO, Vivien studied the caloric value of various natural foods of marine fish, the selection of these foods by wild cod, and compiled a database of all fish observed in the Gulf of St. Lawrence.

One of her lasting legacies is the BIO fish lab. Because of her extensive practical experience working with fish behaviour both in their natural habitat and in aquariums, she assisted in the design and development of this facility. Several design flaws in the original architectural plans were avoided through her practical knowledge.

Vivien's abiding love is animal behaviour, and one of the favourite memories of her work was an opportunity to use a two-person submersible in St. Margarets Bay. This allowed her to observe bottom-feeding cod in their natural habitat. She remarked on the beauty of some of these fish when observed in a pristine state, and not overfished. At the time Vivien was working at BIO, marine research had more of a renaissance flavour than it does today. She studied fish, the ecology of fish, and used current technology, such as ultrasonic tracking and underwater television, to monitor various fish populations. The life of a research scientist was a hands-on affair, with fewer technical staff, and many trips in small boats to collect samples.

In 1972, Vivien left BIO to have more time with her daughter (who is now a successful ecologist at UBC). After several years of part time work, she found a new way of working with her passion for studying animal behaviour, and has been successful in solving behavioural problems in pets.

– Charlotte Keen

Kate Kranck.

"Through strength of character she stayed committed"

KATE KRANCK,

Research Scientist (1964-1993) Marine Geology Section and Coastal Oceanography, Atlantic Oceanographic Laboratory.

Kate Kranck started her career at BIO in 1964 as a summer student in marine geology. In 1971, she became a research scientist in Coastal Oceanography. She received her PhD at the University of Uppsala in 1974. Kate loved the sea and took part in cruises on vessels of all sizes. Her research included classic geological mapping of the surficial geology of, for example, Northumberland Strait. She also worked on environmental problems created by the 1970 *Arrow* oil spill.

Her later, most influential, work centered on sediment dynamics and its relationship to particle behaviour and physical oceanography. A primary methodology in this work was grain size analysis using a Coulter Counter. The behaviour of sediments is a meeting point of many facets of oceanography, involving the water column, coastal processes, geology, and marine habitat. From her studies of grain size, Kate was able to predict the probable oceanography and coastal setting responsible for her observations. She developed an important tool for coastal oceanographers and habitat ecologists working in estuarine settings; a tool that is still gaining in recognition. Some of her research took her far from Canadian waters – to Bangladesh, the Amazon, and Europe – and she became well-known internationally as a pioneer in studies of sediment flocculation and the processes of aggregation and dispersion of cohesive sediment in near-shore environments.

Kate's work in sediment particle dynamics was perhaps more influential internationally than within BIO. She wanted to delve deeply and single-mindedly into the processes behind the observations, and was impatient of a more superficial, broad-brush approach. Rather than strictly remaining within the BIO marine geology community, Kate was physically situated in MEL while organizationally attached to Coastal Oceanography. Even with little support for her studies, she was tough-minded and determined enough to continue her work. As recognition of her contributions increased, she was invited to participate in projects by members of the international community. This allowed her the freedom she desired.

When Kate died in 1993, her work was by no means finished to her satisfaction. However, the concepts were in place, and numerical models quantifying them were beginning to come together. She leaves a lasting legacy both in her research and in her passion and dedication to her work.

– Charlotte Keen and Tim Milligan

CHARLOTTE KEEN,

Research Scientist (1970-1998) Atlantic Oceanographic Laboratory and Atlantic Geoscience Centre.

Charlotte Keen graduated from Dalhousie University with a BSc in physics in 1964, and completed her MSc in geophysics in 1966. Her PhD, awarded from Cambridge University in 1970, was a landmark investigation of the geophysical structure of the Mid-Atlantic Ridge. As part of this research, she organized and conducted the first detailed seismic experiment near an oceanic spreading centre, placing her in the vanguard of those applying the newly proposed theory of plate tectonics to the study of Earth. Charlotte returned to Halifax to take up a position as a research scientist at BIO, a position she held until her retirement in 1998, and where she continues her research as an emeritus scientist. Throughout her career, Charlotte has excelled at both the technically demanding fieldwork required for marine seismology, and the numerical modelling techniques required to interpret the data in terms of physical processes. Her approach has always been characterized by scientific rigour, careful attention to detail, and a clear appreciation of the big picture.

Charlotte Keen.

"An inspiration to a generation of women in Earth Science"

Charlotte has published extensively on the crustal structure of the continental margin of eastern Canada and the ways in which the margin has formed and has evolved. With her colleagues she produced the first quantitative analyses of the thermal and subsidence history of the sedimentary basins on the margin and developed the broad scientific framework for interpreting the petroleum geology of the region. More recently, she has been working on an improved model for the dynamics of the rifting process, with applications to the eastern Canadian and related continental margins. Charlotte's considerable scientific accomplishments have been recognized through many national and international awards and honours.

Charlotte made outstanding contributions to geophysical research both nationally and internationally, and in so doing she has influenced and inspired an entire generation of women in earth science. Despite the barriers she faced as a woman (especially early in her career when research opportunities were often unavailable to women and when there were difficulties going to sea), Charlotte proved that women can excel at scientific research. Charlotte inspires all those who work with her to give their very best, and she creates an encouraging and supportive work climate for them to do so. Charlotte was herself fortunate to have a mentor, the late Dr. Michael J. Keen. His encouragement and support – together with Charlotte's passion for science and commitment to hard work – were keys to her success. Charlotte retired from BIO in 1998, feeling that basic research by government scientists was increasingly discouraged. She continues to do research, to support women in science, and to promote scientific excellence.

– Rebecca Jamieson and Sherry Niven

OUR COMMENTS AND SPECULATIONS

While the experiences of these three women are quite diverse, there are some themes that their stories exemplify which have been recognized more generally as typical of the obstacles and joys that women scientists encounter. The pressure of balancing home life and a life of research and the bald denial of a woman's place in science simply because she is a woman – refusing to consider her for jobs and not allowing her to go to sea – are obstacles these women faced in the early days of the Institute that were not experienced by their male colleagues. They also had to contend with the more subtle forces that still today tend to isolate and sideline women researchers. The common denominator shared by these women was passion for their research.

Passion aroused the bravery, determination, and patience to deal with the everyday impediments to doing what they loved. Of course passion is not limited to women in science. But without it, more men than women can be "successful", because of the support provided by the system and their peers. These women were able to find creative ways around the obstacles they encountered to have successful careers as scientists, and advance scientific knowledge. By doing so, they have inspired others to follow their example.

ACKNOWLEDGEMENTS

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CCGS *Hudson* - A Snapshot of Historic Firsts

- Captain Richard Smith

CCGS *Hudson* is one of Canada's foremost deep-sea, multi-disciplinary science ships. *Hudson* is named after the explorer Henry Hudson, who organized and led four expeditions into the Arctic in his search for a short route to China. The vessel was the first Canadian ship specifically constructed for hydrographic and oceanographic research. It was designed by Gilmore, German, and Milne of Montreal, and was built in **1963** by Saint John Shipbuilding and Drydock Ltd. of Saint John, New Brunswick at a cost of $7.5 million. Commissioned in February of **1964**, the ship is 296 feet in length, 50 feet in the beam, and has a displacement weight of 4,800 tons. The vessel is powered by four Alco diesel engines coupled to four direct current electric generators that drive two propellers. The *Hudson* has a top speed of 16 knots and a cruising range of 15,000 miles.

Hudson was initially operated by the federal department of Energy Mines and Resources out of the Bedford Institute of Oceanography in Dartmouth, Nova Scotia and, over the years, has been funded and managed by several federal departments that have evolved into the present Fisheries and Oceans Canada (DFO). Originally the "flagship" of the DFO Science Fleet, the *Hudson*

CSS Hudson - *circa, 1970.*

came under the management of the Canadian Coast Guard after the merger of the two fleets in 1996.

Hudson's first major mission was in **1965** to Hudson Bay. This involved an intensive survey of the floor of Hudson Bay by scientists from BIO, the Ottawa office of the Geological Survey of Canada, and the Observatories Branch of Energy Mines and Resources, six Canadian universities, and industry. Information obtained on this mission was deemed to be some of the most valuable to that date. In 1965, the first women sailed on the *Hudson*; they included scientists Charlotte Keen, Joleen (Aldous) Gordon, and Janet Eaton. Also in 1965, a PDP8 computer was installed making *Hudson* one of the first ships in the world to have an on-board computer.

In **1966**, *Hudson* conducted the first winter oceanographic survey in the Labrador Sea, starting a process of collecting data about the water column and the seabed. *Hudson* still makes its annual pilgrimage to the Labrador Sea to continue this research.

During Canada's centennial in **1967**, *Hudson* travelled to Expo '67 in Montreal and was open to the public. In **1968**, a state of the art Satellite Navigation System (Transit) was installed, making *Hudson* the first ship outside of the USA military to be navigated by satellite.

On November 19, **1969**, under the Command of Captain David Butler, *Hudson* embarked on a circumnavigation of North and South America, known as *Hudson '70*. Organized by Chief Scientist Dr. Cedric Mann, the voyage began at BIO in Dartmouth, Nova Scotia and proceeded south along the Gulf Stream, into the Caribbean, down the east coast of South America and into the waters of Antarctica. During the voyage down the east coast of the Americas, scientists studied a variety of marine life including whales, plankton, and mid-depth fish. Christmas 1969 was spent in the South Atlantic with a stop in Rio de Janeiro. A staff change took place in Buenos Aires soon after. Off the southern tip of South America, studies were conducted into the west to east speed of the Antarctic Current. A reverse current (east/west) was also discovered. Visits were made at Admiralty Bay and Deception Island in Antarctica. *Hudson* sailed up the 150-west meridian of the Pacific Ocean with a stop in Chile to study currents in a fjord. In the South Pacific, scientists discovered and named the Hudson Peak and Hudson Deep, two areas previously undetected. *Hudson* visited Tahiti during the voyage in the Pacific. Along the 150-west meridian the absorption of carbon dioxide into the ocean was studied. By late August of **1970**, *Hudson* entered the Beaufort Sea where scientists studied the geology of the sea floor. Off the Mackenzie River, *Hudson* spent four weeks doing transects from the shore to the ice edge some 130 miles offshore. By September 1970, the vessel was enroute across the Arctic via the Prince of Wales Strait and Melville Sound to Resolute. As the ship was heading down the Labrador coast towards home, the Newfoundlanders on board pointed out that if they went through the Strait of Belle Isle, the ship would not have circumnavigated the Americas. Consequently, plans were altered at the last minute and the ship travelled around Newfoundland. The *Hudson* is believed to be the first ship to circumnavigate the continents of North and South America. *Hudson* completed the circumnavigation on October 16, 1970 at BIO after steaming some 58,000 miles. More than 122 scientists participated at various stages of the voyage.

In **1971**, *Hudson* hosted scientists on the first joint geological and geophysical cruise in the Gulf of Maine and Bay of Fundy. Scientists from the Geology and Geophysics Division at BIO were led by L.H. King and Charlotte Keen. The survey assessed the bedrock and basinal structure of the region. Results of the mission led to the publication of significant maps of the seabed and subsurface. Some of these maps formed the basis for the later discussions on the boundary dispute between Canada and the United States in the Georges Bank region, assisting in the determination of the boundary by the World Court in The Hague in 1984.

In **1972**, the *Hudson* was conducting research on the Grand Banks of Newfoundland when called to rescue the crew from a burning fishing vessel near the Southeast Shoals. In January **1973**, the *Hudson* made the first winter run along the Halifax-Bermuda transect. This three-year project collected data on a number of environmental variables (both natural and anthropogenic).

In March **1976**, *Hudson* and crew rescued 18 crewmembers from the Fisheries Patrol Vessel *Cape Freels*. Gale force winds and blizzard-like conditions were present when the *Cape Freels* caught fire and began taking water through the portholes. The crew had to abandon ship into the lifeboats. *Hudson* was nearby conducting research and responded to the distress call, rescuing the crew from certain peril. Also in 1976, during a passage from the Arctic to Halifax, the *Hudson* encountered a terrible storm in the Labrador Sea. A strong wave smashed the windows of the Officers' Lounge one deck below the bridge. The lounge was flooded and emergency repairs were needed. The original square windows were replaced with the round portholes still in place today.

In early **1980**, the *Hudson* conducted the first geological survey of the Eastern Grand Banks. This occurred shortly after the discovery of significant hydrocarbon reserves at the Hibernia well site. Results of the survey delineated the distribution of iceberg

CSS Hudson - *circa. 1985 off Chebucto Head, Halifax Harbour.*

furrows across the Grand Banks and identified thin sediment over the tertiary bedrock. Over the next twenty years, intensive surveys were conducted to assess the risk to hydrocarbon production by icebergs and foundation conditions for both gravity platforms and pipelines.

In 1980, the *Hudson* embarked on another notable voyage of circumnavigation. This time it was around North America via the Panama Canal, up the Pacific Coast, and after a stop in Victoria, British Columbia, on through the Arctic returning to BIO in November of **1981**. The ship was under the command of Captain Lorne Strum, one of the longest serving masters of the *Hudson*.

Between 1980 and 1984, *Hudson* played a major role in the international research on the feasibility of the disposal of high level radioactive waste in deep-sea sediments.

In February **1982**, the drill rig *Ocean Ranger* capsized and sank in a violent storm off Newfoundland. The *Hudson* was involved in the search and rescue activities surrounding that disaster. *Hudson*'s crew recovered several bodies from the *Ocean Ranger's* crew and took them to St. John's, Newfoundland. In March 1982, the *Hudson* embarked on another major science mission to the Norwegian Sea and the Greenland Sea with the furthest latitude north being 79º 45'N. This was at a time of the year when the weather was at its worst.

During **1983-1984**, *Hudson* was host to the testing and final delivery of the "Seabed 2 Deep Ocean Mapping System". The Seabed 2 System was a joint government/industry technological development project with Huntec 70 Ltd. The project aim was to build and deliver a deep ocean seabed mapping system and extend the tools designed for continental shelf depths for use in the deepest parts of the ocean. During the 1984 cruise, with Gordon Fader as the Chief Scientist, the system performed flawlessly and was towed to its design depth of 2000 meters. Components of the system were later used during the search for the *Titanic* shipwreck.

In April, **1987**, the *Hudson* responded to a distress call from the cargo ship *Skipper 1* whose cargo of crushed cars had shifted in heavy weather with the ship taking water through the spurling pipes that down-flooded the holds. The *Skipper 1* started to sink and the crew had to abandon ship. All 24 crewmembers were rescued.

On April 28, **1988**, the *Hudson* was conducting research in the mid Atlantic, when at about 0200 a.m. the 2nd Officer, David Morse, sighted what appeared to be an explosion on the horizon. The ship proceeded with all speed towards the glow in the sky that turned out to be some 40 miles away. They found the tanker *Athenian Venture* in two pieces and on fire. The *Hudson,* under the command of Captain Lorne Strum, steamed perilously close to the burning vessel, often through oil slicks and flames, to search for survivors. Only one crew member's body was ever found. The *Athenian Venture* burned for over three weeks.

In **1993**, the *Hudson* ventured to Greenland for an oceanographic expedition. A decision was made to enter a fjord on the far northeastern coast of Greenland. Multi-year ice and large icebergs were present. The vessel was badly holed by ice leaving a 15-foot gash in the starboard side just inches from the engine room. Danish naval divers, who were flown in by helicopter, inspected the *Hudson* in the fjord. After a hull inspection, the *Hudson* carefully limped out of the fjord and was escorted to Iceland by the Danish Navy for emergency inspection and repairs, and then proceeded to drydock in Canada.

From **1996** to **1998**, the *Hudson* was assigned to a major hydrographic mission to chart Rankin Inlet and Chesterfield Inlet in Hudson Bay. This marked the first time the area had been surveyed since 1926. This was done to facilitate navigation of tankers and other vessels bringing supplies into those communities. In 1998 and 1999, the ship was used to conduct research around the new Hibernia platform off Newfoundland and at various sites on Sable Island Bank to determine the biological effects of drilling and production wastes released during normal oil drilling operations. Also during those years, the *Hudson* was used to investigate the short and long-term effects of otter trawling on the seabed habitat on Western Bank. The ship worked in collaboration with the *Alfred Needler* (1998) and the *Teleost* (1999). In 1998, *Hudson* also assisted with the Swissair disaster off Peggy's Cove. The ship's video and sidescan equipment was used to study the bottom at the site. In 1998, the *Hudson* was involved in a field experiment to determine the immediate and long-term effects of hydraulic clam

CCGS Hudson *circa. 1999.*

dredging on the seabed habitat of Banquereau Bank. This was a joint project with industry and the ship worked in collaboration with the fishing vessel *Atlantic Pursuit*. Research continued in subsequent years.

From **1999** to **2001**, the *Hudson* continued to conduct benthic surveys of the eastern area of The Gully near Sable Island where deep-water corals have been found. In 2000, live coral specimens were collected from The Gully for the first time.

As with any recollection of historic events, time can obscure the facts. Indeed, history is created in the eye of the beholder. What is certain is that the *Hudson* and all those who have sailed on the ship have made their mark in history both in feats of seamanship and scientific excellence. For those who follow in the proud tradition of the *Hudson*, knowledge of the ship and the events of the past will enable them to more fully appreciate the significance of the ship and the labours of the scientific staff and crew.

Hudson '70 Revisited

- George Fowler

In the late summer of 1970, CSS *Hudson* nosed into Barrow Strait to start the last stage of the negotiation of the Northwest Passage as part of its historic circumnavigation of the Americas. To commemorate the occasion, a plaque was installed by ship's crew and scientific staff on a headland a few miles west of the current location of the town of Resolute Bay. It was handmade of bronze and aluminum by Bosun Joe Avery in his workshop onboard ship.

In August 2002, personnel from Ocean Physics and Technical Services were involved in the deployment and recovery of oceanographic instruments in Barrow Strait as part of the long-term Arctic Through Flow Program. Plans called for disembarkation at Resolute.

When Bosko Loncarevic, who was a member of the scientific party on the final leg of *Hudson '70*, heard of our visit to this remote community he proposed trying to track down the plaque and report on its condition and exact location. As luck would have it, the team was weather-bound in Resolute and was able to make contact with Paul Amagoalik, a local resident, who thought that he remembered seeing the marker and was prepared to guide us to the area where it might be found. Having been born on the ship that carried the native resettlement expedition to Resolute Bay in 1953, Paul is very interested in the history of his small community.

Hudson's *bosun, Joe Avery and Roger Belanger, BIO photographer installing the* Hudson '70 *plaque near Resolute Bay, NWT, late summer, 1970.*

Resolute Bay has changed a lot since CSS *Hudson* first sailed off its shores. In 1970, a massive dump covered the shale beach and extended a considerable distance westwards from the town, a product of the cold war and the fact that just about anything shipped to Resolute never leaves. The town itself was crowded between the beach, the dump, and the end of the airport runway. The dump has since been buried and the town itself moved eastward where it has been re-established as a modern, vibrant, self-directed community of which the residents are justly proud.

Taking into consideration the changed geography of dump and town, it still took about two hours of searching in the fog and cold to find the plaque. It is located about 30m above sea level on a rock outcrop at Cape Martyr. This is where Franklin would have turned east, 125 years prior to *Hudson '70*, after circling Cornwallis Island on his way to winter camp at Beechy Island where the tragic destiny of his expedition would begin to unfold. The plaque is in remarkably good condition except for a few bullet holes. Bosun Avery made a fine job of it and, barring vandalism, there is no reason why this memorial to Canadian scientific endeavour will not last long into the future.

Hudson '70 *plaque revisited in 2002. Left to right are: Jim Hamilton (Ocean Physics), Paul Amagoalik and his granddaughter, Angeline (Resolute), Brian Beanlands (Ocean Physics), and Murray Scotney (Technical Services). George Fowler (Ocean Physics) is behind the plaque.*

40TH ANNIVERSARY CELEBRATIONS

BIO *Open House 2002:* "Celebrating 40 Years of Oceanography"

- Joni Henderson

To commemorate the 40th anniversary of the Bedford Institute of Oceanography, staff at the Institute hosted an open house event from April 25-28, 2002. *Open House 2002* attracted upwards of 35,000 people over the four-day period. Visitors had the opportunity to view 70 exhibits depicting current research activities at BIO, visit our premier research vessel, CCGS *Hudson,* and attend a series of staff lectures during the weekend.

