Bedford Institute of Oceanography

2004 in Review

Canada

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Cover photo: CCGS Hudson *engaged in oceanographic research near the* Hibernia *oil platform in the Jeanne d'Arc Basin, 315 km east of St. John's, Newfoundland and Labrador*

Back cover photo: BIO field studies on sea ice

Cat. No. Fs75-104/2004E
ISBN: 0-662-40330-4
ISSN: 1499-9951

Aussi disponible en français

Editor: Judith Ryan

Editorial team: Pat Dennis and Karen Rutherford

Photographs:
BIO Technographics, the authors, and individuals/agencies credited

Design:
Channel Communications, Halifax, Nova Scotia

Published by:
Fisheries and Oceans Canada and Natural Resources Canada
Bedford Institute of Oceanography
1 Challenger Drive, P.O. Box 1006
Dartmouth, Nova Scotia
Canada B2Y 4A2

BIO website address: www.bio.gc.ca

Introduction

The Bedford Institute of Oceanography (BIO) is a major oceanographic research facility, established in 1962 by the Government of Canada and located in Dartmouth, Nova Scotia, on the shores of the Bedford Basin. It has grown to become Canada's largest centre for ocean research. Scientists at BIO perform targeted research, mandated by the Canadian government, to provide advice and support to government decision making on a broad range of ocean issues including sovereignty, defence, environmental protection, health and safety, fisheries, and natural resources. They also undertake environmental planning and oceans management.

Fisheries and Oceans Canada (DFO) is represented by six divisions within its Science Branch including the Canadian Hydrographic Service (CHS), two divisions of the Oceans and Habitat Branch, the Aquaculture Coordination Office, and the Canadian Coast Guard Technical Services for technical and vessel support. Together they provide scientific knowledge and advice on issues related to climate, oceans, the environment, marine and diadromous fish, marine mammals, shellfish, and marine plants. As well, they are responsible for the fish habitat management protection program, environmental assessments, oceans management, and planning initiatives.

Natural Resources Canada (NRCan) is represented by the Geological Survey of Canada - Atlantic (GSC Atlantic), Canada's principal marine geoscience facility. Its scientific research expertise focuses on marine and petroleum geology, geophysics, geochemisty, and geotechnology. GSC Atlantic is also the source of integrated knowledge and advice on Canada's coastal and offshore landmass.

The Route Survey Office of Maritime Forces Atlantic, Department of National Defence (DND), located at BIO, supports ocean surveillance activities. Surveys are conducted in areas of the sea floor of specific interest to DND in cooperation with CHS and GSC Atlantic.

In support of the Canadian Shellfish Sanitation Program, the Shellfish Section of Environment Canada (EC) conducts sanitary and water quality surveys and analyzes the samples at the microbiology laboratory at BIO.

Altogether, approximately 650 scientists, engineers, technicians, managers, support staff, contractors, and others from a variety of disciplines, work at BIO.

This review highlights some of the ongoing research activities at the Institute as well as some of the activities dealing with the management of the oceans.

Bedford Institute of Oceanography with CCGS Hudson.

Message from the Directors

2004 was another year of important contributions to Government of Canada priorities by staff at the Bedford Institute of Oceanography. After several years of research, followed by development of the regulatory framework, the unique canyon called The Gully on the slope of the eastern Scotian Shelf (and its contiguous areas) was declared a Marine Protected Area. This designation provides enhanced conservation for this diverse and important ecosystem. Following the signing in 2003 of the United Nations Convention on the Law of the Sea (UNCLOS), Canada has 10 years to make its claim to the sea floor beyond 200 nautical miles off Atlantic Canada and in the Arctic. To support the preparation of the necessary technical material for the claim, an UNCLOS office has been established at the Institute. Staff at BIO took the lead in preparing the DFO contribution to Canada's plan for the Global Earth Observation System of Systems. The Centre for Offshore Oil and Gas Environmental Research became fully operational, providing research support for this growing industry across the country, with an emphasis on environmental issues. With financial support from partners in the United States, a unique wave tank was installed to conduct research on oil dispersal under a range of wave and temperature conditions. The broader contribution of BIO to oil and gas development off Atlantic Canada is summarized in a feature article of this annual review.

December's catastrophic tsunami off Indonesia generated a global humanitarian response, as well as a gathering of scientific expertise on such issues as early warning systems and coastal erosion. Technical experts from BIO contributed to these efforts. This tragedy highlighted the need to understand Canada's three oceans and their global connections.

The year was important for infrastructure renewal at the Institute. Work has been initiated on the final phase of reconstruction of the Vulcan Building, which comprises the technical shops. In addition, construction of the Level 2 laboratory building was started. This facility will house all of the laboratory work carried out at BIO and will result in an improved working environment for our staff.

2004 was a difficult year for the research fleet. The vessels are old and there was considerable loss of programs due to breakdowns. Modern, well-equipped and -maintained research ships are a crucial requirement for a robust ocean-science program, and the issue of a modern research fleet is the most important challenge facing BIO in the coming years. The Canadian Coast Guard has prepared a long-term plan for fleet renewal, including the scientific research and monitoring component. Implementation of this plan is essential for the future of the Bedford Institute of Oceanography.