BIO Open House volunteers.

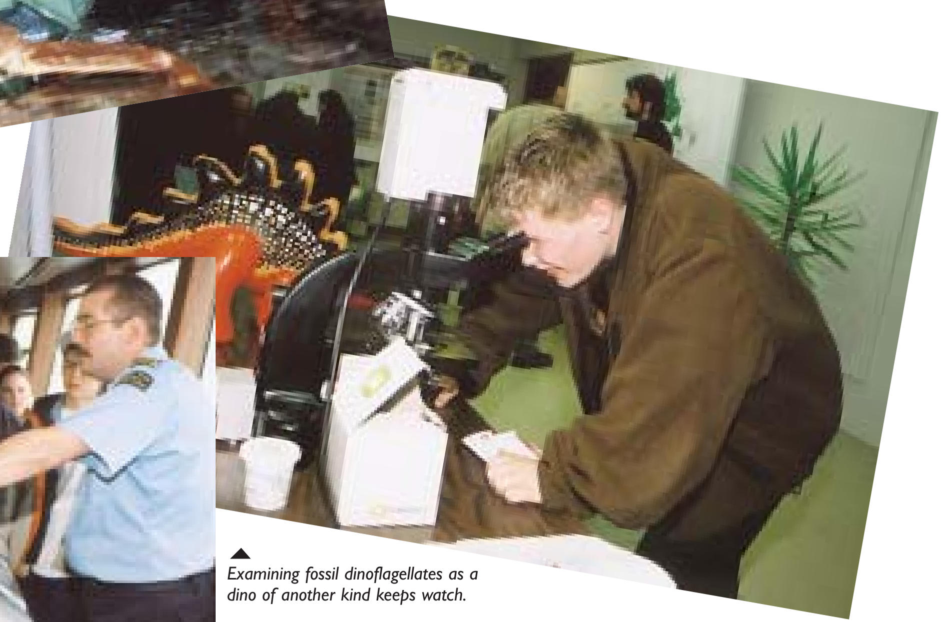
Opening ceremonies were hosted by Dale Buckley of the BIO Oceans Association who presented a historical overview of research highlights of the Institute. Staff and visiting dignitaries were treated to an outstanding performance by the Grade 6 choir of the Bell Park Academic Centre, Lake Echo, under the direction of Mrs. Margaret Perron. The students' choral selections paid tribute to the oceans and sent a message about the importance of preserving the oceans and their resources for future generations. Ms. Cathy Martin, University Native Education Counselor, offered a simple, yet beautiful prayer in Mi'kmaq. Dr. Wendy Watson-Wright, Assistant Deputy Minister, Science, Fisheries & Oceans Canada, and Dr. Jacob Verhoef, Director, Geological Survey of Canada (Atlantic), Natural Resources Canada shared some memories of BIO with the audience, thanked staff for past accomplishments, and passed on best wishes for future endeavours.

After the opening ceremonies on April 25th, elementary school students were offered guided mini tours of exhibits and in the afternoon, staff greeted off-site DFO employees and BIO clients. Friday, April 26th was devoted to junior and senior high schools from around the province with a keynote lecture by Dr. David Suzuki highlighting the day.

On the weekend, BIO was open to the public. Despite the traffic congestion and long lineups created by a multitude of visitors loaded with questions and vying for optimum positioning along the exhibit tour route, the smiles remained and everyone reportedly had a great time. In addition to the many exhibits, a series of informative and thought provoking lectures on current research topics was presented by staff members to near capacity crowds in the auditorium.

A few examples of the exhibits that delighted visitors over the four-day period included: "Taking a Virtual Reality Tour of The Gully" a proposed marine protected area, "Exploring a 65 Million Year Old Buried Canyon", learning about "Sharks of Atlantic Canada", and experiencing the Sea Pavillion with its display of live

Marie Charlebois-Serdynska and a young client examining a crab at the touch tank.



Examining fossil dinoflagellates as a dino of another kind keeps watch.

Captain Michael Hemeon on the bridge of the Hudson describing the steering console to a group of students.

oceanic flora and fauna. An exciting new addition to the staff exhibits were those prepared by winners of the Nova Scotia provincial junior/senior high school science fairs who demonstrated their winning entries. These 23 future scientists, who travelled to the Canada-wide Science Fair in Saskatoon in May 2002, were pleased with the feedback they received on their projects from BIO staff and the public.

Comments such as, "the displays were first class, but what impressed me most was the attitude, enthusiasm, and sincerity of the volunteers…what I observed made me feel proud to be a taxpayer and a Canadian", or as one young visitor was overheard saying as she was leaving, "Dad, when I grow up, I'm going to work here", were especially rewarding for staff. Will we do it again? You bet we will!

BIO Seminar Series and the 40th Anniversary Symposium

- Blair Greenan and Charles Hannah

SEMINAR SERIES

The Bedford Institute of Oceanography (BIO) Seminar Series was established in 2002 to provide an Institute-wide forum for presentations covering topics of physical, chemical, biological and fisheries oceanography, marine geophysics and geology, hydrography, marine ecology, and ocean engineering. This series will continue beyond 2002.

The first presentation of the seminar series was given on April 26th, 2002 by **Dr. David Suzuki** during the BIO *Open House 2002*. Dr. Suzuki's talk was entitled *The challenge of the 21st century: Setting the real bottom line*. Dr. Suzuki captivated his audience of more than 350 people while noting that in the past century, humanity has undergone an explosive change in numbers, science, technology, consumption, and economics, that has endowed us with the power to alter the biological, physical, and chemical properties of the planet. He stressed that it is undeniable that the atmosphere and climate have been altered: air, water, and soil are fouled with toxic pollutants; oceans are depleted; forests are being cleared; and species are disappearing. Currently, most people live in large cities, and our relationship with nature is less obvious.

Dr. Suzuki with the Nova Scotia provincial student science fair winners – April 2002.

Dr. Suzuki pointed out that computers and telecommunications have fragmented information so that we can no longer recognize the interconnectivity of everything in the world. Globalization of the economy has rendered the entire planet a source of resources and all people a market for products, while local communities and local ecosystems are negatively impacted.

He noted that traditional people refer to Earth as their "Mother" and tell us we are made of the four sacred elements: Earth, Air, Fire, and Water. Today science is verifying this ancient wisdom and defines a different set of priorities that should become our bottom line for the 21st century.

Dr. Suzuki concluded his talk by indicating that human beings are one of perhaps 10 to 15 million species on Earth and that we are ultimately dependent on all these species for our well being. He stressed that humanity needs to rediscover humility and our place in the world so that we, and the rest of life, can continue to flourish.

The second lecture in the seminar series was presented by **Dr. Helen Rozwadowski** (Georgia Institute of Technology) who spoke on June 17th on *Scientific research, promotion of fisheries: Evolution of ICES's dual identity*.

Dr. Rozwadowski addressed the role that the International Council for the Exploration of the Sea (ICES) has played throughout its history in providing a forum for discussion that has resulted in many important advances in fisheries science and other branches of marine science. She indicated that the identity of ICES is broader than a purely academic institution would be, encompassing from its founding, a practical mission alongside its scientific goals. As an ideal embraced by ICES founders, the organization has promoted rational exploitation of the sea's natural resources; this has been followed by subsequent generations of marine scientists.

It was often noted that throughout the history of ICES, major scientific contributions appeared simultaneously with recommendations from the Council for intergovernmental action. Important new theories have debuted along with ideas for their immediate application to fisheries problems. Through the efforts of committees such as those dealing with migration, plaice, and whaling, ICES made major contributions to knowledge about fish population dynamics and the effects of fishing on stocks. At the same time, ICES scientists have keenly accepted their responsibility to take a proactive role in fisheries regulation.

This presentation examined the evolution of the dual nature of ICES. Although ICES took a less direct role in regulation development after the formation in 1953 of the Permanent Commission (which became the North-East Atlantic Fisheries Commission in 1964), the Council maintained its dual nature as a scientific and advisory body. Indeed, this dual identity extended into ICES's environmental work when the Council branched out into that new direction.

The most fundamental characteristics of ICES derive from ideals and practices embraced by founders and the first generations of scientific experts.

BIO 40TH ANNIVERSARY SYMPOSIUM

On the occasion of the 40th anniversary of the Bedford Institute of Oceanography, Fisheries and Oceans Canada and Natural Resources Canada hosted a special two-day symposium on the *Future Challenges for Marine Sciences in Canada*, October 24-25, 2002. Twelve speakers were invited to address diverse oceano-

Speakers at the 40th anniversary symposium. Back row: Charles Hannah, Andrew Weaver, Tom Pedersen, Bosko Loncarevic, Eric Mills, Philip Bogden, Peter Schlosser, Don McRae and DFO DM Peter Harrison Front row: Lynne Talley, DFO ADM-Science Wendy Watson-Wright, Maureen Raymo, Philippe Cury, and Marlon Lewis. Missing: Paul Falkowski, Dorrik Stow, NRCan A-ADM Susan Till, and Robert Fournier.

graphic research topics surrounding the future challenges and adventures in oceanographic research.

The dates chosen corresponded exactly to the 40th anniversary of the opening of BIO. On October 24, 1962, W. E. van Steenburgh marked the opening of the Bedford Institute of Oceanography with an address to a special convocation at Dalhousie University. The next day there was a ribbon cutting on the BIO site.

The 2002 symposium was opened by Peter Harrison (Deputy Minister, DFO) and Susan Till (Associate ADM, NRCan). Opening remarks were provided by Bosko Loncarevic (BIO, retired) who provided personal reflections on the achievements of BIO over the last 40 years and thoughts on the future. He also reminded us of the important role of four founders of this Institution, the four Bills: **Bill van Steenburgh,** the Director-General of the Department of Mines and Technical Surveys, who convinced the government that Marine Sciences are a national priority; **Bill Cameron**, the Director of Marine Sciences Branch, who fought day-to-day battles for BIO in Ottawa; **Bill English**, the first Director, who had to create the new Institute on the shores of Bedford Basin; and **Bill Ford**, who developed the concept of the campus and with skill made it the foundation of BIO.

The speakers during the symposium were:

- Eric Mills (Dalhousie University) - *Science in government and science without government: The historical background of Canadian marine science.*
- Andrew Weaver (University of Victoria) - *Earth system models of intermediate complexity: Examining the past to understand the future.*
- Philippe Cury (University of Cape Town) - *The beauty of diversity: Future challenges for fisheries oceanography.*
- Maureen Raymo (Boston University) - *The causes of ice ages in Earth's history.*
- Don McRae (University of Ottawa) - *Marine science and law: Conflict or congruence in regulating the oceans?*
- Marlon Lewis (Dalhousie University and Satlantic) - *Optical observations for operational oceanography.*
- Philip Bogden (Gulf of Maine Ocean Observing System) - *The Gulf of Maine Ocean Observing System: A new kind of public utility and a pilot for the coastal USA.*
- Peter Schlosser (Lamont-Doherty Earth Observatory) - *New insights into high latitude oceanography from tracer studies.*
- Lynne Talley (Scripps Institution of Oceanography) - *North Pacific and North Atlantic overturning and their impact on the global heat budget.*
- Paul Falkowski (Rutgers University) - *Putting biology back into biological oceanography.*
- Tom Pedersen (University of Victoria) - *Hindcasting and forecasting climate on Earth: Paleoceanographic warnings and challenges.*
- Dorrik Stow (Southampton Oceanography Centre) - *Ocean margins: New models, challenges, and resources.*

Closing remarks were provided by Robert Fournier

(Dalhousie University). Dr. Fournier contrasted the post World War II environment, which convinced some individuals of the need for a major Canadian commitment in oceanography, with the present environment. Dr. Fournier also attempted to look at the future through the eyes of William van Steenburgh who was one of the visionaries largely responsible for advancing this national dream, one manifestation of which is BIO. He stated that, based on past performance, van Steenburgh appears to have been a man who could be described as a leader with a vision. Dr. Fournier suggested that those same characteristics would move him beyond purely national interests toward the creation of a global vision for the marine sciences. One reason for that move would undoubtedly rest on the realization that we continue to have three oceans on our doorstep and we cannot ignore that they are part of the global ocean. Dr. van Steenburgh might also suggest that any attempt to re-define or re-interpret ourselves as marine scientists should be carried out by building on our strengths. In other words we should continue doing what we do well, only do it somewhat differently.

During the Symposium, the BIO-Oceans Association presented BIO with a new visitors book. The presentation was made by David Nettleship, (President BIO Oceans Association) to Michael Sinclair (DFO) and Jacob Verhoef (NRCan).

The BIO seminar series committee members are Paul Boudreau (DFO), Sonya Dehler (NRCan), Blair Greenan (DFO), David Mosher (NRCan), and Mike Sinclair (DFO). Charles Hannah (DFO) organized the BIO 40th Anniversary Symposium with assistance from the committee.

Symphony Nova Scotia and the 40th Anniversary Finale

- Jim Reid

SYMPHONY NOVA SCOTIA

One of the events organized to celebrate the Bedford Institute of Oceanography's 40th anniversary was the concert performed by Symphony Nova Scotia in the Institute's auditorium on November 14, 2002. The audience had already filled the auditorium before the traditional bagpiper had completed his rounds announcing the concert's opening ceremonies. During the morning of concert day, the sight of arriving musicians with their instruments, the flurry of the pre-concert setup, and the beautiful sounds of the Symphony in rehearsal grabbed the curiosity and interest of many who visited the cafeteria for their mid-morning break. The Nova Scotia Symphony was here to share their talent and their gift of music as a part of our celebration. The idea for a concert was born within the newly formed group, The Bedford Institute of Oceanography *Friends of Symphony Nova Scotia*. The formation of this group and their positive action in sponsoring the musical chair of violist, Binnie Brennan, in a real and tangible way acted as a catalyst between the Institute and the Symphony and paved the way for the concert itself.

Symphony Nova Scotia at BIO.

At the beginning of the concert, the ceremonial bagpiper, played a short Scottish tune to announce the entrance of the master of ceremonies, Jim Reid, who welcomed the Symphony to BIO and introduced conductor, Gregory Burton; concertmaster, Terance Tam; and the musical chair, Binnie Brennan. Conductor Gregory Burton took center stage as the lights dimmed and the concert began. The opening piece was George Frederick Handel's *Suite in D Major from the Water Music,* followed by, *Summer Night on the River from two pieces for small orchestra* by Frederick Delius. The concert also included traditional and contemporary pieces: Otto Kelland's, *Let Me Fish Off Cape St. Mary's*; *Dark Island* by Silver Maclachlan, and Allister MacGillivray's, *Sea People;* all arranged by Scott MacMillan. Ralph Vaughan Williams', *Sea Songs Quick March* and the finale, Felix Mendelssohn's *The Hebrides Overture (Fingal's Cave) Op.26* completed a program. Closing remarks were followed by a reception that was well attended by musicians and staff.

Looking back, this concert and the reception were a fitting form of celebration for the Institute's 40th anniversary. We had a great symphonic orchestra, a wonderful program of music, and an appreciative audience. The *Friends of Symphony Nova Scotia* hope to make this an annual event.

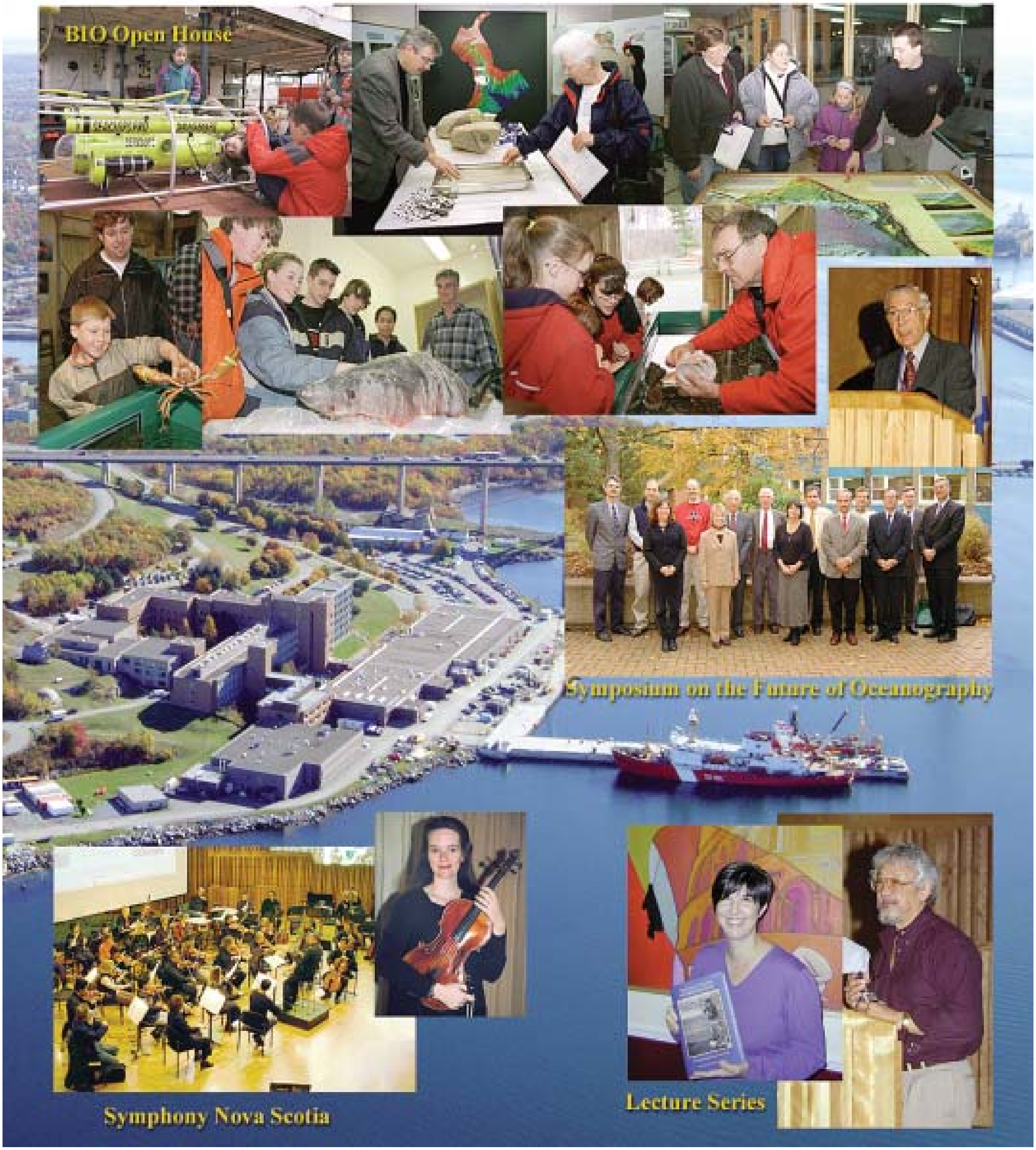
40TH ANNIVERSARY FINALE

On December 16th staff were invited to the 40th anniversary finale. A slide show of highlights of the last 40 years put together by Claudia Currie, Art Cosgrove, and Kelly Bentham brought back memories of a younger Institute and staff. Alastair Macdonald and Jim Reid provided musical entertainment featuring original compositions.

Staff are grateful to the directors and the organizers of all the anniversary celebrations for providing innovative and enjoyable events to mark 40 years at BIO.

40th Anniversary Events at the Bedford Institute of Oceanography

- *Kelly Bentham*



SCIENCE ACTIVITIES

Metals in the Environment (MITE) Research in Canada: The Marine Connection

- Michael Parsons

Metals are natural components of the environment, and are present in varying amounts in the geosphere, atmosphere, hydrosphere, and biosphere. Plants, animals, and humans depend on some metals (e.g., copper, iron, and zinc) as micronutrients, whereas other metals (e.g., cadmium, lead, and mercury) can be toxic even in relatively small amounts. Metals originate from natural geological sources, and their release into the environment can be accelerated by activities of our modern society including mining and mineral processing, burning of fossil fuels, and urban living. Human activities have drastically altered the natural balance and cycling of metals in many locations, resulting in environmental contamination and serious impacts on ecosystems and human health. Effective management of the risks associated with metals requires a thorough understanding of the sources, transport pathways, and specific forms of metals in the environment, as well as the relationship between metal concentrations and the incidence and severity of adverse biological effects.

As one of the world's largest producers of metals, Canada has a vested interest in understanding how metals behave in the environment, and in promoting environmentally responsible development and use of natural resources. Over the past five years, knowledge of the sources, cycling, and impacts of metals in the Canadian environment has increased substantially as a result of multidisciplinary studies undertaken by researchers in government, academia, and industry. These studies have been funded through a number of nationwide initiatives, including the Metals in the Environment Research Network (1998–2004, http://www.mite-rn.org/), the Toxic Substances Research Initiative (1998–2002, http://www.hc-sc.gc.ca/hecs-sesc/tsri/index.htm), the Collaborative Mercury Research Network (2001–2006, http://www.unites.uqam.ca/comern/index.html), and the Geological Survey of Canada's - Metals in the Environment Initiative (GSC-MITE I, 1997–2002; GSC-MITE II, 2003–2006). Researchers with Natural Resources Canada and Fisheries and Oceans Canada at BIO have participated directly in all of these initiatives.

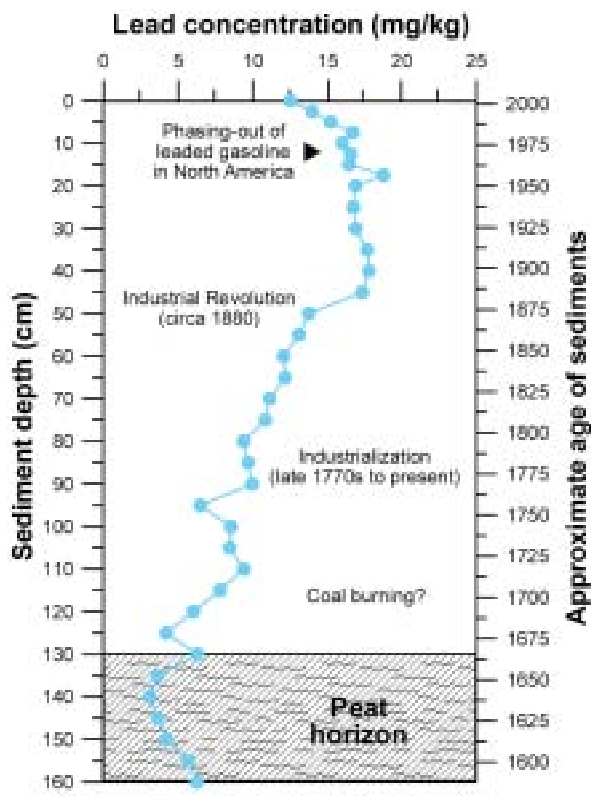
The GSC-MITE I Program provided a geological basis for environmental studies, defining the range of natural background metal concentrations, the mineral form and reactivity of metals, and the processes controlling their movement in the surface environment.

Mine tailings in the marine environment near the abandoned Little Bay copper mine in north-central Newfoundland. Recent studies by Fisheries and Oceans Canada have shown that wild mussels (Mytilus edulis) *from this site have some of the highest copper concentrations ever reported.*

This initiative responded to increasing government and industry requirements for geoscience knowledge needed to develop national and international policies concerning metals and their release into the environment, and to create appropriate regulations for Canada. New studies into metal cycling and source apportionment will begin in April 2003 as part of the GSC-MITE II Program (http://www.nrcan.gc.ca/ess/themes/env_e.php#mite).

Since 1999, environmental geochemistry research at GSC Atlantic has focused primarily on the distribution, transport, and fate of metals in the marine environment near mining and mineral processing facilities, and in the vicinity of ocean dumpsites. These studies continue GSC Atlantic's long-standing involvement in MITE-type research, which has examined metals in marine waters and sediments at many locations around the world since the early 1970s (under the direction of Dale Buckley and Ray Cranston, now both emeritus scientists with GSC Atlantic). Recent studies concentrate on determining the specific chemical forms of metals in waters and sediments, and on characterizing the processes that control the availability of metals to biota.

A major component of the first GSC-MITE Program was the Point Sources Project, which examined the spatial distribution and forms of metals in the environment around three Canadian base-metal smelters. As part of this project, GSC Atlantic characterized the sources, transport, transformation, and fate of metals in marine sediments near Noranda's Brunswick Smelter, a primary lead smelter and refinery located along the south shore of the Bay of Chaleur in Belledune, New Brunswick. Previous marine environmental research in the early 1980s, by scientists from BIO and other institutions, documented high concentrations of cadmium and other potentially toxic elements in sediment, water, and shellfish within a few kilometres of the smelter facility. The present study evaluated the regional dispersal of metals emitted from the smelter, and from other natural and anthropogenic sources of metals to the Bay of Chaleur. Chemical analyses of sediment samples collected at distances up to 100 km away from the smelter in 1998 and 1999 revealed elevated lead concentrations (i.e., at least three to four times background values) in surface sediments throughout the entire bay. In harbour sediments sampled immediately adjacent to the smelter, metal concentrations are highest approximately 5 cm below the sediment-water interface and decrease towards the surface, reflecting reductions in smelter emissions since the mid-1970s. Dispersion of smelter emissions by wind and ocean currents has resulted in an area of elevated metal concentrations in surface sediments that extends at least 20 km from the smelter. Characterization of the isotopic composition of lead in the surface sediments suggests that the enrichment of lead throughout most of the bay is mainly derived from smelter emissions and historical combustion of leaded gasoline. These results clarify the impact of the Brunswick Smelter on the surrounding marine environment, and provide scientific information to support risk assessment and risk management decisions at coastal smelters worldwide.



Lead concentration profile in a sediment core from the Tantramar salt marshes near Amherst, Nova Scotia. The concentration data have been corrected to account for the effects of varying sediment grain size—the residual profile reflects changes in atmospheric lead fluxes over time. Sediment dates are based on radiocarbon data from Dr. John Shaw, GSC Atlantic.

In the past few years, GSC Atlantic has also carried out several other multidisciplinary studies of metals in coastal marine environments throughout Atlantic Canada. In summer 2001, we examined the environmental impacts associated with historical disposal of sulfide-rich mine tailings into the ocean near two abandoned copper mines in northern Newfoundland. High-resolution bathymetry mapping, chemical analysis of sediments and waters, and characterization of benthic foraminifera were used to determine the distribution, mobility, reactivity, and biological impacts of tailings on the seafloor. Metal concentrations have also been examined at ocean dumpsites in Saint John Harbour, Grand Manan Island, Northumberland Strait, and in Cape Breton. In general, the concentrations of metals at most of these sites are not sufficiently elevated to result in adverse biological impacts; however, the distribution of certain metals (e.g., vanadium) in the sediments serves as a useful tracer of dredge spoil dispersion. Finally, metals have also been examined in sediments from relatively pristine environments, including Passamaquoddy Bay and the Tantramar salt marshes. Careful analysis of metal profiles in sediment cores from these locations provides an historical record of changes in atmospheric metal deposition over time.

Knowledge of the sources, cycling, and fate of metals in marine ecosystems is crucial for developing better environmental quality guidelines for coastal zone and fisheries management. Future studies under the new Earth Sciences Sector, Geoscience for Oceans Management Program will focus on linking geochemical observations to biological impacts, and will be conducted in collaboration with researchers from Fisheries and Oceans Canada at BIO. Results from this work will be used to better understand relationships between metal concentrations in water and sediment, adverse effects on marine organisms, and potential impacts on fishery resources.

The CHS Atlantic 'On Datum' Project

- Steve Forbes, Doug Regular, Craig Zeller, Nick Stuifbergen, Steve Grant, and Arthur Wickens

BACKGROUND AND DESCRIPTION

The Canadian Hydrographic Service (CHS) Atlantic Region's On Datum Project, is a two-year project initiated in 2001. It was designed to update charts to a common international horizontal datum, to bilingualize the charts, to incorporate a limited amount of existing unincorporated data and, where practical, to upgrade the chart symbols to modern standards. Each of these objectives is explained below, the project logistics and flow are discussed, and the conclusions take a brief look at the results and at the future direction for this approach to upgrading CHS charts.

Horizontal Datum - The introduction of radio positioning systems such as Loran-C and the Global Positioning System (GPS) caused a fundamental change in the practice of navigation. In the past, mariners used visual and radar observations to plot their positions relative to charted features. If latitude and longitude were needed they were scaled from the latitude/longitude grid. Today, mariners first obtain latitude/longitude electronically and then plot their position using the latitude/longitude grid. If the grid is non-existent, if the relationship between the grid and the charted features and dangers is unknown, or if it is not consistent with that provided by GPS, a potentially unsafe situation exists and mariners will make decisions based on incorrect information. This might lead to collisions, groundings, and/or loss of life. The relationship between a chart's latitude/longitude grid and the land and sea areas it portrays is related to the horizontal datum or definition of the grid location. The horizontal datum in use throughout North America today is the North American Datum 1983 (NAD83) but many CHS charts are on older or unknown datums. Since a very important objective of this project is to shift the latitude/longitude grid to place as many as possible of these older charts 'on datum', it has become known as the 'On Datum' project. As a result of this project, mariners will be able to take full advantage of modern, highly accurate positioning systems like GPS when using these charts.

At the start of the project, 175 of Atlantic Region's 289 charts were not on NAD83. However, 117 of these charts were on known older datums, usually North American Datum 1927 (NAD27), so the latitude/longitude grid shifts to NAD83 were known. Indeed, the majority of those charts included a note giving the shift values so mariners could 'correct' their GPS/Loran-C positions before plotting them on the chart. The shift values for the remaining 58 charts were unknown.

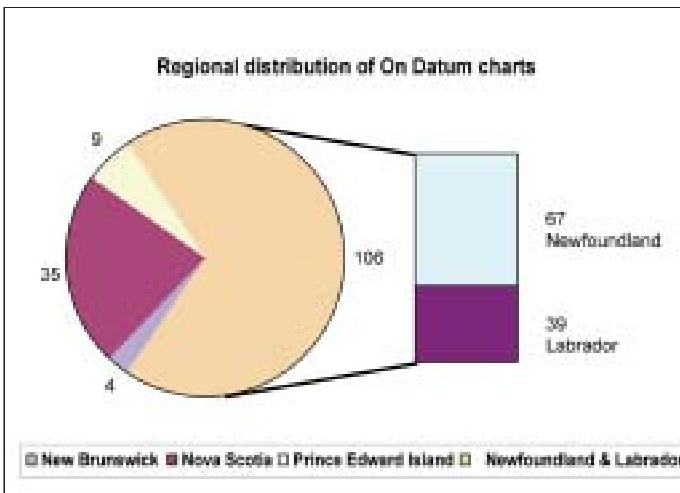


Figure 1.The 154 charts of the On Datum Project broken down by province.

Bilingualization - CHS has undertaken to make all of its products bilingual. This is the second major objective of the On Datum Project. At the start of the project only 36 of the 175 On Datum charts were bilingual; at the end of the project every chart will be bilingual.

Unincorporated Data - Many older charts were published 30, 40, or even 50 years ago. Although they have been kept up-to-date for critical changes involving safety of navigation by the publication *Notices to Mariners*, CHS has on file varying amounts of unincorporated data that may be of use to the mariner. Therefore, a further thrust to this project is to review these data, to archive data that has been superseded, and to incorporate a limited amount of critical unincorporated data.

Symbology - On older charts, many of the symbols used to portray various features are obsolete. Another priority for this project is to upgrade charts with modern symbology. However, the limited time and resources available has meant that compromises were necessary and many time-consuming and expensive upgrades that did not affect safety of navigation would not be done. For example, 'cliffy' shoreline symbology, marsh symbols, and roads as two parallel lines (instead of the modern solid gray line) were not changed.

IMPLEMENTATION OF THE ON DATUM PROJECT

Typically, CHS Atlantic publishes 10 to 15 new charts and new editions each year. The goal of the On Datum Project was to publish 154 new editions within 18 months. Therefore, a new model had to be devised that would allow this increase in production. Figure 1 gives a breakdown of the 154 On Datum charts by province. A further 22 off-datum charts are being handled via the regular production stream.

Nautical Data International Incorporated, St. John's, Newfoundland and GeoNet Technologies, Central Bedeque, Prince Edward Island were assigned the project. For each chart, a Statement of Work (SoW) detailed every task to be performed. Each contractor was given access to CHS Chart Specifications and other CHS standards. CHS staff assist with the in-house project coordination and quality control. CHS is also working closely with the Canadian Coast Guard to update the charting of as many navigation aids as possible.

Raster editing techniques utilizing the Microstation/IRASB system rather than using the standard vector approach were used. Raster techniques are simpler and faster, and all CHS charts had been scanned during a Y2K project. An added advantage is that raster charts can be maintained using the same raster tools. The resulting products can be used to produce Print On Demand (POD) copies of the chart as needed by the marine community which reduces the stock warehouse costs.

At the start of the project, 58 charts were on unknown horizontal datums. However, using special techniques developed by Nick Stuifbergen, CHS Atlantic, it was possible to derive datum shifts for 36 of those charts by comparing them with topographic maps and hydrographic source documents. Consequently, only 22

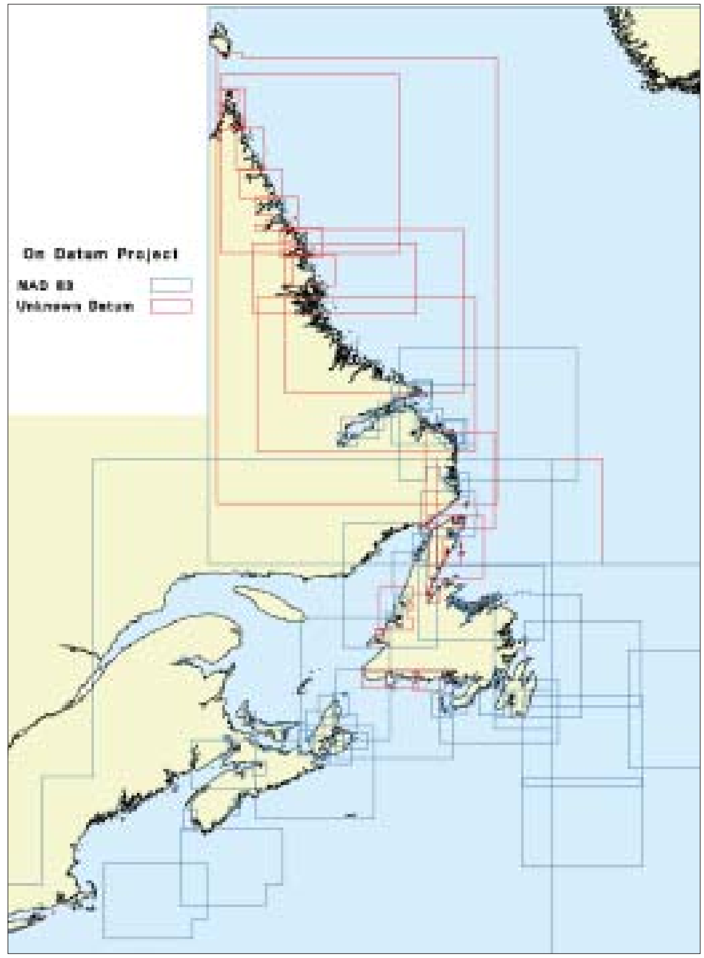


Figure 2. Distribution of 154 On Datum Project charts. Blue charts will be corrected to NAD83 while the 22 red charts will remain off datum. This represents about half of all Atlantic Region charts. See the latest Chart Catalogue for more details - figure prepared by M. McCracken.

charts will not be 'on datum' at the end of the project. The unrecoverable charts are based on old mid-1800s British and French surveys. However, they can still be used with care using traditional navigation techniques. Figure 2 shows the 154 charts of the On Datum Project; the 22 red charts will continue to be off datum, the 132 blue charts will be on datum.

CONCLUSIONS

As a result of the On Datum Project, all CHS Atlantic charts will be bilingual and all but 22 charts will be compatible with modern positioning systems such as GPS. They will be up-to-date, they will have modern symbology, and they will be in digital raster format that will enable them to be used with modern, highly efficient electronic chart systems. The ability to publish these products using POD techniques will mean that Atlantic Canadian mariners will be able to purchase up-to-date chart products. In the future, CHS Atlantic will be able to maintain the product suite more easily and efficiently because of its digital format. This will also facilitate the production of the full vector-based chart products. Moreover, these new production models will assist in revamping CHS's production to fit the requirements of the nautical community and the realities of the modern world.

Macroscopic Perspectives on Microscopic Life in the Sea

- William Li

In the oceans, microscopic forms of life constitute the bulk of living matter. Collectively, marine microbes represent an enormously rich genetic biodiversity since they include organisms from all three of the most fundamental domains of life on earth, namely *Bacteria, Archaea,* and *Eukarya*. In addition, viruses are found everywhere in the sea as infectious biological agents of other microbes. The domains *Bacteria* and *Archaea* comprise the prokaryotic component of the marine plankton. Prokaryotes are single-celled organisms that have been called the unseen majority of the biosphere. In the oceans, they number more than 10^{29} cells. As a group, the prokaryotes are exceedingly diverse in their metabolic capabilities. These activities underlie the transformation of elements such as carbon, nitrogen, phosphorus, and sulphur in great planetary cycles. The microbial plankton members of the *Eukarya* are highly diverse in form and function. They include not only all the algae such as the familiar diatoms, dinoflagellates, and coccolithophores, but also all the flagellated protists and ciliates (sometimes known as the "protozoa", a term that is now less often used because "first animal life" does not adequately describe the variety of ways by which these organisms can obtain their nutrition). In all three domains of the marine microbes, new and unexpected forms are being discovered at a rate that is greatly accelerated by molecular phylogenetics.

As megafauna, we may find it difficult to appreciate the essential role played by microbes in the ocean. Three distinguished scientists, who have each been awarded the Huntsman Medal of the BIO (www.bio.gc.ca/huntsman/huntsman-e.html), concur in their view of marine microbes. Ramon Margalef stated that "the relatively recent recognition of the omnipresence of very small prokaryota, forces any phytoplankton student to reconsider the classical views". David Karl noted that "the classic marine food chain - algae, zooplankton, fish - can now be considered as a variable phenomenon in a sea of microbes". Lawrence Pomeroy claimed that "Old paradigms die slowly, Thomas Kuhn told us - mainly through the death of their adherents. Many fisheries scientists do not believe it, but the marine food web consisting principally of diatoms, copepods, and fishes is now generally seen as an occasional excrescence from what is normally a microbial food web".

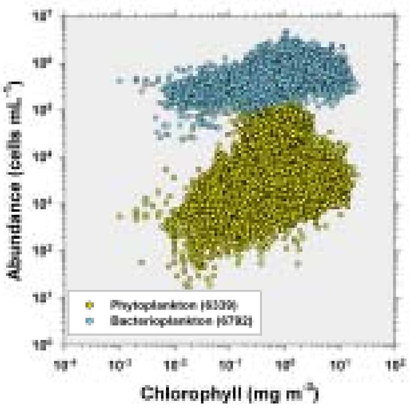
As the new paradigm of the microbial food web takes hold in oceanography, we face the difficult task of characterizing and explaining the abundance, distribution, and diversity of these organisms; in other words, the task of ecology. Anyone who has looked at satellite images of ocean colour (www.mar.dfo-mpo.gc.ca/science/ocean/ias/remotesensing.html) cannot fail to notice how the patchwork of blues, greens and reds locate in different regions and change over time. These are global views of the phytoplankton in the surface sunlit layers of the ocean: they are but one manifestation of the tremendous variability in the occurrence and growth of the plankton. In this regard, marine microbial ecology largely emphasizes the distinctions between different kinds of organisms and ecosystems, and on the extensive spatial and temporal variation within ecosystems. Ecological systems are viewed as highly idiosyncratic, being contingent on the organisms present, and the particular circumstances of the environment in space and time.