The articles in this 2004 Annual Review will give you the flavour of the wide range of work on ocean and coastal issues that is being carried out at the Institute for both Canadians and the international community.

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Maritimes Region, Fisheries and Oceans Canada

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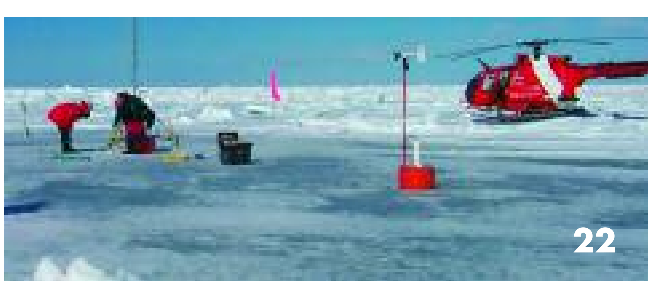

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FINANCIAL AND HUMAN RESOURCES

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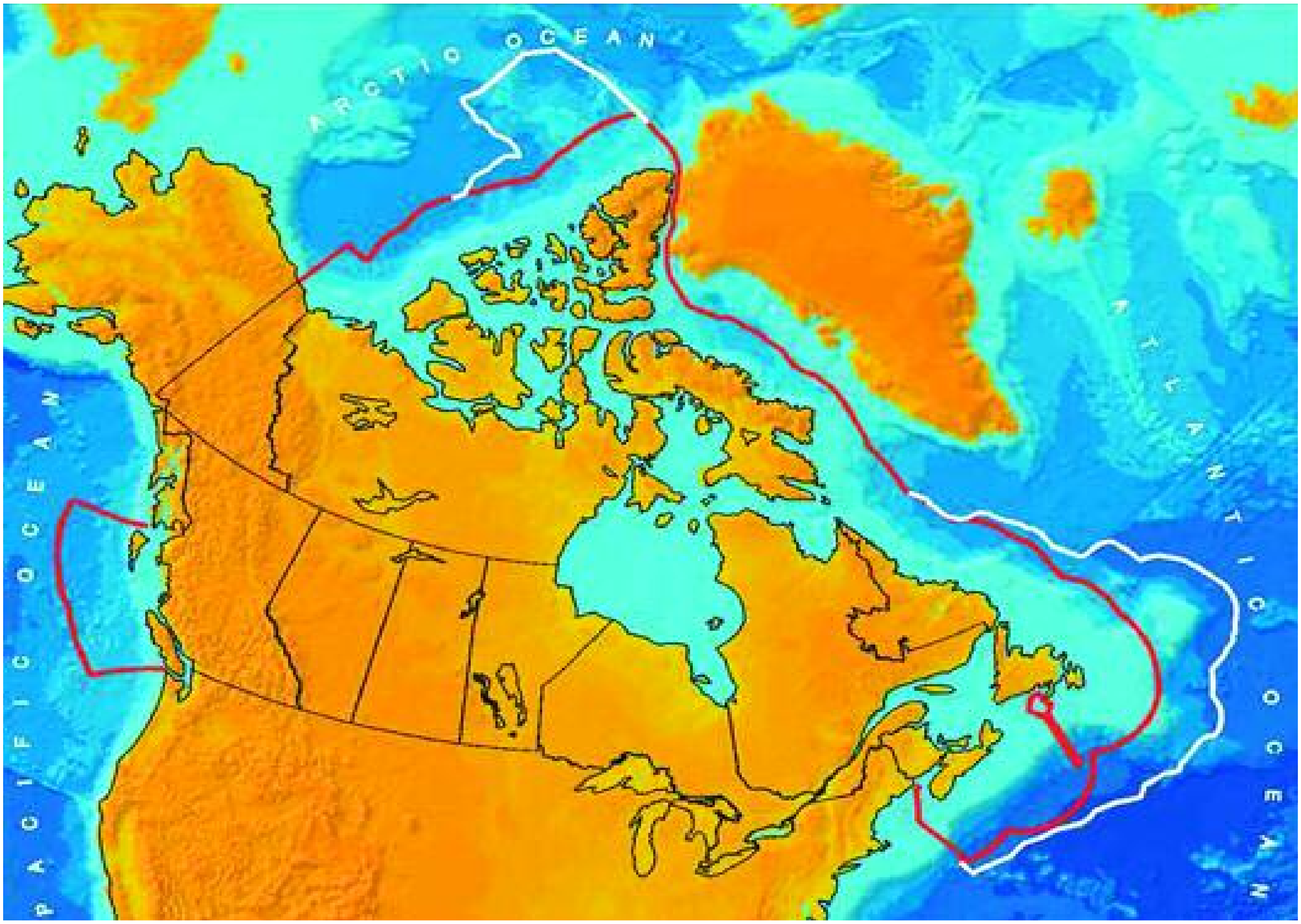
HIGHLIGHTS AND NEW INITIATIVES