The eminent scientist John Lawton has argued that this contingency is tractable at two levels of ecological organization. Tractability is evident at relatively simple levels such as the population dynamics of single or small numbers of species. However, at the intermediate scales of community ecology, the overwhelming number of case histories complicates the contingency to an unmanageable form. Interestingly, the contingency becomes manageable once again in large sets of species, over large scales of space and time in the form of statistical patterns when local details are subsumed; in other words "macroecology". We should therefore not be surprised to find widespread, repeatable patterns emerging from a large collection of observations in spite of the numerous contingent processes that underlie the collection.

A macroecological study requires enough observational data to ensure that the range of natural variability is covered as fully as possible. Measurements of the abundance and diversity of marine microbes through the depths of the entire water column are painstakingly acquired from collections at sea. Remote sensors to provide real time data for "armchair" oceanographers are not yet a practical reality. Not surprisingly, microscopic organisms are usually examined by microscopy, a method that reveals much taxonomic detail at the expense of low sample throughput. Alternatively, methods have been developed at the Institute that sacrifice taxonomic detail in favour of a greatly enhanced speed by which cells can be counted. With this capability, it is feasible to map - in both space and time - the properties of marine microbes at a resolution limited only by the number of water samples recovered in hydrographic surveys. As one of the international pioneers in the shipboard use of flow cytometry for rapid plankton analysis, the Institute has acquired a dataset of North Atlantic phytoplankton and bacterioplankton that is arguably the most extensive, and almost certainly the most methodologically consistent in existence. Out of this dataset has emerged some interesting patterns. These patterns point to rules, and perhaps even general laws by which we might understand the nature of plankton assemblages.

In the northwestern North Atlantic Ocean, a striking feature in the statistical distribution of phytoplankton and bacterioplankton in relation to chlorophyll pigment biomass is the polygonal nature of the patterns.

The filled data space within these polygons indicates the variability in thousands of individual plankton samples, representing

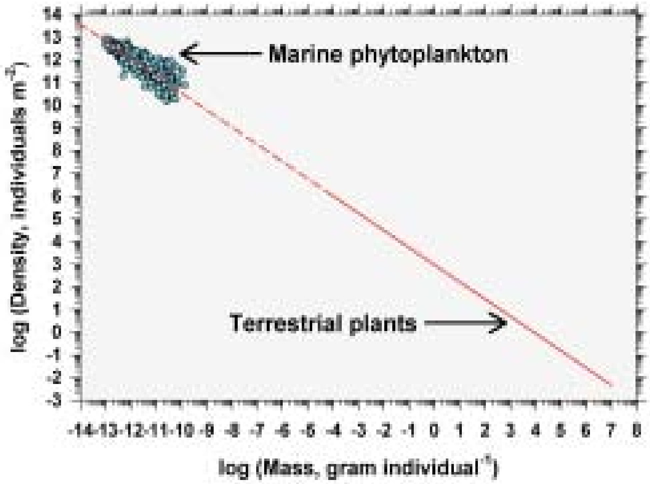


Macroecological patterns of phytoplankton and bacterioplankton abundance in the northwest North Atlantic Ocean.

hundreds of separate cases of time and space histories. Emerging from this complexity are the boundaries of the polygons, which appear distinct and quite well-defined. These limits suggest that there are fundamental constraints on the plankton assemblage characteristics permissible in nature.

Another remarkable pattern emerges when we consider all the plants of the world together on the common basis of body mass. A universal law seems to describe the natural areal abundance of all photosynthetic organisms as a function of individual body mass, from the largest tree on land to the smallest unicellular cyanobacterium in the ocean.

In an interesting essay on estimating marine primary productivity on the global scale, John Raven considered the problems of scaling up local measurements and asked “Today a bottle of seawater, tomorrow the world?”. This may not be too far-fetched. A useful approach may be to view the microorganisms through a “macroscope”.



Allometric scaling of the areal abundance of plants. The relationship derived for terrestrial plants by Enquist et al. (1998. Nature 395:163-165) for body masses in the range 10^{-4} to 10^{+7} grams can be extrapolated to the cell mass range for phytoplankton 10^{-13} to 10^{-10} grams.

Isotopic Iodine (^{129}I) Ventilation Ages for Denmark Strait Overflow Water in the Labrador Sea

- John N. Smith

The transport of heat in the oceans and the regulation of climate is, to a great extent, governed by the global thermohaline circulation or, more graphically, the global ocean conveyer belt (Figure 1). Dense water, produced by winter cooling in the Greenland/Icelandic/Norwegian seas, flows over the ridges separating Greenland from northern Europe and cascades to the bottom of the North Atlantic Ocean. These “overflow” waters then pass through the South Atlantic and Indian oceans en route to the Pacific Ocean as they warm and slowly rise to the surface. The waters eventually return to the North Atlantic in the Gulf Stream, carrying the heat to Europe that maintains its comparatively warm temperature and completing the global transport cycle. Most climate models predict that emissions of greenhouse gases will produce future warming and freshening of water in the Nordic Seas that could contribute to a slowing of circulation along the global conveyer belt. Indeed, recent studies indicate that the overflow has been steadily freshening during the past 3-4 decades and that it may be slackening as well. To understand the influence of climate on global circulation, scientists at BIO have been developing new methods to determine the production rates of the overflow waters and to follow their downstream passage through the world’s oceans.

One of the simplest types of experiments to determine water flow rates is to inject tracers into the ocean and measure the speed of their subsequent movement propelled by wind and ocean currents. This experiment has been inadvertently carried out on a grand scale by the discharge of the long-lived ($t_{1/2}$ = 16 million

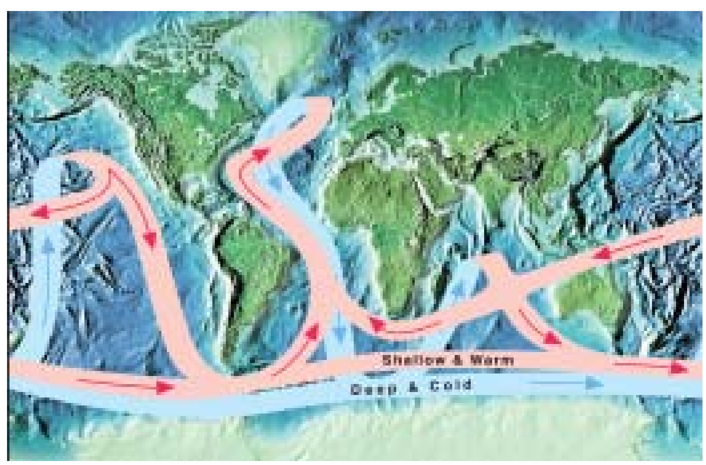


Figure 1. The transport of heat in the ocean and the regulation of climate is to a great extent governed by the global ocean conveyer belt which is driven by the production of cold, dense water in the high latitude North Atlantic Ocean which sinks to the bottom and flows south through the Atlantic, Indian, and Pacific oceans, eventually returning to the North Atlantic as surface water flow.

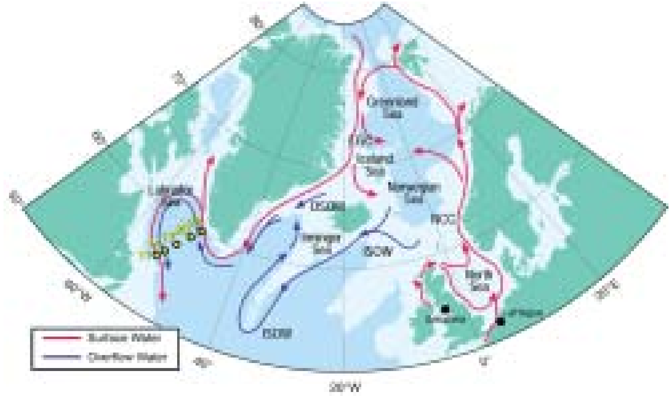


Figure 2. ^{129}I tracer surface water plumes from Sellafield and La Hague mix in the Norwegian Coastal Current with North Atlantic fallout and are injected into the overflow waters in the Nordic Seas. Iceland Scotland Overflow Water (ISOW) crosses the Mid-Atlantic Ridge, flows northward into the Irminger Sea Basin where it overrides Denmark Strait Overflow Water (DSOW) flowing across the Denmark Strait sill and the two water masses flow together into the Labrador Sea. The five time-series stations (1997-2001) occupied in the Labrador Sea are indicated by filled circles.

years) radioactive isotope of iodine, ^{129}I, from European nuclear fuel reprocessing facilities. ^{129}I is released into the Irish Sea and English Channel from nuclear facilities at Sellafield, UK and La Hague, France and is then transported by surface currents through the North Sea and into the Norwegian/Greenland seas. There the ^{129}I is injected into Denmark Strait Overflow Water (DSOW) that spills over the sill between Greenland and Iceland into the Irminger Sea (Figure 2). This water mixes with Iceland Scotland Overflow Water (ISOW) that arrives by a more circuitous route, and then flows around the tip of Greenland into the Labrador Sea, eventually becoming part of the Deep Western Boundary Current (DWBC) that effectively ventilates the deep North Atlantic. Although ^{129}I is present at very low levels, modern analytical innovations in accelerator mass spectrometry (AMS) mean that ^{129}I can now be measured on 1 litre water samples practically anywhere in the Arctic and North Atlantic oceans, thereby positioning ^{129}I as a new and very powerful oceanographic tracer.

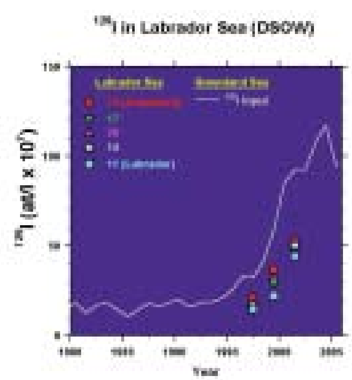


Figure 3. Input function for ^{129}I in the Greenland/Icelandic seas (solid line) is compared to ^{129}I concentrations measured in DSOW in the Labrador Sea. The time lag of about two years between the Labrador Sea data collection and the Greenland Sea input function represents the transit time from the Icelandic/Greenland seas to the Labrador Sea. Station numbers in the figure refer to the locations marked on Figure 2.

Until 1990, ^{129}I inputs to the ocean increased only gradually, but between 1991 and 1999, ^{129}I discharges to the Greenland Sea increased by 600% (Figure 3), mainly as a result of sharply increasing releases from La Hague. In order to trace this large "ramp" in ^{129}I concentrations through the North Atlantic Ocean, ^{129}I measurements were begun in 1997 on the AR7W section in the Labrador Sea (Figure 2). Three ^{129}I "sections" in 1997, 1999, and 2001 (Figure 4) show a remarkable increase in the ^{129}I concentration. Background levels of ^{129}I in the ocean are only 2.5 x 10^7 atoms per litre (at/l) so the results in Figure 4 where ^{129}I levels are all > 5 x 10^7 at/l (double the background levels) indicate that the entire Labrador Sea had been contaminated by inputs from European nuclear fuel reprocessing plants. Furthermore, the highest ^{129}I levels were measured at the bottom of the Labrador Sea in Denmark Strait Overflow Water which shows the direct connection maintained between deep waters in the Labrador Sea and surface waters of the Icelandic/Greenland seas.

^{129}I levels increased by approximately 250% in DSOW at the bottom of the Labrador Sea between 1997 and 2001 (Figure 3) which is similar to the proportional increase in ^{129}I in the Greenland Sea between 1995 and 1999. These results indicate that the leading edge of the 1995-2000 ramp in the tracer input function reached the bottom of the Labrador Sea between 1997 and 2001, and that water therefore flows from the Greenland Sea into the deep North Atlantic Ocean on very rapid time scales of the order of 2 years. This study indicates that the steep leading edge of the ^{129}I tracer spike had already passed through the Labrador Sea by 2001 and that the tracer signal was heading southward in the Deep

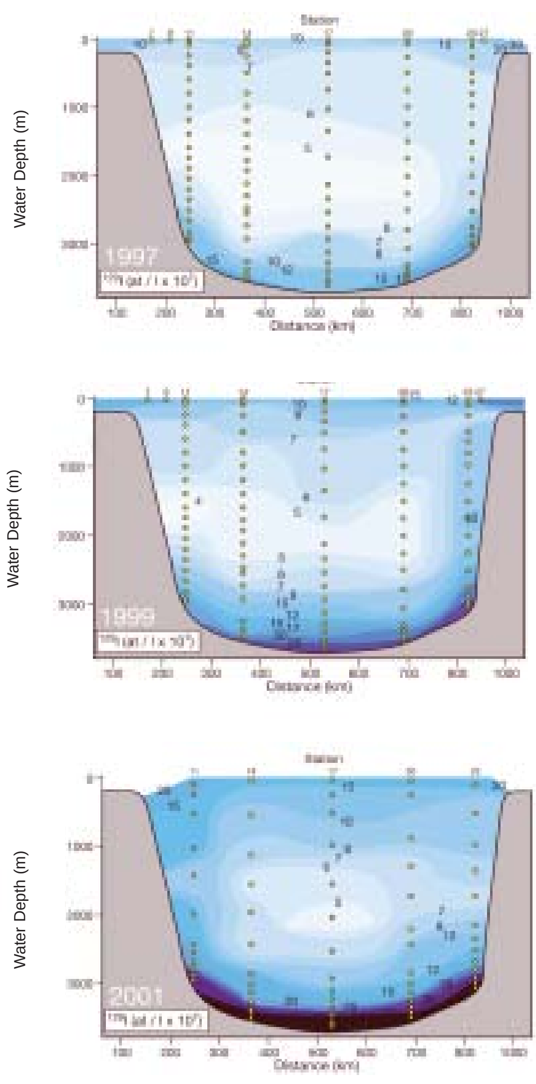


Figure 4. ^{129}I sections on the AR7W line in the Labrador Sea for 1997, 1999, and 2001 show concentrations increasing with time in bottom DSOW as the leading edge of the ^{129}I tracer spike from the mid-1990s (Figure 3) enters the North Atlantic Deep Waters (NADW). Elevated ^{129}I levels in surface water represent inputs from the West Greenland Current spreading into the Labrador Sea and mixing downward by winter convection.

Western Boundary Current (DWBC). Previous studies have shown that by the time the Deep Western Boundary Current has entered the subtropical North Atlantic, it is very difficult to distinguish DSOW from other water masses owing to mixing. However, measurements of the leading edge of the ^{129}I spike should provide a much better method for identifying the overflow waters as they pass through the deep regions of the Atlantic Ocean and produce more accurate estimates of the age of DSOW and the amount by which it is diluted by mixing. It is ironic that discharges of radioactivity from two nuclear fuel reprocessing plants in Europe are providing scientists with a unique tool to determine the speed at which high latitude climate signals are communicated to the deep North Atlantic Ocean. These studies should help us better understand the basic climate connections between the ocean and the atmosphere.

Species at Risk Research at BIO

- Kirsten Querbach, Patrick O'Reilly, Peter Amiro, Jamie Gibson, Rod Bradford, Jim McMillan, and Arran McPherson

The Maritime Aquatic Species at Risk Office (MASARO) co-ordinates the regional strategy for protecting and recovering species at risk for Fisheries and Oceans Canada. In 2002, MASARO assisted in coordinating a number of initiatives, including species at risk research efforts. Research programs at the Bedford Institute of Oceanography have focused on inner Bay of Fundy Atlantic salmon (*endangered*), Atlantic whitefish (*endangered*), Lake Utopia dwarf smelt (*threatened*), and the leatherback turtle (*endangered*). The species at risk research conducted within the Diadromous and Marine Fish divisions during the past year has been undertaken with the direction of multi-stakeholder recovery teams and/or internal DFO review teams to ensure specific needs of each species are being addressed.

INNER BAY OF FUNDY (IBOF) ATLANTIC SALMON

Wild anadromous iBoF Atlantic salmon have declined by 90% or more since 1989. Juvenile salmon have not been detected recently in nearly one-half of the rivers in which they previously occurred. One research initiative has focused on estimating total population size and survival rates. Survival from smolt to adult is being assessed using mark-recapture studies of both seaward migrating salmon smolts and adults that returned to freshwater to spawn. Within the freshwater environment, models are being developed to estimate total juvenile abundance within a river from electrofishing data. At the smallest spatial scale, electrofishing catchability is modelled and used to make inferences about population density within an electrofishing site. These densities can be modelled as a function of habitat type, which is categorized using remote sensing and a geographic information system (GIS). At the largest spatial scale, population size is estimated for a watershed from the electrofishing data and the distribution of habitat types within the watershed. The results of these analyses will be used to document the decline, status, and recovery of Atlantic salmon in inner Bay of Fundy rivers, identify critical habitat within freshwater, and aid in the development of strategies for their recovery.

A growing body of evidence suggests that the sharp decline of iBoF salmon is due to low marine survival resulting from unknown causes. To prevent the imminent extinction of this assemblage of populations, the recovery team has protected remnant populations in captivity until causes of mortality can be identified and mitigated. Maintenance of small populations in captivity can be complicated and problematic. Inbreeding and loss of genetic variation are concerns for the long-term health of these captive populations and are a result of: (1) the limited pool of founders (many of which may be related), (2) the high reproductive potential of this species, and (3) the expected absence of migration (geneflow) to these populations in the future. Furthermore, exposure to captive conditions may bring about physiological, behavioural, and genetic changes that are thought to decrease the wild fitness of salmon upon their return to their native river habitat.

Rotary screw trap used to live-capture Atlantic salmon smolts in the Big Salmon River, N.B. - photo by Ross Jones.

Many of these concerns have been addressed by incorporating a broodstock management program that includes both captive and wild components. First, remaining iBoF salmon are DNA fingerprinted, and placed into population-specific pedigrees. This pedigree is then consulted to carry out a mating scheme that simultaneously minimizes co-ancestry, inbreeding, between family domestication selection, and mal-adaptive change due to small population sizes, and random genetic drift. Most of the progeny resulting

Atlantic whitefish - photo by Bob Semple.

A leatherback turtle - photo of the Nova Scotia Leatherback Turtle Working Group.

from such crosses are released into the wild, where they are subject to natural selection. A small portion from each family is also being retained in captivity. When it is time to produce the next generation of genebank salmon, juveniles about to go to sea will be recovered from the wild, DNA fingerprinted, pedigreed, and captive-reared to adults. When the original founding families are not present in these wild-exposed samples, representatives from these missing families will be taken from the captive population of genebank salmon. Use of a genetically-sound broodstock management program, and a strategy that involves river-exposure of juvenile salmon, will increase the wild-fitness of salmon and hence, the likelihood of success of future attempts to restore self-sustaining runs of anadromous Atlantic salmon to the inner Bay of Fundy.

ATLANTIC WHITEFISH

The endangered Atlantic whitefish is endemic to Nova Scotia and has historically been found in only two river systems. A suite of factors, including over-fishing, river acidification, inadequate fish passage, and the introduction of exotic fish species is thought to have contributed to the loss of all anadromous runs of this species. Consequently, the potential for re-establishment of Atlantic whitefish populations has been the focus of the recovery program. Research to date has included: (1) assessment of habitat quality in candidate lakes for re-introduction, (2) assessment of habitat requirements for natural life-cycle closure, and (3) development of a captive breeding program to support physiological research and the anticipated re-establishment program. Investigated metrics of habitat suitability have included the extent of acidification and species composition/abundance of both benthic macroinvertebrates and stream/lake fish assemblages. The captive breeding program has yielded three age classes of fish which can now be used to assess the tolerance of Atlantic whitefish to water quality variables. Release strategies expected to improve the likelihood of establishing self-sustaining populations will be developed from this information.