Canada ratified the **United Nations Convention on the Law of the Sea (UNCLOS)** in November 2003. Funding for the survey work was provided in the federal budget of February 2004. Canada has until 2013 to submit evidence for a claim to territory on the continental shelf outside the existing 200-nautical-mile Exclusive Economic Zone (EEZ). The UN Commission on the Limits of the Continental Shelf was established to process and review claims from coastal states. The Commission has produced a guidelines document outlining the data to be submitted for a claim. Each nation is required to submit the coordinates of the limit it has delineated, along with the supporting technical and scientific data. A preliminary analysis of existing data has identified areas where new data will be required to substantiate Canada's claim for an extended continental shelf, and plans have been developed to acquire this data. NRCan/Geological Survey of Canada (GSC) and DFO/Canadian Hydrographic Service (CHS) will carry out the mapping and surveying required for Canada to submit a claim under UNCLOS for the Atlantic continental shelf. A successful claim will mean enhanced Canadian control over this area and any mineral and hydrocarbon resources in those areas beyond the customary 200 nm EEZ. Beginning in 2005, Canada will acquire seismic and bathymetric data in strategic areas to support its claim.

The **Oceans Action Plan (OAP)** is one result of the *Oceans Act*



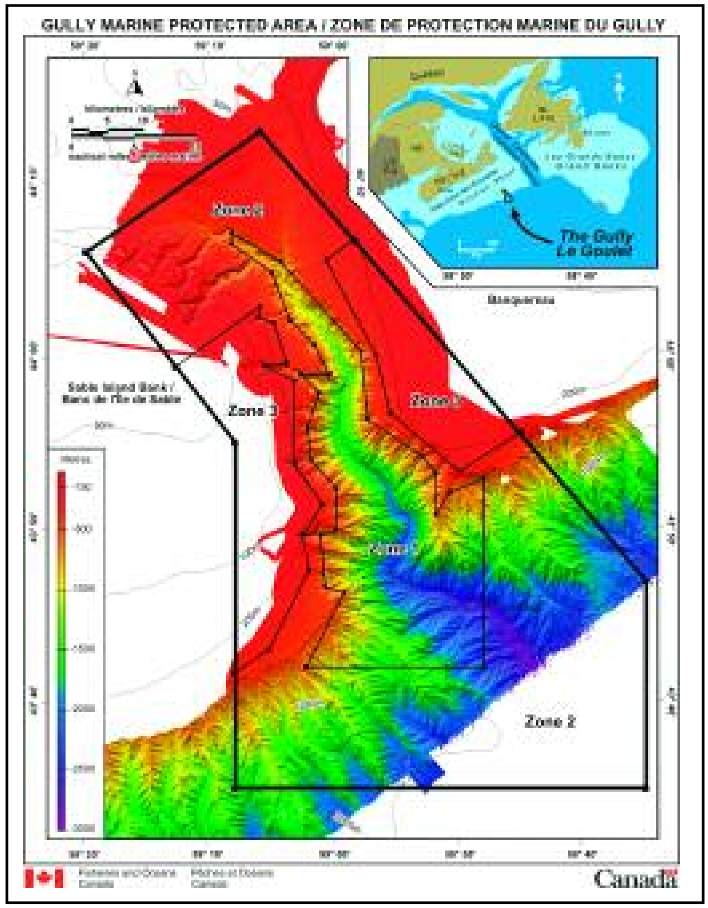
Map shows, in red, Canada's existing jurisdiction under the 200-mile limit, and the potential expansion under UNCLOS, in white. The extended region encompasses an area equivalent in size to Canada's three Prairie Provinces.

of 1997 and the release of *Canada's Oceans Strategy* in 2002. The OAP articulates a government-wide approach and serves as the framework to seize opportunities for sustainable development of our oceans. The Plan is based on four inter-connected pillars: International Leadership, Sovereignty, and Security; Integrated Oceans Management for Sustainable Development; Health of the Oceans; and Science and Technology. The first phase of the plan includes a series of initiatives that will set the foundation for achieving the long-term objectives of the *Oceans Act* and *Canada's Oceans Strategy*. A subsequent phase will broaden the geographic scope of oceans management. BIO will have significant involvement in the OAP as NRCan and the CHS undertake seabed mapping to increase scientific understanding of the physical environment and associated habitats in support of integrated management planning and the identification of marine areas in need of protection.

On January 9, Ellen Kenchington presented the Centre of Marine Biodiversity (CMB) national plan for research on marine biodiversity, entitled ***Three Oceans of Biodiversity***, to the Canadian Conference for Fisheries Research at St. John's, Newfoundland and Labrador. This plan outlines Canada's potential contribution to the global international initiative on the discovery of marine biodiversity, the ***International Census of Marine Life (ICoML)***. The Conference identified the next steps required to implement the plan.

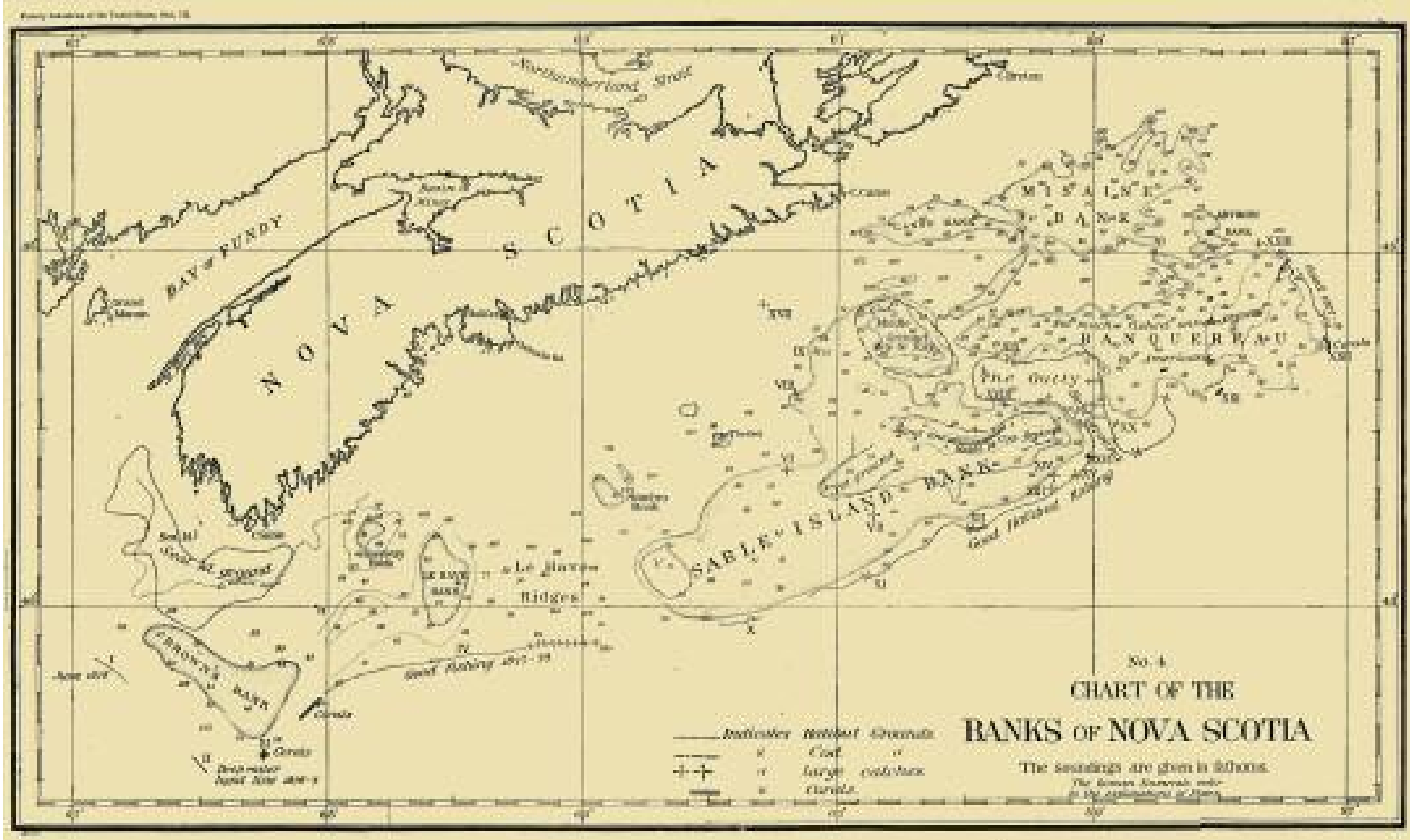
The ICoML continues to be well supported at BIO, particularly their program, **Ocean Biographic Information System (OBIS)**. In 2004, BIO led its Regional OBIS Node initiative, and contributed further to the program by appointing Robert Branton to the Management Committee (OBISMC) chair; hosting the first OBISMC meeting; installing the first regional Distributed Generic Information Retrieval server; and by publishing CMB partner data collections (e.g., Canadian and United States research trawl survey results). BIO's other contributions include the appointment of Robert Branton to the Gulf of Maine Ocean Data Partnership Executive Committee and the formal adoption of the partnership's work plan for 2005.

Beowulf came to BIO in March, when the **Ecosystem Modelling Group** of the Biological Oceanography section of DFO's Ocean Sciences Division (OSD) acquired a **High Performance Computing Linux cluster**, also known as a ***Beowulf cluster***. The initial cluster consists of six compute nodes connected to a master for a total of 14 processors and 14 GB of memory. Although considered modest in the world of supercomputing, this cluster brings to the group the computing power needed for the development and validation of numerical ecosystem models. The interest in such technology resides in its ability to scale up to meet increasing computing demands at a fraction of the cost of equivalent proprietary systems. The cluster moves BIO's numerical modelling community into a new era of computing.



In April, the OSD completed the field phase of a **continental slope moored-measurement program for currents and water-mass variability** on the Halifax line across the Scotian Slope. Current-meter moorings were successfully recovered from three sites, providing multi-year time series going back to June 2000. The program was supported by the federal Panel on Energy Research and Development (PERD), and several oil and gas companies. PERD and Exxon Mobil Canada Ltd. are also supporting the new OSD moored-measurement program for currents and water-mass variability in Orphan Basin on the northeast Newfoundland Slope. Started in June, the program has moorings deployed at five sites across the Labrador and Deep Western Boundary currents.