LAKE UTOPIA DWARF SMELT

Lake Utopia, New Brunswick is one of several oligotrophic lakes in eastern Canada where at least two forms of smelt occur in sympatry; the traditional smelt and the dwarf form, the latter of which was designated as 'threatened' in 1998. Threats to population viability include: (1) perceived low spawner abundance, (2) restricted spawning, (3) adult capture in a recreational dipnet fishery, and (4) potentially high predation as a consequence of fish stocking programs. In collaboration with province of New Brunswick biologists and colleagues at the University of New Brunswick, research has focused on accumulating information on spawner abundance, spawning distribution, habitat requirements, and the appropriateness of the stated threats to dwarf smelt. Initial results suggest that spawner abundance may be in the tens of thousands and therefore greater than previously thought. Further assessment of genetic structuring, development of reliable criteria for morphological identification, and systematic surveys of smelt spawning activity are underway.

LEATHERBACK TURTLE

Staff of the Bedford Institute of Oceanography have partnered with Dalhousie University since 2000 to study leatherback turtles using satellite-linked timed-data recorders (SLTDRs). This project has tracked leatherback turtles to gain information about migration and feeding (diving and foraging) behaviour. Dalhousie researchers and fisher members of the Nova Scotia Leatherback Turtle Working Group, led by Dalhousie University student Mike James, have been able to live-capture free-swimming leatherback turtles and attach the SLTDRs using a harness fitted to the animal.

Preliminary results from this work have revealed coastal and offshore foraging movements (characterized by shallow dives of short duration) in Canadian and USA waters, with extensive feeding in slope waters east of the Fundian Channel and Georges Bank. Time spent in Canadian waters has varied considerably; some animals depart soon after tagging while others remain foraging in Canadian waters for three to four months. Tagged leatherback turtles have migrated to Caribbean waters adjacent to nesting sites, to pelagic waters at low latitude, and to shelf waters off the southeastern United States. Data collected through this research will assist in evaluating the vulnerability of this species to human activities occurring in Canadian waters and throughout its North Atlantic range.

FUTURE

With the Species at Risk Act scheduled for proclamation in 2003, MASARO is creating a regional species-at-risk website to be launched shortly thereafter. This website will house information on recovery planning and provide updates on recovery-related research projects, like the ones described here.

Research Voyages in 2002

- David McKeown

CCGS Hudson *deploying Campod at La Poile Bay, Newfoundland, September 2002.*

The Bedford Institute of Oceanography utilizes the following research vessels, that are operated by the Canadian Coast Guard:

- CCGS *Alfred Needler*, a 50m offshore fisheries research trawler;
- CCGS *Hudson*, a 90m offshore research and survey vessel;
- CCGS *Matthew*, a 50m coastal research and survey vessel;
- CCGS *J.L.Hart*, a 20m inshore research vessel;
- CCGS *Navicula*, a 20m inshore research vessel;
- CCGS *Pandalus* III, a 13m inshore research vessel.

In addition, scientists at the Institute sometimes conduct field programs on vessels of opportunity such as federal government buoy tenders and icebreakers, commercial fishing and survey vessels, and research vessels of other countries.

During February and March 2002, the CCGS *Alfred Needler* was used for shellfish and winter groundfish surveys on the Scotian Shelf. From May to November, scientists from the Bedford Institute of Oceanography, Gulf Fisheries Centre and Institut Maurice Lamontagne employed the vessel to conduct offshore finfish and shellfish ecosystem surveys and related research programs on the Scotian Shelf from Georges Bank to Cabot Strait and into the Gulf of St. Lawrence.

During the winter of 2001/2002, CCGS *Hudson* completed the final phase of an extensive refit to prolong its working life for another seven to ten years. Although scheduled to commence its season at the beginning of April, problems encountered during the refit forced the cancellation of the annual spring Atlantic Zone Monitoring Program (AZMP) cruise. The ship finally departed BIO on May 3, 2002 to conduct a major seismic survey on the Grand Banks. Near the conclusion of that expedition, the starboard stern tube developed a significant leak forcing the ship to return to BIO prematurely for an emergency dry-docking. In early June, the ship recommenced its scheduled program with a habitat mapping geophysical survey on Georges Bank. In late June, the ship sailed to the Labrador Sea to service oceanographic moorings and conduct hydrographic (conductivity/temperature/depth {CTD}) survey operations as part of Canada's contribution to global climate studies. At the conclusion of this expedition, the ship had been scheduled for a lengthy mid-season maintenance period. However, this was shortened considerably to allow resumption of the program cancelled in May on geohazard and pipeline route surveys in the Sable Island area done in collaboration with the Atlantic Canada Petroleum Institute (ACPI). This was followed by another geohazard survey on the Scotian Slope. A team of BIO habitat ecologists then boarded the ship to conduct a deep sea coral survey along both sides of the Laurentian Channel. During that study, the first documented observation of the occurrence of the coral *Lophelia* in North America was made. At the mid-point of this cruise, scientists from the Northwest Atlantic Fisheries Centre, St. John's, Newfoundland joined the BIO contingent to begin the first season of a three-year field program to explore the relationship between groundfish and their habitat. From mid-October to mid-November, oceanographers from BIO and the Northwest Atlantic Fisheries Centre conducted two consecutive cruises to obtain the autumn AZMP physical and biological oceanographic dataset. The final voyage of the season involved the placement of a mooring array at Flemish Cap followed by a study of the over-wintering depth distribution of zooplankton in the Labrador Sea as part of the BIO contribution to the UK Global Ocean Ecosystem Dynamics (GLOBEC) project. The season concluded on December 12 when the ship was docked at BIO for the winter.

CCGS *Matthew* was scheduled to begin its season on May 19 with a cruise to the Sable Island area to study sharks. Unfortunately, because of delays in completing the annual refit, this cruise was cancelled and the subsequent start of the hydrographic field season scheduled for June 1 was delayed until June 18. At this time the vessel proceeded to the south coast of Newfoundland to commence its annual hydrographic charting program. When ice conditions permitted, the ship moved to the Labrador Coast to continue hydrographic surveying until early October before returning to BIO. After being re-configured with geophysical equipment, it carried out a geoscience survey in the Sydney and Bras D'Or Lakes areas. Its operational season ended at BIO on October 30.

The smaller inshore fisheries research vessels, CCGS *J.L.Hart*, CCGS *Navicula* and CCGS *Pandalus III* also had a busy season. These vessels are used by a large number of scientists who conduct a wide variety of scientific programs including stock assessment, fisheries and habitat research, and geophysical surveys. CCGS *J.L.Hart*, operating for the most part out of the St. Andrews Biological Station, spent the field season supporting research programs in the Bay of Fundy area. The CCGS *Navicula* served as a platform for a cooperative DFO/First Nations fisheries research program in the Bras D'Or Lakes as well as supporting a number of other fisheries and habitat research programs in the Bay of Fundy and coastal areas of Cape Breton, Nova Scotia. The CCGS *Pandalus III,* operating out of the St. Andrews Biological Station in New Brunswick, conducted numerous daily trips in the local area throughout the year.

Oceans and Coastal Management and Canada's Oceans Strategy (COS)

- Bob St-Laurent

Fisheries and Oceans Canada, Oceans and Coastal Management Division (OCMD), leads and facilitates the development and implementation of Canada's Oceans Strategy on the Scotian Shelf and along the Atlantic coast from the Canada – USA border to Cape North, Cape Breton, including the Bras d'Or Lakes. The Division is composed of four sections: Direction & Administration, Coastal Management, Oceans Management, and Planning & Information Services.

Canada's Oceans Strategy (COS), released in July 2002, affirms the Government of Canada's approach to managing Canada's ocean resources from a sector-based approach toward integrated ocean management. It provides a national policy framework with the overarching goal to ensure healthy, safe, and prosperous oceans for the benefit of current and future generations of Canadians. It is intended to guide the co-ordination and integration of management activities in or affecting Canada's estuarine, coastal, and marine environments. One of its key elements is that all levels of government retain their respective legislative and jurisdictional responsibilities and authorities. COS defines the vision, principles, and policy objectives of ocean management; supports programs aimed at understanding and protecting the marine environment; supports sustainable economic opportunities; and promotes international leadership.

OCMD's approach to the implementation of Canada's Oceans Strategy, includes continued implementation of *Oceans Act* programs for Marine Protected Areas (MPA), Integrated Management (IM), and Marine Environmental Quality (MEQ).

MARINE PROTECTED AREAS

Two examples illustrate the critical role MPAs play in the conservation and protection of marine life and their habitats: the Musquash Estuary and The Gully.

The Musquash Estuary is located approximately 20 km west of the city of Saint John, New Brunswick and is considered one of the last ecologically intact estuaries in the Bay of Fundy. OCMD has been actively involved in a community association called Friends of Musquash, and established the Musquash Advisory Committee. OCMD provides a lead role by developing the regulatory and management proposals for the area. The primary responsibility of the advisory committee and its members is to coordinate implementation of the resources and authorities at its disposal to protect the Musquash Estuary, including the application of existing programs and policies.

The Gully, a large offshore submarine canyon on the edge of the continental shelf, which has been the focus of national and regional conservation efforts since the early 1990s, was selected as an Area of Interest (AOI) in December 1998 and accepted as a MPA candidate site. In the fall of 2002, OCMD's Oceans Management Section worked on a regulatory proposal to formally designate The Gully as a MPA, pursuant to the *Oceans Act*. Discussions were held with a variety of interested parties while several ecological and socio-economic assessments were completed. Work also continued on the contents of a MPA management plan. The conservation and management strategies to be detailed in the plan will be fully developed in the coming year with input from The Gully Advisory Committee.

INTEGRATED MANAGEMENT

OCMD is engaging with stakeholders to achieve integrated planning and management of all ocean activities by working to apply the principles of integrated management, sustainable development, ecosystem-based management, and precautionary and collaborative approaches. As a relatively new office, effort has been made to build trust, develop capacity (internally and externally), and engage the diverse range of interests involved. The examples below give an

Salt marshes and intertidal mudflats found in the Musquash estuary - photo by David Thompson, Conservation Council of New Brunswick.

overview of some of the accomplishments realized in 2002.

OCMD's Coastal Management Section (CMS) has been involved in laying the foundation for an integrated management plan with an emphasis on building the required partnerships to manage human activities in the entire Bras d'Or Lakes and their watersheds, as well as the River Denys watershed (intended to serve as a pilot project). Among the various interest groups that have been formed, OCMD works closely with the five bands of the Cape Breton First Nations, through the Unama'ki Institute of Natural Resources, to help build their capacity to take an active role in the management of the ecosystem of the lakes.

Also, the Coastal Management Section is actively involved with the Minas Basin Working Group (MBWG), one of the many working groups of the Bay of Fundy Ecosystem Partnership (BoFEP). The MBWG specifically focuses on developing sustainable management plans for the region based on issues and efforts of local residents and groups. In 2002, there was a series of community meetings in Wolfville, Truro, and Parrsboro, where the goal of these meetings was to initiate wider community involvement in fostering sustainable economic, social, and ecological development within the Minas Basin watershed. These discussions identified and prioritized seven major issues: agriculture, development, fisheries management, forestry practices, recreation, sewage/water quality, and the Avon River Causeway. The next step is to move forward specific actions that will mobilize community leaders and develop integrated management plans.

Under the Large Oceans Management Area (LOMA) concept for the Atlantic Ocean, OCMD's Oceans Management Section (OMS) has been working with a range of stakeholders through a collaborative process called the Eastern Scotian Shelf Integrated Management (ESSIM) Initiative. The first ESSIM Forum in February 2002, was instrumental in stimulating multi-stakeholder dialogue on the proposed ESSIM process and integrated oceans management and planning. The workshop succeeded in highlighting to the broader community the ongoing efforts for government engagement and coordination. In preparation for the second ESSIM Forum (February 2003), OMS worked in collaboration with interested parties to prepare a draft ocean management plan framework for discussion. This drafting process is focusing on the structure and key elements of the plan, including a vision statement, guiding principles, and high-level management objectives, indicators, and strategies for achieving environmental, social/cultural, economic, and institutional sustainability through the management plan.

CONSISTENCY AND LINKAGES

One of OCMD's ongoing commitments to the implementation of Canada's Oceans Strategy has been to ensure consistency and linkages to OCMD's and DFO Maritimes Region's initiatives and lessons learned through integrated management and marine protected area initiatives underway since 1998. During 2002, OCMD's Planning & Information Services Section has participated in a series of events, seminars, and meetings involving other DFO sectors, other federal government departments, provincial governments, academia, industry, and community organizations. The objective of this process was to promote the value of the COS principles and objectives, particularly coordination and integration.

SUMMARY

Through *Oceans Act* principles and approaches, OCMD is mandated and striving to achieve an effective, sustainable balance among environmental, social, and economic objectives in Atlantic Canada's coastal and ocean areas through integrated management and planning.

Fish Habitat in Halifax Harbour: A Resource Worth Protecting

- Jim Ross

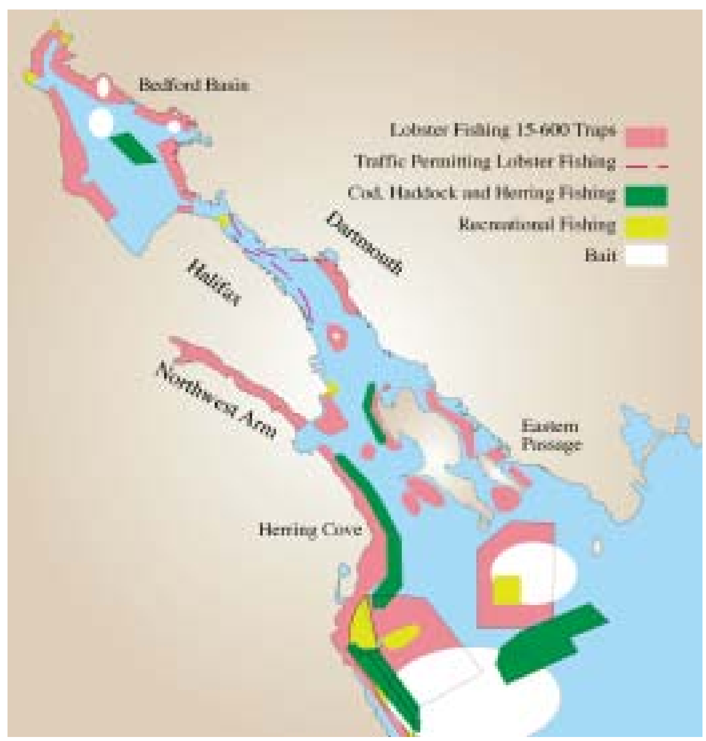
From prehistoric times to the present day, Halifax Harbour has provided valuable habitat that has contributed to important fisheries resources. However, impacts from development pressures in and around the harbour have had substantial effects on these habitats. It is important to understand that we all have a duty to protect fish habitat and the fisheries it supports. It is equally important to understand the responsibilities that the *Fisheries Act* places on us in this regard.

HISTORIC FISHERIES IN HALIFAX HARBOUR

Evidence exists of prehistoric and historic occupations on McNabs Island dating to 10,000 years before present (YBP), the time of the retreat of the glaciers. Shell middens examined by researchers show that the people relied on the harbour to provide a diet of fish and shellfish.

Edward Cornwallis was so impressed by the fishery potential of Halifax Harbour that the day after he sailed into the harbour in 1749 he wrote to his superiors, the Lords of Trade in London, saying, "…The harbour itself is full of fish of all kinds. All officers agree the harbour is the finest they have ever seen."

Today, Halifax Harbour is desperately trying to be all things to all people. It is an industrial harbour, it provides recreational and tourism opportunities, while at the same time supporting viable commercial fisheries.



Areas of fishing activity in Halifax Harbour, based on information from 1991, 1993, and 1999.

THE *FISHERIES ACT* AND FISH HABITAT

Habitat Management Division administers the habitat protection provisions of the *Fisheries Act*, in particular section 35(1) that states that, "No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat." Fish habitat is defined as "… spawning grounds and nursery, rearing, food supply, and migration areas on which fish depend directly or indirectly in order to carry out their life processes." This relates to the effects of physical impacts to habitat rather than chemical impacts. These are addressed in section 36 of the *Fisheries Act*.

A review undertaken recently by the Habitat Management Division demonstrates that there are still numerous viable fisheries and their habitats in Halifax. In addition to finfish, the harbour supports a diverse shellfish population; however, the harbour is presently closed to shellfish harvesting.

HOW FISH HABITAT IS ALTERED OR DESTROYED

One of the more visible means by which fish habitat is altered or destroyed is through infilling, or placing fill in the marine environment to create land where none previously existed. Infilling destroys habitat directly by displacement of bottom habitat and displacement of water column habitat. The resulting silt can settle at a distance from the original infill, smothering bottom habitat. Indirectly, the introduction of suspended particles in the water column can have serious effects on fish.

Slope altered due to infilling in the intertidal zone.

Infill in Halifax Harbour.

Commercial or private wharves, breakwaters, boat ramps, and walls constructed to protect against erosion, can alter or destroy fish habitat. Many of these structures change the slope of the natural intertidal zone.

WHAT HAPPENS WHEN THE INTERTIDAL AREA IS INFILLED?

When an intertidal area is infilled there are both direct and indirect habitat losses. Direct losses occur when the slope of the intertidal zone is altered producing a steeper and greatly reduced intertidal zone available to crustaceans and other marine life. Natural slopes provide complexity and biodiversity that have developed slowly over time. Complexity and biodiversity are missing from altered substrates and they will take years to re-establish. Natural slopes can still be seen throughout the Northwest Arm, Bedford Basin, and the outer harbour.

Indirect habitat losses occur with the release of sediment and other deleterious substances when fill is introduced into the marine environment. Habitat losses may continue with each subsequent runoff event. Storms may resuspend previously settled silt that may harbour various deleterious substances.

HABITAT MANAGEMENT'S GOALS FOR HALIFAX HARBOUR

The *Policy for the Management of Fish Habitat* (Habitat Policy) describes how we should implement the habitat provisions of the *Fisheries Act*. Specifically, it is a statement of DFO's objectives, goals, and strategies for the management of fish habitats in support of Canada's freshwater and marine fisheries. The policy objective of a net gain of habitat is supported by the three goals of habitat conservation, restoration, and development. Habitat conservation is guided by the *no net loss* principle. The goals of habitat restoration and development are intended to complement the conservation goal by providing opportunities for a net gain of habitat.

The conservation goal is the standard that must be met by all development proposals large or small that could have an impact on marine resources in the harbour. Unless authorized by the Minister, projects must not result in a harmful alteration, disruption or destruction of fish habitat.

It is our objective to apply the Habitat Policy in a consistent manner in the harbour. However, fish habitat is not consistent throughout the harbour. For instance, the industrial sections of the harbour, although they do provide fish habitat, are now composed largely of habitat that would support the migration of fish and provide food supply, whereas in the Northwest Arm and Bedford Basin there is a greater diversity of habitats. The need to protect this diversity of habitats means that we have to use different techniques depending on the habitats we must protect. Therefore, we try to protect nearshore habitats in lesser developed areas of the harbour and migration and other habitats throughout the harbour in general.

Halifax Harbour has been blessed with an abundance of fish habitat, much of which still exists despite development pressures. It is important to understand that we all share the challenge of protecting this habitat. It is equally important to understand that the key to healthy fish habitat and viable fisheries in the harbour is co-operation, communication, and consideration of the needs of both a healthy environment and stakeholders, along with the development of an integrated approach to habitat protection.

TECHNICAL SUPPORT HIGHLIGHTS

Outreach at BIO 2002

- Joni Henderson and Jennifer Bates

The year 2002 marked the 11th year of operation for the Bedford Institute of Oceanography's guided and self-guided tour program. Since its formation in 1991, the tour program has promoted the Institute and its work within the community. This year's tour was comprised of a series of educational films, informative wall panels, and interactive models that have highlighted a sample of the scientific disciplines found at BIO. Commentary was provided by the tour guides who are university students well versed in the work of the Institute.