Spring 2004 saw experiments begin at the **new oil-spill-dispersant wave tank** at BIO. Although the logistical advantages of using chemical oil dispersants over physical recovery methods are clear, concerns over their use remain. Studies are needed to determine factors such as the wave-energy controlling dispersant effectiveness and to address toxicity issues. Controlled studies with the wave tank will provide



1887 chart shows fishing grounds and coral sites including The Gully


Fulmars in The Gully MPA


Redfish or ocean perch at a depth of 451 m near the mouth of The Gully

scientifically-based advice for the development of oil dispersant use guidelines. Led by Dr. Kenneth Lee of the Centre for Offshore Oil and Gas Environmental Research (COOGER) and Dr. Al Venosa of the U.S. Environmental Protection Agency, the oil dispersant research program will bring together experts from universities, other government departments, and the offshore petroleum industry.

In May, regulations were enacted to formally designate **The Gully Marine Protected Area (MPA)** under Canada's *Oceans Act*. The Gully becomes Canada's second *Oceans Act* MPA, and the first in the Atlantic Region. The purpose of the MPA designation is to conserve and protect the natural biological diversity of The Gully and to ensure its long-term health. The Gully MPA comprises 2,364 km^2 and includes the habitat of deep-sea corals and a variety of whale species, including the at-risk northern bottlenose whale. The MPA contains three management zones with varying levels of protection based on the conservation objectives and ecological vulnerability of each zone. Zone 1, comprising the deepest parts of the canyon, is preserved in a near-natural state with full ecosystem protection. Zone 2 imposes strict protection for the canyon head and sides, feeder canyons, and the continental slope. The adjacent sand banks, which are prone to regular natural disturbance, comprise Zone 3. The Gully MPA regulations and accompanying Regulatory Impact Analysis Statement can be found online at: (http://canadagazette.gc.ca/partII/2004/20040519/html/sor112-e.html).

In July, staff from **DND's Route Survey Office** were deployed to Lake Ontario to survey a small area near Kingston **in search of models from the AVRO Arrow project** of the 1950s. Nine models, fired on the end of NIKE Rockets into the lake to check the aerodynamics of the new planes, have never been located. Unfortunately, no models

Minke whale protected in The Gully

The rare Lophelia pertusa *coral - Photo by Pal Mortensen*

Northern bottlenose whale

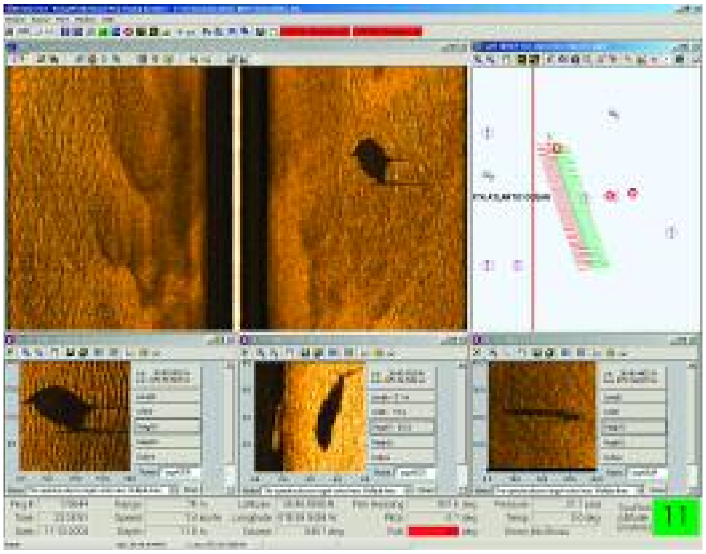
were found during the three days of searching in July, but a 31-metre schooner sitting upright was located during one of the turns. Investigation continues into the schooner's name and why it sank.

Oceans and Habitat Branch worked with the fishing industry and the Resource Management and Science branches of DFO to design a coral conservation area at the mouth of the Laurentian Channel. The **Lophelia Coral Conservation Area** protects a rare, cold-water coral reef complex from bottom-impacting fishing gear. All bottom fishing activities are excluded from the 15-km^2 area. *Lophelia pertusa*, also known as "spider hazards", is a long-lived, slow-growing coral that forms reefs which can support a wide variety of species. The conserved reef represents the only known living occurrence of *Lophelia pertusa* in Canadian waters. The reef is made up of both living and dead coral, and has been damaged by fishing activity over the past few decades. It is hoped that the closure will lead to the eventual recovery of the reef, which could take decades. For more information on the closure, including its co-ordinates, see the press release of August 13, at (http://www.mar.dfo-mpo.gc.ca/communications/maritimes/news04e/NRMAR0414E.html).

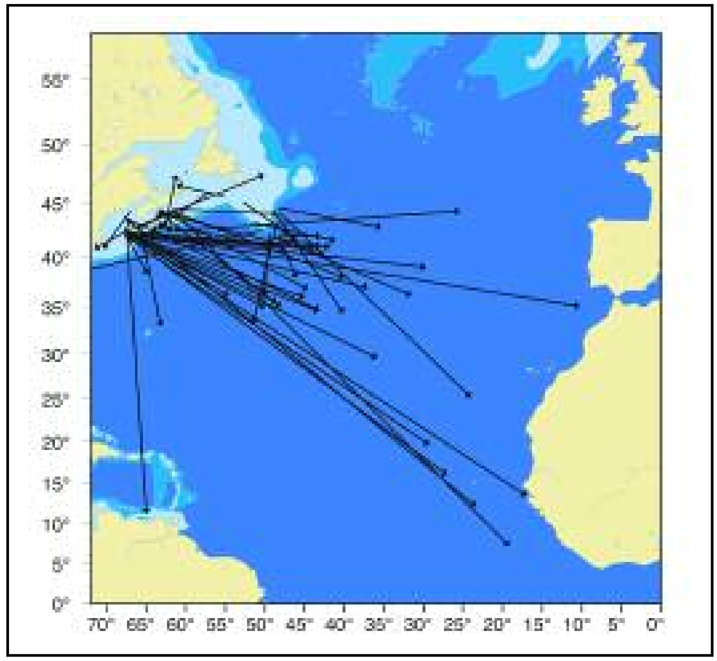
Mystery schooner located by DND's Route Survey Office in Lake Ontario while searching for Avro Arrow models.

Since 1982, surveys conducted on board the CCGS *Alfred Needler* have been the main source of research data used in the annual Groundfish Assessment process. This is true for Marine Fish Division (MFD) scientists in DFO's Maritimes Region as well as the Gulf and Quebec regions. A fire on the *Alfred Needler* in September 2003 damaged the ship extensively and while *Needler* was undergoing repairs, the CCGS *Templeman* and the CCGS *Teleost* from the Newfoundland and Labrador Region undertook the disabled ship's duties. A reduction of the research fleet from three to two trawlers is planned for the near future. A **Comparative Fishing Program** for the three trawlers was planned to begin in July 2004 and extend for two full survey seasons in DFO's four Atlantic Ocean area regions. However, due to delay in delivery of the *Needler*, mechanical problems on both other vessels, and labour disruptions, less than 5% of the expected comparative fishing work was completed. The Comparative Fishing Program, with the *Alfred Needler* and the *Teleost*, will continue in February and March 2005 on Georges Bank and the Eastern Scotian Shelf, and it is hoped will be ongoing into late 2006, to provide enough comparative sets to allow the interchangeability of vessels and data in each region.

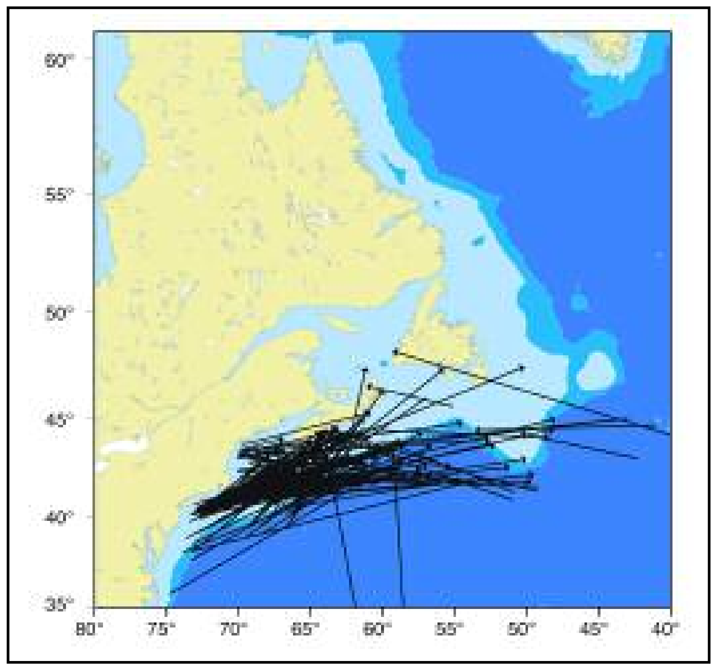
The Gully Seismic Research Program investigated the potential impacts of seismic sound on marine mammals along the Scotian Shelf, including the northern bottlenose whale, a species at risk living in The Gully MPA. The project was conducted in collabora-



Shark imagery taken by side scan sonar during a Route Survey Office exercise off Virginia



Blue sharks tagged during the MFD Shark Research Program



Blue sharks recovered during the MFD Shark Research Program

tion with industry and academic sectors. By monitoring operational seismic surveys, the project provided essential data to validate and improve sound propagation models used in environmental assessments. Results were presented in a public forum in October and will be published in a technical report by the Environmental Studies Research Fund in early 2005.

In November, staff from the **Route Survey Office** embarked in HMCS *Shawinigan* for an exercise off Norfolk, Virginia. The team was involved in **collecting, processing, and producing charts in support of mine warfare**. The charts allowed for a better appreciation of the seafloor. During the exercise a shark was imaged with the side scan sonar.

On November 25, CCGS *Hudson* launched the 1500th profiling float in support of the **International Argo Program**. This marked the achievement of the launch of half of the planned global array of 3000 profiling floats. For the first time, the temperature and salinity of the upper 2000 metres of the ocean are being observed in real time every 10 days. The profiling float, based on a French design, was built by Metocean, a Dartmouth ocean instrument manufacturer.