The tour program benefited as a result of the positive publicity generated by the 40th anniversary celebration activities that occurred during the year. The success of *Open House 2002* resulted in an increase in visitors during the summer tour season. In addition, some of the open house exhibits were incorporated into the tour route. These include:

- An illuminated table featuring a multibeam image of Bedford Basin;
- An illuminated image of a Sable Gully scale worm. The images in this light box will be changed from time to time;
- Posters containing current data on Nova Scotian fisheries;
- New photographic images depicting the evolution of the Institute over the years;
- New series of photographic and digital images in the window display area adjacent to the main auditorium;
- Enhancements to the large animal display tank located in the Fish Lab;
- A large display tank housing young or rare marine species in the Sea Pavilion; and
- A permanent exhibit of the deep sea corals is being developed and should be in place early in the new year;

Support for education was once again a priority for BIO staff. School presentations, participation in school science fairs, and numerous job-shadowing requests were among the many activities of BIO employees. A variety of resources ranging from guided tours for students to provision of scientific information for teachers and students continued for "Oceans 11", the grade 11 science course developed by BIO staff in conjunction with the Nova Scotia Department of Education.

Fisheries and Oceans Canada staff were proud to host Nova Scotia's first ever "What's Hot Forum", a gathering about our youth doing science, technology, and innovation. Nova Scotia was the last

Youth Forum Science Consultant Marilyn Webster with Mike Sinclair and students Jenna MacNeil, Cecila Peters, and Jim Proudfoot.

Digby 2002 - EdGEO (geoscience education for teachers) Workshop.

stop on a cross-country tour organized by Youth Science Foundation (YSF) Canada, the nation's leading organization for youth innovation in science and technology. Members from the National Foundation and the Nova Scotia Youth Experiences in Science (NS YES), along with some of the province's student winners at this year's Canada-wide Science Fair in Saskatoon, spent an afternoon at BIO where they interacted with local industry representatives and staff.

In the Gift Shop, sales were brisk and the product line was expanded. Items ranging from ball caps to track suits, and our special 40th anniversary cookbook proved popular with employees and visitors.

Staff would like to acknowledge the invaluable contribution of the "BIO-Oceans Association" to the Outreach program. Members are quick to volunteer for all initiatives under the Outreach umbrella and their efforts are greatly appreciated.

Geoscientists at the Geological Survey of Canada (Atlantic)/Natural Resources Canada, and members of the Nova Scotia EdGEO Workshop Committee hosted the ninth annual teachers' workshop. Thirty teachers travelled from locations throughout Nova Scotia to attend the two-day workshop at Digby Regional High School. The program included interactive presentations on the basics of geology (rocks and minerals, fossils, dinosaurs, and geological time) plus sessions on soil, climate change, and oil and gas. A half-day field trip gave the teachers an excellent overview of the geology of Digby and surrounding area. This program is very popular with the education sector and attracts both teachers and those involved with museum programs, science centres, and private sector educational services. Observers from Fisheries and Oceans Canada and the Institute of Biological Sciences of the National Research Council attended to develop ideas for hosting their own workshop for teachers in the future. Funding was provided by the National EdGEO Program. Support was generously provided by the Geological Survey of Canada (Atlantic), the Nova Scotia Department of Natural Resources, Dalhousie University, the Halifax Regional Municipality School Board, Atlantic Science Links Association, and Digby Regional High. The EdGEO 2003 workshop will be held at the Fundy Geological Museum in Parrsboro.

Following from the publication of *The Last Billion Years: A Geological History of the Maritime Provinces of Canada* in 2001, GSC Atlantic staff are now busy leading offshoot activities. A talk series at the Nova Scotia Museum of Natural History in Halifax was attended by record numbers and runs until May 2003. Posters

Field trip of EdGEO participants in the Digby area.

focussed on selected content of the book will be available in 2003. The listing of the book on the Nova Scotia Book Bureau entitles teachers to purchase the book for use in their classrooms. In addition, the Nova Scotia Department of Education and Culture will place one copy of *The Last Billion Years* in each school throughout the Province.

NRCan geoscientists continue to participate in several ongoing outreach endeavours: the development of the EarthNet website (earthnet.bio.ns.ca); invited talks at schools, universities and libraries; and, collaboration with museums, science centres, societies and associations, and other government offices to develop outreach products and activities.

Community Assistance in 2002

- Shelley Armsworthy

Staff and retirees of Bedford Institute of Oceanography continue to assist the community by donating time, financial support, and goodwill to many charitable events.

The largest organized charitable movement is the Government of Canada Workplace Charitable Campaign (GCWCC) that involves United Way/Centraide, Health Partners, and numerous other registered charities across Canada. In 2002, the DFO Maritimes Region Government of Canada Workplace Charitable Campaign raised a total of $95,968, exceeding the previous year's contribution by over 12%! The GCWCC canvassers are at the heart of the stimulating employee contributions. Under the leadership of Tara McRae, the GCWCC-DFO Account Executive, this year's regional campaign has been a great achievement. NRCan's small contingent at BIO raised over $1277.

In addition to the gifts from staff and retirees, a portion of the total GCWCC funds was raised through the following events:

- The 9th annual GCWCC Golf Tournament at Fox Hollow Golf Club in Stewiacke, NS was held on September 13th and raised $881;
- A book sale throughout the month of November took place outside the BIO library; books donated by BIO staff and retirees sold for $733;
- The 11th annual staff hockey game, family skate, and Christmas party raised $2406,
- A DFO internet auction raised $1,386;
- A draw for a "Weekend Getaway for Two" that included a two-night stay at the Delta Halifax, a gift certificate for the Crown Bistro, a moonlight cruise on *Mar II*, a two-day car rental, and a dinner cruise on the *Harbour Queen* I raised $2031;
- Middle Manager's Conference raised $365;
- National Public Service Week 6 months free parking draw raised $180; and
- National Public Service Week Job Shadow Auction raised $235.

2002 GCWCC canvassers at a Regional Management Committee meeting. The team was invited to a special luncheon in recognition of their contributions. Individuals listed from left to right. First row: Pat Young, June Spurrell, Tara McRae, Joan Jeffries, Debbie Graham, Norwood Whynott. Second row: Penny Reedie, Wanda Farrell, Theresa MacDonald, Elaine Myers, Bettyann Power, Claudette Hébert, Sheila Shellnutt, Bruce Anderson, Victoria Clayton. Back row: Neil Bellefontaine, Kim MacIsaac, Sharon Young, Wanda Arsenault, Rick Boyce, Melissa McDonald, Celine Renaud, Don Belliveau, Cathy Langille, and John Adams. Photo courtesy of Al McLarty. All canvassers were not present for the photograph.

In addition to events in support of the Government of Canada Workplace Charitable Campaign, numerous interesting and entertaining special events were organized and hosted by volunteering BIO staff and retirees for other charities. During April, $1365 was collected at BIO from the sale of daffodils to support the Canadian Cancer Society. Also in April, the fourth annual *Beat the Winter Blues Kitchen Party* was held in the BIO auditorium, featuring musicians and singers from BIO and guest artists from the community. An eclectic musical mixture of folk, blues, country, jazz, traditional, Newfoundland folk, instrumental, and a cappella was performed. "Open mike" sessions were available to anyone wishing to show off their hidden talents. Admission, in the form of either a cash donation or a non-perishable food item, provided $231 and eight boxes of groceries for the Parker Street Furniture and Food Bank in Halifax.

At Christmas, a traditional time of giving, staff and retirees of BIO initiated numerous charitable activities in the hope that many could enjoy the holiday season. Throughout the month of December, non-perishable food items were collected for the Metro Food Bank for donation during the Christmas period. Also during this time, fruitcakes were sold for the Multiple Sclerosis Society. The Marine Environmental Sciences Division (MESD) hosted coffee break fundraisers to purchase gifts and food for four disadvantaged families at Christmas.

Since 1995, volunteers from BIO and the Parker Street Furniture and Food Bank have participated in assembling and delivering boxed Christmas dinners to people in need. Originally undertaken by NRCan, this volunteer activity has been embraced by others at the Institute and has been officially called a "Christmas Gift of Giving" where volunteers constitute a "Community Care Network". Just before Christmas, a well-organized three-day process at Parker Street Furniture and Food Bank begins. Day one consists of unloading food supplies from trucks and repackaging the items into portions for family-sized dinners. The boxes include typical ingredients for a complete Christmas dinner. Day two is reserved for box pick up, where recipients who do not require delivery come to the food bank to pick-up their Christmas dinner box. Day three is a delivery day for boxed dinners to go to those who are not able to leave their residence. In 2002, the "Community Care Network" prepared 550 food boxes.

Musicians Tom Donovan, Ron MacIntyre, Stephen Britton Osler, and Alastair Macdonald playing at the 4th annual Beat the Winter Blues Kitchen Party - photo by Jim Reid.

Lynn Doubleday, of the BIO cafeteria, continued to represent the Society for Prevention of Cruelty to Animals (SPCA). Throughout the year, Lynn collected donations of old blankets and towels, cleaning products, non-perishable pet food items, and Sobey's receipts. Hand-made crafts and pet emergency door stickers were sold in the cafeteria. Lynn collected over $2000 for the SPCA. The society uses the donations and proceeds from sales to assist homeless or abused domestic animals until loving owners can be found for them.

Benevolence and participation of BIO staff and retirees are precious qualities that serve to help define the character of the Institute. Any of the aforementioned charitable activities would gladly welcome new volunteers.

Public Works and Government Services Canada - New Heating and Cooling for BIO

- Wilf Lush

The Department of Public Works and Government Services (PWGSC) is the real property service agent to Fisheries and Oceans Canada (DFO) at BIO. An energy project to build a new cooling plant and modernize the existing heating plant is being implemented by PWGSC on behalf of DFO. The Sustainable Development Strategy (SDS) was a strategic driving force when PWGSC created the designs for both plants. The new cooling plant is part of a redevelopment project for BIO, and is the product of approximately five years of planning and design. The entire building design incorporates materials that are either recycled, or have the lowest energy input to manufacture, and that fit within the project budget. Environmental initiatives allow this plant to reduce 480,000 kg of green house gasses annually while producing 1000 tons of refrigeration (or 12,660 megajoules, equivalent to 1500 window mounted air conditioners). The modernization of the heating plant includes conversion from steam to hot water (hydronic) that will produce a further reduction of 500,000 kg of greenhouse gasses per annum.

The cooling system utilizes cold Bedford Basin water pumped from a 30-meter depth, where the temperature is approximately 5º Celsius. The cold salt water is passed through a heat exchanger where it cools the water in the building cooling system that is then

Installation of grass roofing material.

used to keep the BIO structures cool. The salt water is discharged back into Bedford Basin at a depth and temperature that does not affect marine life.

One creative feature, which is also the most obvious, is the cultivation of prairie grass on the roof. This "green" roof acts as insulation, moderates heat within the building itself, and prolongs the life of the roofing membrane system. The roof consists of four layers:

- The top layer is grass from selected varieties which grow to no more than 12.5 to 15 cm in height requiring no cutting maintenance
- Top soil is on the second layer. It is a specific mix of material designed to hold water.
- The third layer is a filter that water runs through.
- A drainage panel lies beneath the upper layers to allow space for water to run off the roof.

Energy Center Cooling Plant near completion.

It is noteworthy that this is the first installation of this roofing technology on a Government of Canada facility.

Other Sustainable Development Strategy features include the use of a combination of shaded glass panels and solar panels on the south side of the building. The shaded glass panels allow the facility to maximize use of natural light while the shades reduce heat gain. The solar panels are used to energize the ventilation motors that operate windows in the cooling plant to take advantage of natural ventilation.

The heating portion of this project went into service in December 2002 and the cooling component will be completed for May 2003.

Other projects are: the new Level II containment laboratory for which design is currently underway and is scheduled to be in service in 2005; and construction will start in 2003 to renovate the Vulcan Building.

Science Administrative Support Team

- Cathy Wentzell

There is a group of dedicated workers in DFO's Science and Oceans & Environment branches who meet twice a year to discuss innovative approaches to administration and workload issues. They are known as the Science Administrative Support Team (SAST).

ORIGIN

Originally formed in 1988, the group's charter members consisted of a forward-thinking group of women who provided administrative support to the then Biological Sciences Branch of the former Scotia-Fundy Region. The nature and diversity of their work, coupled with their varied geographic locations, namely, the former Halifax Fisheries Research Laboratory, the St. Andrews Biological Station, and the Bedford Institute of Oceanography, led to a need for a team approach to both plan

SAST members 2002 (left to right). Front Row: Carla Carney, Debi Campbell, Sheila Shellnutt, Cathy Wentzell, Bettyann Power, Second Row: Wanda Farrell, Trish Hopkins, Theresa Dugas, Victoria Clayton, Brenda Best, Daisy Williams, Judy Simms, Marie Charlebois-Serdynska, Back Row: Jennifer Dupuis, Sharon Young, Rachelle Noel, Michele Saunders, Melissa McDonald, Celeine Renaud, Tara Baker, Gabriela Gruber, Lynn Cullen, Missing from photo: Debbie Anderson, Jane Avery, Carol Beals, Wilma Boyd, Sandy Burtch, Katherine Collier, Sharon Gillam-Locke, Joanne Gough, Marilyn Landry, Sharon Morgan, Carol Simmons, Shaun Smith-Gray, Bob St-Laurent, and Nancy Stobo. Retired in 2002: Casey Dines and Pat Williams.

and streamline work activities. After collaboration with computer specialist, Bob Branton, the first working group was formed and led by Darlene Guilcher, a former DFO employee in the branch manager's office. With the full support of the Branch Management Team, the group held its inaugural meeting at the former Halifax Fisheries Research Laboratory in 1989. One of the first items of business was a name; the group agreed on the name Word Processing Special Interest Group. Semi-annual meetings were scheduled, alternating among the three locations. A key example of the work carried out by this group was to standardize the format and procedures for the roll-up of the Branch Program Review, Evaluation, and Planning document, also known as "The Red Book." It was because of the forethought and hard work of this group that the annual production of this 400 plus page document became seamless.

The group has evolved and grown over the years, in numbers and in spirit. With the amalgamation of two regions (Scotia-Fundy Region and Gulf Region) in 1995, we were fortunate to have the added strength of the former Gulf Region Science Branch administrative staff. One of the highlights during this period was the two-day *Workshop for Administrative Professionals: Challenges for the New Millennium* held in Moncton, New Brunswick in late fall of 1999. Invitations to attend the workshop were extended to administrative support staff in all branches within the Maritimes Region. The turnout was phenomenal and the workshop deemed a huge success. It was also during this period that the group unanimously agreed it had outgrown its name and thus was renamed the Science Administrative Support Team, or SAST.

CURRENT STRUCTURE

Some fourteen years since its inception, SAST has become a vital component in the efficient operation of its respective branches. Its membership of thirty plus gives a wide influence in every section, division, and at branch levels within the Science and Oceans & Environment branches. Collectively, SAST has a strong voice and, as such, has been instrumental in bringing administrative issues to the forefront. An excellent example was a joint meeting of the Science Administrative Support Team and the Joint Branch Management Committee in St. Andrews, New Brunswick in June 2001 where SAST members presented workload issues and discussed solutions at a plenary session with division managers and branch directors.

Although the group has weathered many changes over the years, the mandate remains, as always, *to foster continuity and team spirit*.

This is achieved through:

- a team approach;
- forums for discussion and training;
- proactive planning;
- sharing ideas and work experiences; and
- liaising with management on branch administrative matters.

Members are proud of their work and pleased with opportunities to showcase their respective talents and expertise. Election of a new chairperson and recording secretary every two years gives interested members first-hand experience in conducting multi-faceted meetings and workshops. Some members have conducted training sessions for the group in the field of communications; others have provided hands-on 'tips-n-tricks' presentations on various software packages. Invited guests from DFO Corporate Services bring members up-to-date on the latest programs, procedures, and directives, while motivational speakers help members stretch beyond their comfort zones.

2002 MEETINGS

At the spring 2002 meeting, held at the St. Andrews Biological Station, invitations were extended to, and accepted by, administrative support staff in the Southwest New Brunswick Area Offices. Highlights of the meeting included interactive presentations on communications given by a noted Dale Carnegie trainer, and on Choice Theory, given by a certified learning consultant. Presentations by DFO Corporate Services staff from Informatics and Finance & Administration were also featured. The fall meeting, held at the Bedford Institute of Oceanography, highlighted a presentation by Power Talk Communications with each SAST member having an opportunity to participate. DFO Corporate Services staff from Human Resources and Finance & Administration also gave informative presentations. It has become our custom at the close of each meeting to do what we call a 'round-table' where each member is given the opportunity to offer feedback on the meeting and to make suggestions for future meetings.

SAST's presence and dedication to excellence in science administration have remained a constant during changing times. The Science Branch and Maritimes Region have undergone many changes over the years, i.e., creation of the new Oceans Branch in 1999, and a separation within the Maritimes Region to once again form the Gulf Fisheries Management Region and the Maritimes Region. Through it all SAST has remained committed to its original purpose. Indeed, it is such changes that fuel the team's originality and resourcefulness.

The Science Administrative Support Team appreciates the continued support of its managers and directors, and the opportunity to contribute proactively to its respective branch mandates.

Three Oceans of Biodiversity - Centre for Marine Biodiversity and Census of Marine Life: Workshop on Marine Biodiversity in Canada

- Kees Zwanenburg and Ellen Kenchington

Biological diversity - or biodiversity - is the term used to describe the variety of life on Earth and the natural patterns it forms; marine biodiversity refers to the variety of life in the oceans. At present, we have identified about 200,000 species of marine organisms, but experts consider that there may be as many as 100 million yet to be discovered. Presently only 15% of all known animal species are described as being from marine systems, reflecting a poor understanding of the marine environment rather than reflecting the real distribution of species. For example, although 4,500 trawl hauls have been made on the Scotian Shelf since 1970 (and this is considered a well-sampled system) the larger bottom-dwelling invertebrates have not been counted or identified in these surveys until recently. Canada is not unique in this regard; most marine ecosystems have been poorly sampled for biodiversity. For many groups of organisms such as bottom-dwelling invertebrates on continental slopes or the abyssal plain, we have little idea of the numbers of living species. The fossil record however, shows us that new species arise slowly whereas extinctions occur rapidly. It takes a very long time to build up the complex communities of marine organisms that we see today. To rebuild these, once destroyed, would take in the order of millions of years, if it occurs at all. This alone should be sufficient incentive to stimulate improved understanding of modern marine biodiversity, its controlling mechanisms, and its conservation.

By signing the *International Convention on Biodiversity*, Canada has agreed to make inventories of biodiversity, to monitor changes in biodiversity, and to make plans to conserve biodiversity. Although Canada ranks among the world leaders in marine research, knowledge of biological diversity and the processes that control it within its vast Pacific, Atlantic, and especially Arctic ocean territories (a total of 6.5 million km^2 in all) is still rudimentary for many areas and for many groups of organisms. In order to fulfill international obligations and to respond to the desire of Canadians to ensure conservation of our marine habitats and their diversity, we must improve our knowledge of what lives in the oceans, what processes control and affect their well-being, and how to conserve this heritage.

In partnership with the Census of Marine Life (CoML), the Centre for Marine Biodiversity (CMB) held a national workshop in February of 2002 to begin this process for Canada's three oceans. The global objectives of the Census of Marine Life are to describe what lives, what lived, and what will live in the world's oceans. At present this consists of a number of pilot projects exploring various

Soft coral (Anthomastus grandiflorus) *of the group Alcyoncea taken with Campod, at a depth of about 350 m, during a survey at the Stone Fence (outer part of the Laurentian Channel, east-northeast of Sable Island) autumn 2002.*

Sea anemone (species unidentified), sea urchin Strongylcentrotus sp.*, truncate soft-shell clam* Mya truncata*, arctic hiatella* Hiatella arctica*, shrimp (species unidentified), barnacle* Balanus sp.*, mysid* Mysis sp. *and kelp* Agarum cribosum *in 15m of water near Qikiqtarjuaq, Nunavut - photo by Tim Siferd, DFO Winnipeg.*

aspects of the census. The development of a national plan to address marine biodiversity in Canada represents a logical next step in the evolution of the CoML from pilot projects through national initiatives to the global census. The specific objectives of the workshop were:

- to identify the present knowledge and knowledge gaps about marine biodiversity in Canada's three oceans;
- to identify the present state of knowledge on major processes affecting biodiversity;
- to develop a 5-10 year plan outlining data collection and research directions to address gaps in 1 and 2 above; and
- to establish a national committee on marine biodiversity to implement and adapt the plan.

The workshop recommended the establishment of four national working groups to develop and implement the findings of the workshop outlined in Zwanenburg et al. 2002. These fall into four broad categories: development of data inventories, augmentation of current monitoring projects to fill gaps in knowledge, the develop-

Lingcod (Ophiodon elongatus) *resting on pinnacles covered in pink hydrocoral* (Stylaster sp). *This photo was taken at a depth of 24 fathoms in the Mt Edgecumbe Pinnacles Marine Reserve, Southeast Alaska. This is the only complete no-take groundfish reserve in the Gulf of Alaska - photo by Victoria O'Connell, Alaska Department of Fish and Game.*

ment of research initiatives to better understand processes controlling and affecting marine biodiversity, and the development of an institutional framework for this work.

Recommendations arising from the workshop included completion and integration of the Pacific, Arctic, and Atlantic meta-data registries developed for the workshop. These detail the sources of information on marine biodiversity currently available for our three oceans. We found that there are also many biological sampling and survey activities that provide invaluable information on marine biodiversity in each of our three oceans. However, none of these surveys provide a comprehensive view of marine biological diversity in Canada. The Arctic Ocean was identified as an area for which we have very little baseline information relative to the other oceans. It was recommended that existing monitoring activities be examined with a view towards augmenting them to broaden the taxonomic and geographic scope of the information collected.

The workshop also reviewed evidence which shows that marine and terrestrial ecosystems may have some common characteristics. Just as in land-based ecosystems, the fundamental characters of pelagic marine ecosystems are determined by a relatively small number of environmental factors. The amount of sunlight and wind mixing in the upper water column controls the character of these marine systems much as terrestrial biomes are determined by soil types and rainfall. For bottom communities, the workshop saw that principles of terrestrial landscape ecology would be equally applicable and might be a good way to predict what communities will occur under what conditions and where. Further work on these controlling processes is strongly recommended.

The workshop also recognized that Canada requires a long-term vision with regard to understanding and conserving marine biodiversity. This vision could be encapsulated in the development and implementation of a network of *Marine Biodiversity Discovery Corridors* located in each of the Pacific, Arctic, and Atlantic oceans. *Marine Biodiversity Discovery Corridors* would be used to provide detailed estimates of biodiversity across all taxa and to provide focal points for studies of the processes affecting or maintaining biodiversity. The location of these corridors would be based on the analysis and exploration of available marine biodiversity information as described in the completed regional registries. Corridors might be chosen because they are representative of existing ecosystems, or because they are unique. Some corridors could be areas where human impacts are minimized to provide conservation areas and reference areas for comparison to exploited areas, while others might be areas where human activities occur, to examine their impacts. The public would have access to the results of the research being carried out on *Marine Biodiversity Discovery Corridors* through a variety of vehicles including displays, publications, web-sites, and the potential for hands-on interactions.

LITERATURE CITED

Zwanenburg, K.C.T., K. Querbach, E. Kenchington, and K. Frank [Editors] 2002. Three oceans of biodiversity – Development of a science plan for marine biodiversity in Canada; Proceedings of Census of Marine Life and Department of Fisheries and Oceans workshop. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2432.

The BIO-Hypatia Project: Promoting Gender Equity in Science and Technology (S&T) at BIO

- Sherry Niven

The Hypatia Project is a partnership of public and private sectors in Nova Scotia that has been formed to design and implement strategies to improve the representation of women in science and technology (S&T). The focus of the Hypatia Project is on changing stereotypical images, attitudes, and institutional policies and practices that limit the entry of women into S&T career streams as well as their participation and advancement in the workplace. The project has four program areas – the schools, post-secondary institutions, workplaces, and communities – recognizing that systemic barriers for women in S&T exist throughout society and are best addressed through the coordinated efforts of education institutions, workplaces, and the community.

The Hypatia Project welcomed BIO as its first workplace site in October 2001. BIO is one of the largest S&T employers in Nova Scotia, has strong credibility as a research institute, and has demonstrated a commitment to the S&T community at large (for example, through its outreach activities, and its long history of partnering with educational institutions and the private sector). Key to the BIO-Hypatia Project is the federal government's commitment to finding sustainable solutions to employment equity issues and to creating workplaces of choice and, particularly, the commitment of BIO staff and management to promoting gender equity in S&T.

The primary objective of the BIO-Hypatia Project is to assess the factors limiting the recruitment, participation, and retention of women in S&T and to develop and implement an action plan to achieve sustainable solutions to these factors at BIO. A central strategy of the BIO-Hypatia Project is to build awareness of the importance of diversity to a healthy organization and a creative science culture.

The BIO-Hypatia Project is a community initiative (that is, initiated, developed, and led from within the BIO S&T community) with the support of the BIO Management Team and the participating departments. The assessment phase of the project has been funded through the Public Service Commission/Treasury Board Secretariat *Employment Equity Positive Measures Program (EEPMP)* with matching funds from the lead department, Fisheries and Oceans Canada. All of the federal departments represented at BIO are involved in the project.

In the federal S&T workforce, women currently hold 15% of research positions and 26% of technical and applied science positions, as well as disproportionately more junior and fewer permanent positions than men.

The BIO-Hypatia Project has generated a lot of interest within the S&T community because of the need to increase the participation of women in these fields. Not only is this necessary to meet the Canadian government's commitment of a representative workforce, but it is also recognized to be of critical importance in creating the diversity of perspective and approach that is key to innovative solutions in science and technology. In addition, as competition for S&T employees intensifies in the near future, employers cannot afford to waste the talent of half the population. Without women in science, we have half the talent, half the insights, half the solutions.

The interest in the BIO-Hypatia Project also results from a growing consensus that gender issues in the workplace must be addressed before full participation of women in S&T will be achieved. An improved work experience is required both to retain and promote women in the existing workforce and to increase representation in the S&T recruitment pool (by providing positive role models and breaking down gender stereotypes).

The strategic plan for the BIO-Hypatia Project identifies actions to achieve the following objectives:

1. *Ensuring equal opportunities and fair evaluation* by, for example,

- systematically integrating equal opportunities for women and men into all policies, programs, and practices;
- increasing awareness of gender bias and implicit assumptions about gender roles and abilities that can lead to biased evaluation; and
- developing and applying policies/guidelines for representation on all career-influencing committees as well as advisory and programming committees.

2. *Decreasing the marginalization and isolation of women* by, for example,

- encouraging and facilitating the development of professional networks and supporting the BIO Women's Network, which provides informal networking and personal support;
- increasing women's "voice" at BIO;
- celebrating the contributions of women to science and technology; and
- encouraging the use of mentors.

3. *Developing and implementing a recruitment strategy*, with the ultimate goal of achieving critical mass (~35%) throughout the organization to accrue the benefits of gender diversity, and
4. *Assisting employees in achieving and maintaining work-life balance.*

Key accomplishments of the first year of the BIO-Hypatia Project are:

- An independent assessment of the status of women in S&T at BIO, through a review of literature, statistics, and information gathered from staff and managers.
- An independent report on the factors affecting the recruitment of women to S&T positions at BIO.
- A strategic action plan to ensure equal opportunities for women in S&T at BIO.
- Increased awareness of gender issues in S&T and stimulation of open discussion on the value of diversity to science.
- A demonstrated willingness by staff and managers to work together to create a workplace that respects and supports individual difference.
- Development of networks to share information and to co-ordinate initiatives.

The BIO-Oceans Association: The Dream and the Cheers

- David N. Nettleship, President, BIO-OA

It is only natural, come the 40th anniversary of the establishment of the Bedford Institute of Oceanography (BIO), for thoughts to focus on the past, recalling the major benchmarks and scientific advancements. Yet often, less conspicuous things happen that vividly reveal the special nature of those primary work accomplishments and the community of people associated with them. The establishment of the BIO-Oceans Association (BIO-OA) is one of those events. The Association's creation is a reflection of the success of the BIO initiative – a natural outgrowth owing to the Institute's rich history of quality science and purpose.

The BIO-Oceans Association was established in 1998 with three principal objectives: (1) to foster the continued fellowship of its members and current/former employees of BIO; (2) to help preserve, in cooperation with BIO's managers and staff, the Institute's history and spirit; and (3) to support efforts to increase public understanding of the oceans and ocean science. Membership is open to anyone associated with the Bedford Institute of Oceanography, past or present, as a staff member, associate or 'friend' with an interest in the marine environment.

BIO has played a prominent role in the development of the marine sciences in Canada and the acquisition of knowledge of our ocean waters. The Institute provides a unique opportunity to its workers to participate and excel in exciting and important marine research. That fact has generated a sense of accomplishment and pride in BIO, and served as the catalyst to prompt the formation of BIO-OA by a group of retired staff. The establishment of the OA in 1998, and its subsequent growth, displays a strong desire to stay connected and continue to contribute to BIO.

The year 2002 has been a time of discovery and development for BIO-OA. Not only has the Association grown to over 150 members throughout Canada (some offshore) in a short four years, but also has identified, nurtured and developed programs and projects that will ultimately provide valuable contributions to BIO and its research and management goals. The major effort between mid-May and October 2002 was an examination of "In-progress" projects with a preliminary assessment of progress achieved to date, as well as a review of potential projects considered to have merit, but as yet uninitiated. The number of projects underway or under consideration is impressive (for details, see: *BIO-Oceans Association Newsletter*, Issues 16, 17 & 18; and the OA website, www.bedford-basin.ca/main.html under 'Executive Meeting Minutes'). The review task was to determine the status of each project, assess its feasibility for further action and development, and establish working groups to set precise goals and deadlines for completion. Existing projects are divided into three categories: <u>archives</u> (library, photo and equipment/artifacts); <u>other major projects</u> such as BIO chronology of events, staff publications (a bibliography), historical staff list, oral history, Beluga Award, histories of BIO ships, etc.; and <u>short-term projects</u> (seminars, BIO calendar 2003, gift shop, social activities, etc.).

The results of the initial review were unanimous. The immediate OA effort should be to gather and safeguard the history of

During the Symposium, the BIO-Oceans Association presented BIO with a new visitors' book. The presentation was made by David Nettleship (President BIO Oceans Association, on the left) to Michael Sinclair (DFO, center) and Jacob Verhoef (NRCan, on the right).

BIO by moving forward on archival projects. The rationale for doing so was simple: "*To know the Past is to Understand the Present, and to Predict the Future*", or in the words of the late Peter Gzowski, "*If you don't know where you've been, you sure as hell don't know where you're going*". And so, the consensus that evolved was to start with 'Library Archives' and the development of related BIO archival policy, and the identification of the BIO-OA role within it. Action began in September 2002 with the establishment of a Library Archives Working Group under the chairmanship and guidance of OA executive member, Bosko Loncarevic in association with BIO Archivist Librarian Marilynn Rudi. Major strides forward were also made with both the 'Photo Archives' and 'Equipment/Artifacts Archives' working groups, chaired by OA executive members Michael Latrémouille and Charles Schafer, respectively. Presently, these working groups are investigating the most valuable feedback source available: i.e., the knowledge base of BIO staff members, past and present, people who have actually produced and used the archival materials under discussion. The aim is to obtain as much information as possible related to these three archival projects with the coordination of activities provided by the chairs and members of the newly established working groups. Clearly, BIO-OA can promote innovation and growth in the documentation of the history of the BIO in many additional ways.

Highlights of OA's other principal activities in 2002 follow with more complete information available at the BIO-OA website (www.bedfordbasin.ca):

- *BIO Calendar 2002* – Produced jointly by OA and DFO's Technographics Unit (coordinators: Dale Buckley and Art Cosgrove) with a theme of technological innovations in the marine sciences and distributed via the BIO Gift Shop.

- *BIO Open House* – The BIO-OA exhibit at the 'Open House', held 25-28 April 2002, comprised a history of BIO, a display of the first hydrographic chart, an overview of the history and significance of the 'Beluga Recognition Award', and an archival display of oceanographic equipment used in past research cruises. Dale Buckley served as 'master of ceremonies' at the official opening on 25 April, and a total of 21 OA members served as exhibit volunteer guides over the four-day period.

- *BIO-OA Beluga Award 2002* – Congratulations were extended to Peter Vass (Habitat Ecology Section, Marine Environmental Sciences Division, BIO), the second recipient of the Beluga Recognition Award, on 9 May 2002 for his exceptional contributions as a biologist to multi-disciplinary research projects in fisheries, environmental, and habitat science over the past 25 years.

- *BIO-OA 'Visitors' Book Presentation* – On 25 October 2002, as part of the "Future Challenges for Marine Sciences in Canada" Special 40th Anniversary Symposium at BIO, President David Nettleship, on behalf of the BIO-Oceans Association membership, presented BIO Directors Dr. Michael Sinclair (Fisheries & Oceans Canada) and Dr. Jacob Verhoef (Natural Resources Canada) with a new leather bound, gold gilt and embossed Visitors' book. This book is meant to provide a record of distinguished visitors to BIO, and to serve as an index of the importance of the Institute as a place for the exchange and transfer of information and knowledge.

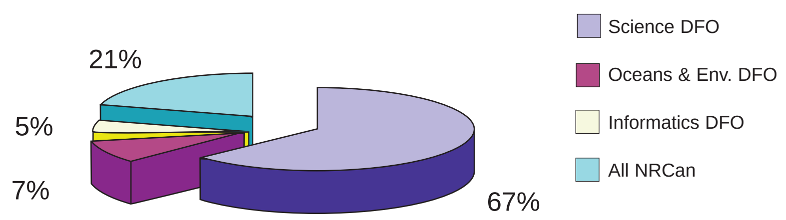
- *BIO-OA Social Events* – Numerous social gatherings were convened through 2002 including: 'Ceilidh & Potluck Supper' (5 April: Ron & Mary Macnab, hosts); Annual Summer Barbeque at 'Ferncliffe', Portuguese Cove (8 August: Bob & Heather Cook, hosts); 'TransCanada Trail Walk' (6 October: Roger Belanger, leader); planning sessions of the 'Canal Boat Holiday to the South of France' (28 October and 2 December: Michael Latrémouille & Clive Mason, coordinators); and 'Fall Celebration: Special Seminar & Wine/Cheese Party' (6 November; speaker: Don Peer, lecture "Sailing to Byzantium in schooner *Peers' Fancy*: a 2-year trans-Atlantic sail from Nova Scotia to Turkey and return").

In conclusion, the BIO–Oceans Association has had an unusually active and productive year through 2002. The above summary provides a glimpse of the activities underway within the Oceans Association. Other on-going projects range from additional historical research initiatives and active study programs associated with the future of oceanography to reviews of noteworthy book publications and travel destinations. Membership in OA is open to all BIO staff and associates, past and present, with an interest in the marine environment and related BIO activities. Everyone is invited to visit the OA website for additional information (www.bedfordbasin.ca) and request a complimentary copy of the current issue of the *BIO-Oceans Association Newsletter* published four times a year. In closing, congratulations to BIO on its 40th Anniversary, long may the 'quest' and 'thirst' for knowledge continue – the true foundation of the BIO experience!

FINANCIAL AND HUMAN RESOURCES

Where the Institute obtains funding and how it is spent

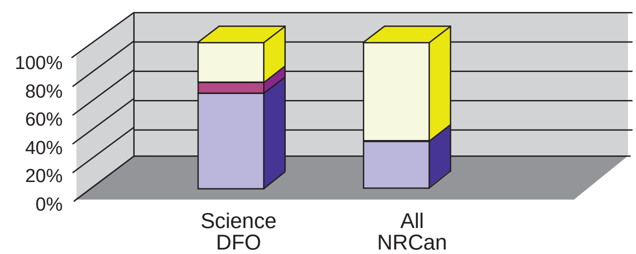
Annual appropriation from government by parliamentary vote



DEPARTMENT	SECTOR	AMOUNT ($000)
DFO	Science	34,605
DFO	Oceans & Env.	3,507
DFO	Informatics	2,565
NRCan	All	10,978

Environment Canada and DND have staff working at BIO. These resources are not captured in the above figures. The DFO Science numbers have increased significantly from 2001 because Marine Environmental Sciences Division moved from Oceans and Environment to Science Branch.

Other sources of funding

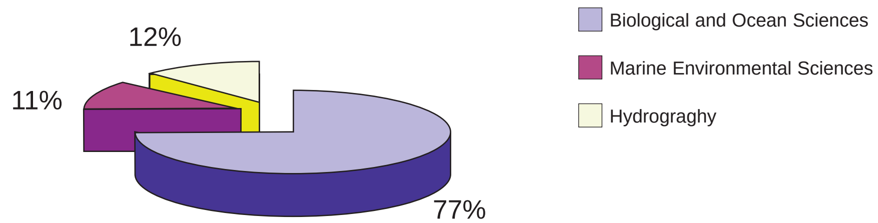


DEPARTMENT	SECTOR	GOVERNMENT ($000)	INSTITUTIONS ($000)	INDUSTRY ($000)
DFO	Science	3,127	321	1,277
NRCan	All	850		2,000

Industry   Institutions   Government

Program spending

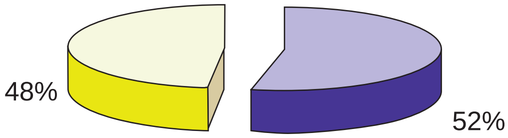
DFO Science



SECTOR	AMOUNT ($000)
Biological and Ocean Sciences	30,353
Marine Environmental Sciences	4,449
Hydrography	4,529

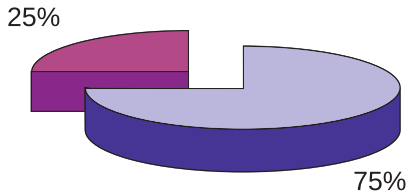
Program spending cont.

DFO Oceans and Environment



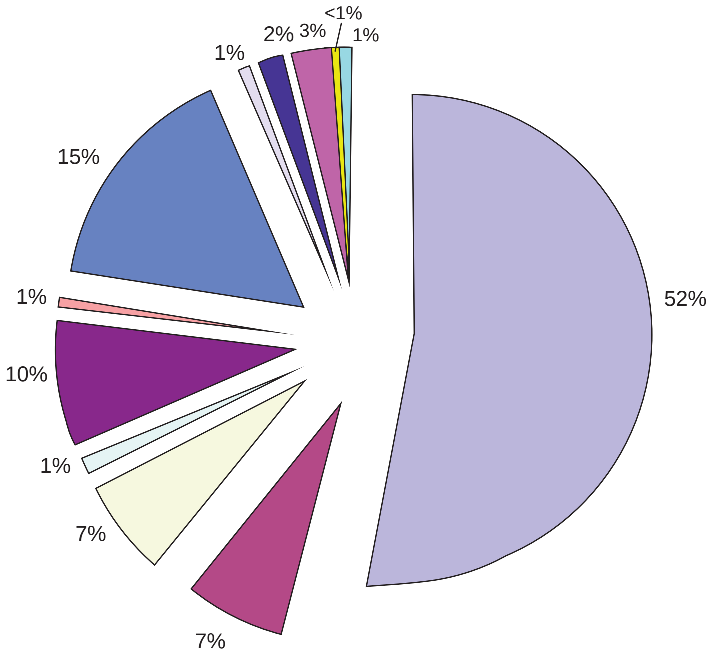
SECTOR	AMOUNT ($000)
Habitat Management	1,820
Oceans	1,687

NRCan



	AMOUNT ($000)
Research	8,233
Technology/Equipment	2,745

BIO staff by department/division



DFO - Science	342
DFO - Oceans & Env.	47
DFO - Informatics	48
DFO - Other	6
DFO - Coast Guard Tech Services	66
DFO - Aquaculture Coordination	5
NRCan - GSC Atlantic	95
EC - Operational Laboratories	5
DND - Survey Office	10
PWGSC - Site Operations	18
Health Canada - Nursing Unit	1
Research Coordination Units	9
Total	652

The numbers are taken from the staff list and do not include contractors, students, visiting scientists, or emeritus scientists. The DFO Science numbers have increased from last year by the transfer of the Marine Environmental Sciences from the Oceans and Environment Branch.