An interregional, interdepartmental group of scientists from DFO, Environment Canada, National Defence, and academia has spent almost a year planning the development of **a national environmental forecast system** to provide, among other results, a foundation for integrated ocean management and the safe and efficient use of Canada's oceans. The incremental approach comprises two linked streams for ocean forecasting: a basin/global stream to predict conditions in the major ocean basins adjoining Canada, and a nested regional stream, dedicated to forecasting in regional shelf seas and inland waters, including biogeochemical and ecosystem applications. It is anticipated that the final, fully validated coupled ocean-ice-atmosphere forecast system will be linked to global data streams produced by the Canadian Group on Earth Observations System of Systems.

The MFD's **Shark Research Program** prepared the first comprehensive analyses of the status of blue and shortfin mako sharks in the Canadian Atlantic Ocean. These analyses became part of an international effort coordinated by the International Commission for the Conservation of Atlantic Tunas to determine the population health of large sharks in the North Atlantic. The Canadian results indicated that the blue shark population has declined by about 50% over the last ten years.

The OSD now has the results of a 2002 **collaborative field study between the OSD and Swedish scientists**. The study indicates that the freshwater export in the East Greenland Current flowing from the Arctic Ocean is confined close to the Greenland coast. It is apparent that the fresh water is not easily transported to the region of deep convection in the Greenland Sea where it could impact the global thermohaline circulation, potentially creating entirely different climate regimes in North America and Europe. It appears that sea ice is the main source of fresh water to the convection region.

WORKSHOPS AND SPECIAL MEETINGS

The passage in 1997 of Canada's *Oceans Act* began a new era in the management of Canada's ocean resources. In the past, human activities were managed by each ocean industry separately, with little interaction. Today a more holistic approach is being pursued. This is particularly relevant when considering how best to manage the use of, and impacts on, the benthic habitat, in which a number of ocean industries—for example, fisheries, oil and gas, and communications—are involved. In 2001, under the auspices of the Regional Advisory Process (RAP), DFO Science and Oceans and Habitat branches initiated a three-phase approach to outline how DFO should manage impacts on the benthic habitat. Phase 1, conducted in 2001, involved examination of potential classification systems of the benthic habitat. This led to exploration of the classification system proposed by Dr. Richard Southwood, a United Kingdom scientist. Dr. Southwood categorized habitat according to its exposure to physical disturbance and the exposure of organisms living there to physiological stressors. Phase II was initiated in a workshop in January 2004, when Vladimir Kostylev of NRCan presented **a classification of the benthic communities of the Scotian Shelf**, based on the Southwood model, to a RAP meeting of federal and provincial scientists, industry, and NGOs. Dr. Kostylev played a lead role in bringing together information on geology, oceanography, and benthic ecology. This dramatically new way of considering benthic ecosystems stimulated discussion, and the meeting results will be used to conserve diverse sea-floor ecosystems. A second workshop held December 7-9 further explored the concepts and application of the model to the Scotian Shelf. This work is considered innovative and very promising in its capacity to provide a scientific basis for the management of benthic ecosystems, and initial work on phase 3—how best to manage human activities—begins in 2005. (*See **Towards a New Benthic Habitat-Mapping Paradigm**.*)

The first planning meeting for the ***Gulf of Maine Marine Biodiversity Corridor of Discovery***, an initiative of BIO's Centre of Marine Biodiversity (CMB) which will involve several BIO staff in coming years, was held at the St. Andrews Biological Station (SABS) in January. A Corridor of Discovery is tentatively defined as a swath of bottom and the water column above it, encompassing a variety of ecologically interlinked seascapes/habitats that may support a range of biodiversity and may contain previously unknown species and processes. The CMB has articulated a conceptual framework to define the scope of biodiversity study with the objective of undertaking, within five to ten years, as complete an inventory as possible of species and seascapes within a "proof of concept" corridor. Such an initiative would provide a focus for additional objectives, including: critical training in systematics, biodiversity education, and outreach (including data sharing), and a monitoring program related to long-term change. The Gulf of Maine was chosen for the pilot because of international, trans-boundary involvement; the variety of biogeographic regions, diverse habitats, and gradients; access to deep-water habitats relatively close to shore; and inclusion of both well- and poorly-known areas.

The workshop, **Environmental Studies for Sustainable Aquaculture**, was held at BIO, January 27-29. The workshop marked the completion of a three-year project that involved scientists from three DFO regions at study sites associated with concentrations of aquaculture activity—Baie d'Espoir (Newfoundland and Labrador); Letang Inlet (New Brunswick); and the Broughton Archipelago (British Columbia). Led by Maritimes Region scientists, the project evaluated the bay-wide impacts of extensive salmon aquaculture on environmental quality. The research results will be used to assist the industry in evaluating management options, and DFO Habitat Management in monitoring and regulating the industry.

NRCan hosted the **Geoscience for Ocean Management (GOM) Workshop** at BIO, February 4-6, to present an overview of current work in the program, to solicit feedback from stakeholders, and to identify both emerging and lower priority issues. The 125 attendees included representatives from other government departments, industry, and academia. The meeting identified new opportunities that will be pursued to strengthen the program as it evolves.