People at BIO in 2002

DEPARTMENT OF NATIONAL DEFENCE

LCdr Robert Smith
Lt(N) Scott Moody
CPO2 Ian Ross
PO1 Wendy Martin
PO2 Ron Clark
PO2 Chris Moncrief
MS Dale Stryker
MS Corey Brayall
MS Krista Ryan
LS Sean Truswell

ENVIRONMENT CANADA

Christopher Craig
Kate Collins, Student
Erland Hart
David MacArthur
Rick McCulloch, Student
Laura O'Connor, Student
Diane Tremblay
Jamie Young

FISHERIES AND OCEANS CANADA

Canadian Coast Guard – Technical Services

Systems Engineering Group
George Steeves, Supervisor
Garon Awalt
Arthur Cosgrove
Kelly Bentham
Bob Ellis
Francis Kelly
Mike LaPierre
Daniel Moffatt
Glen Morton
Neil MacKinnon
Val Pattenden
Todd Peters
Nelson Rice
Greg Siddall
Heinz Wiele

Technical Maintenance
Jim Wilson, Supervisor
Gerry Dease
Don Eisener
Jason Green
David Levy
Robert MacGregor
Richard Malin
Morley Wright
Mike O'Rourke
Mark Robbins

Vessel Support
Andrew Muise, Supervisor
William Butt
Jim Corbin
Stephen Eisener
Kirby Fraser
Jason George
Martin LaFitte
Richard LaPierre
Derick MacAdam
Alan MacLean
Leonard Mombourquette
Richard Myers
Stanley Myers
Steve Myers
Lloyd Oickle
Bill Preston
Harvey Ross
Freeman Savoury*
Raymond Smith
David Usher

Dartmouth Technical Workshop
Paul Mckiel, Supervisor
Lorne Anderson
Bob Brown
Ray Clements
Allen Crowell
Peter Ellis
Milo Ewing
Brian Fleming
Heather Kinrade
Susan Kolesar
Brian LeBlanc
Susan Lever
Pat Lindsay
Andrew Malloy
Doug Murray
John Reid
Tom Roberts
Helmut Samland
Dave Somerton
Mike Szucs
Jonathan Towers
Phil Veinot

Canadian Coast Guard – Central and Arctic, Operational Services

Michelle Brackett

Science Branch

Regional Director's Office
Michael Sinclair, Director
Alyson Campbell, Student
Marie Charlebois-Serdynska
Richard Eisner
Dianne Geddes
Sharon Morgan
Bettyann Power
Carla Sears

Canadian Hydrographic Service (Atlantic)
Richard MacDougall, Director
Bruce Anderson
Stefan Baumgart, Student
Carol Beals
Dave Blaney
Frank Burgess
Bob Burke
Fred Carmichael
Mike Collins
Chris Coolen
Gerard Costello
Andy Craft
John Cunningham
Elizabeth Crux
Tammy Doyle
Theresa Dugas

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2002.
*Retired in 2002.

Helen Dussault
Mike Earle
John Ferguson
Steve Forbes
Claudine Fraser
Doug Frizzle
Jon Griffin
Judy Hammond
Jolette Hannon
James Hanway
Malcolm Jay
Roger Jones
Heather Joyce
Glen King
Mike Lamplugh
Christopher LeBlanc
Kirk MacDonald
Bruce MacGowan
Grant MacLeod
Clare McCarthy
Dave McCarthy
Paul McCarthy
Mark McCracken
Dale Nicholson
Larry Norton
Stephen Nunn
Charlie O'Reilly
Nick Palmer
Richard Palmer
Paul Parks
Stephen Parsons
Ken Paul
Bob Pietrzak
Vicki Randhawa
Doug Regular
Gary Rockwell
Glenn Rodger
Dave Roop
Tom Rowsell
Chris Rozon
Mike Ruxton
Cathy Schipilow
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Greg Perley
Darcy Pettipas
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Michael Thorburne
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Malcolm Webb
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DFD- Gulf Fisheries Center
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Invertebrate Fisheries Division
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Amy Chisholm
Victoria Clayton
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Ron Duggan
Cheryl Frail
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Lea-Anne Henry, Student
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Benedikte Vercaemer
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Maritimes Aquatic Species at Risk Office
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Jerry Conway
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Arran McPherson

Marine Fish Division
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Diane Beanlands

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2002.
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Marjo Laurinolli
Bill MacEachern
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Jeff McRuer
Bob Mohn
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Phil Williams
Bill Wood

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Don Douglas

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Kelly Bezanson
Randy Dickson
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Tammy Heisler
Mark Vickers

OTHERS ON THE BIO CAMPUS

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Venetia Stuart, Executive Scientist

Partnership for Observation of the Global Oceans (POGO)

Shubha Sathyendranath, Executive Director
Tony Payzant

Fishermen and Scientists Research Society (FSRS)

Jeff Graves
Carl MacDonald
Shannon Scott

Centre for Marine Biodiversity

Lorraine Hamilton
Kirsten Querbach

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Mike Belliveau
Graham Standen
Martin Uyesugi

Maritime Tel & Tel

Paul Brown
Tim Conley

Contractors

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Kumiko Azetsu-Scott, Ocean Circulation
Abhi Bhade, Biological Oceanography
Shawna Bourque, CHS & IFD
Heather Breeze, OCMD
Pierre Brien, Marine Fish
Derek Broughton, Marine Fish
Catherine Budgell, Library
Walter Burke, CHS
Clare Carver, Invertebrates
Barbara Corbin, Records
Tania Davignon-Burton, Marine Fish
Mike Friis, Records
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Yuri Geshelin, Ocean Circulation
Patricia Gonzalez, Inverterbrates
Steven Grant, CHS
Bob Hasse, CHS
Gary Henderson, CHS
Karen Hiltz, MESD
Yongcun Hu, Ocean Circulation
Edward Kimball, Ocean Circulation
Weibiao Li, Ocean Circulation
Carrie MacIsaac, CHS
Louise Malloch, Biological Oceanography
Jill Moore, Invertebrates
Lene Mortensen, MIDI
Kee Muschenheim, MESD
Shawn Oakey, Coastal Ocean Sci.
Tim Perry, Biol. Oceanography
Merle Pittman, Ocean Physics
Jeff Potvin, Informatics
Edith Rochon, Library
Sylvie Roy, MESD
Heidi Schaefer, OCMD
Victor Soukhovtsev, Coastal Ocean Sci.
Jacquelyn Spry, Biological Oceanography
Patricia Stoffyn, MESD
David Trudel, CHS
Tineke van der Baaren, Coastal Ocean Sci.
Susan White, Ocean Physics
Wesley White, Diadromous Fish
Alicia Williams, Marine Fish
Inna Yashayaeva, Ocean Circulation
Baoshu Yin, Ocean Circulation

Scientist Emeritus

Piero Ascoli
Dale Buckley
Ray Cranston
Lloyd Dickie
Fred Dobson
Subba Rao Durvasula
Jim Elliott
Ken Freeman
Alan Grant
Peter Hacquebard
Lubomir Jansa
Brian Jessop
Charlotte Keen
Tim Lambert
John Lazier
Mike Lewis
Doug Loring
Brian MacLean
Ken Mann
Clive Mason
Peta Mudie
Charlie Quon
Charlie Ross
Hal Sandstrom
Charles Schafer
Stuart Smith
Shiri Srivastava
James Stewart
John Wade

Recognition

BIO staff wish to recognize the contribution and support provided by the Captains and crew of Canadian Coast Guard vessels tasked to assist BIO-based research.

INDIVIDUALS WHO RETIRED IN 2002

Fisheries and Oceans Canada

Bob Barnes retired in September 2002 after 29 years of service. Bob began his career with DFO in the Fisheries Management Branch (Conservation and Protection Division) as a Fisheries Officer who was enthusiastic and knowledgeable of the job and his geographic area of responsibility. In 1976, Bob took on the role of Field Supervisor in Bridgewater, Nova Scotia. Bob moved to BIO in 1999 to apply his knowledge and skills to Species at Risk issues within the Maritimes Region, and worked with other departments and stakeholders. Bob will be missed by all who have had the pleasure of working with him.

David Currie retired from the Mactaquac Biodiversity Facility, Diadromous Division, in July 2002 after 31 years service. David began his career as a seasonal employee at the Saint John River, Mactaquac Dam, Fish Collection Facility in 1969. In 1980 he transferred to the Mactaquac Fish Culture Station (now Biodiversity Facility) for full-time work as a Hatchery Technician. Following Program Review, he became one of two Hatchery Technical Supervisors who assumed all the technical responsibility formerly held by five technicians. During his last 5 years, David was an integral part of the many technical and operational changes that have converted the former Fish Culture Station into a Biodiversity Facility. We will greatly miss his leadership and technical abilities.

Jim Cuthbert retired from Informatics in July 2002 after 31 years of service. Before joining DFO, Jim spent time at Camp Aldershot as a weapons instructor and was employed with Newfoundland Power. Jim's past training put him in good stead for the role of Operations Manager, a position he held until the phase out of the cyber mainframe in 1993. The following year, Jim spent a short time at DFO Regional Headquarters in Halifax but he decided to return to BIO the following year. Upon his return, Jim assumed the role of network specialist, much to everyone's delight, because he had hand strung most of the network wiring at BIO and knew every wiring closet in the Institute. From paper tape and punch cards, through 40MB hard drives to terabytes of data, from connecting two scientists within BIO, to wirelessly transmitting data to just about anywhere in the world, Jim was the man. Jim will be greatly missed; he and his wife Marg are planning a trip to Scotland and the British Isles.

Brian Jessop retired in April after 32 years of service as a stock assessment biologist within the Diadromous Fish Division. Brian conducted assessments on American eel, alewife, blueback herring, striped bass, American shad, shortnose sturgeon, Atlantic silverside, and inner Bay of Fundy Atlantic salmon. He produced a total of 30 primary (and many more secondary) publications on the biology of these fish. He is widely respected nationally and internationally for his scientific expertise pertaining to the management of these species and was frequently invited by American colleagues to provide input to the formulation of advice and management plans of these fish in the Northeast USA. Fortunately for the Division, Brian has stayed on as emeritus scientist and continues to publish scientific papers. During the finer weather, Brian and wife Carolyn can be found at their newly constructed seasonal home on the Amherst Shore.

On May 22, 2002, **Dr. Donald Lawrence** officially retired after a career of more than 35 years with the Government of Canada. He spent virtually all of his working life in the field of Coastal Ocean Science, where he made field measurements, analyzed data, and dabbled in modelling. His primary contributions were in the field of "operational oceanography". He was a member of the Regional Environmental Emergency Team (REET), and responded to marine emergencies, such as the *Arrow* and *Kurdistan* oil spills in the 1970s. In addition, he helped make some seminal current measurements in Cabot Strait and Halifax Harbour, while in recent years, he became the local expert in data gathering from the ARGOS satellite.

John Loch retired in April 2002 after a career of more than 31 years with the Government of Canada. John started his career at the Freshwater Institute in Winnipeg, Manitoba in 1971 and in 1982 became the Regional Director of the Science Branch of the Gulf Fisheries Center in Moncton, New Brunswick. When the Scotia-Fundy and the Gulf regions were integrated in 1995, John stayed on as the Science Director for the newly formed Maritimes Region. In 1999, after almost 20 years as Science Director, John felt it was time to address other challenges and took on the task of starting the new Species at Risk office at BIO.

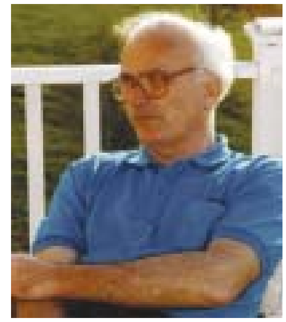
Freeman Savoury retired in August 2002 after 36 of service with the Canadian Coast Guard. During his career, Freeman served as a seaman and leading seaman on several vessels within the Canadian Coast Guard fleet. In the early 1980s, he came ashore to work with the yard and buoy maintenance group at the Dartmouth Coast Guard Base. He subsequently moved into the carpenter shop where he participated in the repair and upkeep of lighthouse stations and aids to navigation towers. In the early 1990s, Freeman became the Group Leader in the carpenter shop and made annual site visits to these locations to assess the requirements for minor repairs and provide input into submissions for funding of larger repairs or upgrade projects. Freeman also contributed significantly in the move of the carpenter shop from the Dartmouth Coast Guard Base to the Bedford Institute of Oceanography in the fall and winter of 2000.

Patti (M. Patricia) Williams retired in September 2002 after 35 years of outstanding service. She began as a term employee with BIO in 1967, moved to DND, and returned to BIO in 1975 to Ocean Circulation, and then to the Director's Office, Atlantic Oceanographic Laboratory in 1978. As office automation arrived, Patti led secretarial staff through the challenges associated with the evolution of these positions towards administrative support. She worked with management in the reorganization of the Ocean Sciences Division and played a major role in the development of the Universal Classification System (UCS) job descriptions within the branch. She was also instrumental in negotiating with management and Corporate Services on behalf of her colleagues on the impacts resulting from added tasks and responsibilities transferred to the division. Patti was a loyal Public Servant; her skills, dedication, and empathy are greatly appreciated by her colleagues, her direct supervisors, and all with whom she worked and interacted.

Natural Resources Canada

Ray Cranston retired in January after 33 years with Natural Resources Canada. An inorganic geochemist, Ray led and contributed to a diversity of domestic and international projects. He was involved in assessing the feasibility of disposal of radioactive waste in the deep oceans; pioneered early climate change research in carbon budgets in the ocean; and partnered with colleagues to assess transport and deposition of anthropogenic sediments in the environment. Ray is now an emeritus scientist at GSC Atlantic and is continuing collaborative research on a CIDA-funded project transferring environmental geochemical techniques to colleagues in Uruguay.

In Memoriam



George Needler.

Bedford Institute of Oceanography lost a colleague, a leader, and a friend with the passing of George Treglohan Needler on 7 June 2002. George joined BIO in 1962 and led its theoretical oceanography group. He also established a strong link to graduate student training by teaching a course in ocean dynamics at Dalhousie University. As a young scientist, he attacked the problem of the thermohaline circulation and made major contributions to the development of ocean 'thermocline' theory. His early interest in the use of tracers for determining ocean circulation led to his participation in the planning and review of the Geochemical Ocean Sections Study (GEOSECS) and the Transient Tracers in the Ocean (TTO) programs of the 1970s and early 1980s. He was especially gifted in bringing scientists together to contribute their knowledge and expertise to collaborative programs and to issues important to society. He chaired both a GESAMP (Group of Experts on the Scientific Aspects of Marine Pollution) working group and an IAEA (International Atomic Energy Agency) committee that provided the scientific basis for these assessments and established dumping limits for low level radioactive wastes in the ocean. He was a member of the steering groups for the GARP Atlantic Tropical Experiment (GATE) in 1974 and for POLYMODE in the late 1970s. As the first director of the International Planning Office for the World Ocean Circulation Experiment (WOCE), he oversaw the development of its Science and Implementation Plans, and since that time has contributed greatly to the planning of its successors, Climate Variability and Predictability (CLIVAR) and the Global Ocean Observing System (GOOS).

George also played important roles in the development of Canadian oceanography. As a founding member of BIO, he helped shape its scientific program. He served as Head, Ocean Circulation Division from 1975 to 1978 and as Director, Atlantic Oceanographic Laboratory from 1978 to 1985. After his return to BIO in 1991, he served on the Canadian Global Change Planning Board and its Research/Policy Committee and facilitated the development of an initial Canadian plan for the Global Ocean Observing System (GOOS).

PUBLICATIONS AND PRODUCTS

Publications 2002

FISHERIES AND OCEANS CANADA - BIO

1) Biological Sciences

Recognized Scientific Journals:

Baechler, J., C.A. Beck, and W.D. Bowen. 2002. Dive shapes reveal temporal changes in the foraging behaviour of different age and sex classes in harbour seals (*Phoca vitulina*). Can. J. Zool. 80: 1569-1577.

Beck, C.A., J. I. McMillan, and W. D. Bowen. 2002. An algorithm to improve geolocation positions using sea surface temperature and diving-depth. Mar. Mamm. Sci. 18: 940-951.

Budge, S., S.J. Iverson, and W.D. Bowen. 2002. Among and within species variability in fatty acid signatures of marine fish and invertebrates on the Scotian Shelf, Georges Bank, and southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 59: 886-898.

Campana, S.E., W. Joyce, L. Marks, L.J. Natanson, N.E. Kohler, C.F. Jensen, J.J. Mello, H.L. Pratt, Jr., and S. Myklevoll. 2002. Population dynamics of the porbeagle in the Northwest Atlantic Ocean. N. Am. J. Fish. Manag. 22: 106-121.

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Comeau, L.A., S.E. Campana, and G.A. Chouinard. 2002. Timing of Atlantic cod (*Gadus morhua)* seasonal migrations in the southern Gulf of St. Lawrence: Interannual variability and proximate control. Int. Counc. Explor. Sea J. Mar. Sci. 59: 333-351.

Freeman, K.R., E. Kenchington, and S.P. MacQuarrie. 2002. Comparative settlement depths of *Mytilus edulis* and *Mytilus trossulus*: I. A mesocosm study. J. Shellfish Res. 21: 59-66.

Halliday, R.G. 2002. A comparison of size selection of Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) by bottom longlines and otter trawls. Fish. Res. 57: 63-73.

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Jessop, B.M., J.-C. Shiao, Y. Iizuka, and W.-N. Tzeng. 2002. Migratory behaviour and habitat use by American eels *Anguilla rostrata* as revealed by otolith microchemistry. Mar. Ecol. Prog. Ser. 233: 217-229.

Joyce, W., S.E. Campana, L.J. Natanson, N.E. Kohler, H.L. Pratt, and C.F. Jensen. 2002. Analysis of stomach contents of the porbeagle shark (*Lamna nasus*) in the Northwest Atlantic. Int. Counc. Explor. Sea J. Mar. Sci. 59: 1263-1269.

Kenchington, E., K.R. Freeman, B. Vercaemer, and B. MacDonald. 2002. Comparative settlement depths of *Mytilus edulis* and *Mytilus trossulus*: II. Field observations. J. Shellfish Res. 21: 67-74.

Kenchington, E., B. MacDonald, L. Cao, D. Tsagkarakis, and E. Zouros. 2002. Genetics of mother-dependent sex-ratio in blue mussels (*Mytilus* spp.) and implications for doubly uniparental inheritance of mitochondrial DNA. Genetics 161: 1579-1588.

Lambert T. C. 2002. Overview of the ecology of the Bras d'Or Lakes with emphasis on the fish. Proc. N.S. Inst. Sci., 42, 65-100.

Manske, M., W.T. Stobo, and C.J. Schwartz. 2002. Estimation of age-specific probabilities of first return and annual survival rates for the male grey seal (*Halichoerus grypus*) on Sable Island from capture-recapture data. Mar. Mamm. Sci. 18: 145-155.

Natanson, L.J., J.J. Mello, and S.E. Campana. 2002. Validated age and growth of the porbeagle shark (*Lamna nasus)* in the western North Atlantic Ocean. Fish. Bull. (Wash. D.C.) 100: 266-278.

O'Reilly, P.T., A.A. McPherson, E. Kenchington, C. Taggart , M.W. Jones, and P. Bentzen. 2002. Isolation and characterization of tetranucleotide microsatellites from Atlantic haddock (*Melanogrammus aeglefinus*). Mar. Biotechnol. 4: 418-422.

Schweigert, F.J., M. Luppertz, and W.T. Stobo. 2002. Fasting and lactation effect fat-soluble vitamin A and E levels in blood and their distribution in tissue of grey seals (*Halichoerus grypus*). Comp. Biochem. Physiol. Part A 131: 901-908.

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[1] Available from Nautical Data International, Inc. at: (http://www.digitalocean.ca).

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