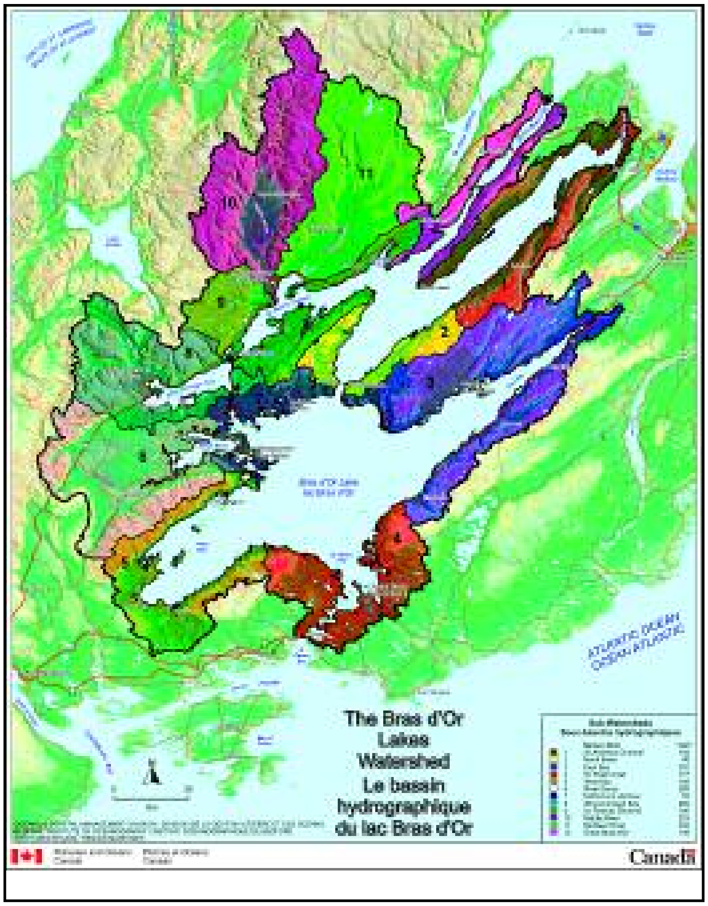
The DFO Oceans and Coastal Management Division (OCMD) hosted the **Junior Shorekeepers Workshop** at BIO, March 23-25. The workshop provided a group of 15 local teachers, NGO representatives, and government employees, with training on local habitats, intertidal species, physical measurement techniques, and conducting surveys. In the Halifax area, several surveys by school and university students were completed between June and August. The Junior Shorekeepers protocol was also presented at the 1st annual community-based Environmental Monitoring Network, held at Saint Mary's University on June 21.

More than 25 delegates representing 12 member countries of the **International Council for the Exploration of the Sea (ICES) Working Group on North Atlantic Salmon (WGNAS)** met at BIO March 29-April 8. The WGNAS meets annually to address questions relating to the status of Atlantic salmon in the North American, North-east Atlantic and West Greenland Commission areas. These questions are posed by the North Atlantic Salmon Conservation Organization. Participants also took in several Women's World Hockey Championship games and toured the DFO Coldbrook Biodiversity facility and Nova Scotia Power's new Whiterock fish passage facility. The WGNAS report is available on (www.ices.dk).

On April 19-20, a **Canada-United States meeting to discuss mitigation for acid rain impacts on Atlantic salmon** and their habitat was held at St. Andrews, New Brunswick under the aegis of the BIO-based Diadromous Fish Division and the Atlantic Salmon Federation. The freshwater habitats of Atlantic salmon within Maine and the Maritime Provinces—Nova Scotia, in particular—are deleteriously impacted by acid rain. This workshop was held in response to increasing interest by stakeholders and the governments of Canada and the United States in considering jointly the causes, effects, and mitigation options for acid rain.

The second **SIMBOL (Science for Integrated Management of the Bras d'Or Lakes) Progress Review** was held in Whycocomagh on April 22. BIO staff from Coastal Ocean Science, a section within DFO's Ocean Sciences Division (OSD), played a lead role at the workshop. Since the 2001 Progress Review, much has been accomplished by DFO and their First Nations partners in this continuous planning process in which stakeholders and regulators reach general agreement on the best mix of conservation, sustainable resource use, and economic development. This review provided an opportunity to present the results of the multi-disciplinary science program to interested Cape Breton communities. The event closed with a discussion of future SIMBOL activities.

On October 7-8, more than 150 people gathered at the Wagmatcook Culture and Heritage Centre at the Wagmatcook First Nation for the **Second Bras d'Or Lakes Collaborative Environmental Planning Initiative (CEPI) Workshop**. Hosted by



the Unima'ki Institute of Natural Resources in conjunction with the Integrative Health and Healing Project, the workshop was a follow-up to the 2003 gathering and was designed to engage citizens and government in the process of planning for the Bras d'Or Lakes ecosystem. Participants developed a vision for a healthy, sustainable Bras d'Or; examined present environmental conditions; identified areas of emphasis; developed specific objectives for the planning process; and provided advice including 13 recommendations for moving the initiative forward. The objectives represent a major milestone in the development of the CEPI and will provide direction for the further development of the plan. The OCMD supports and facilitates this collaborative initiative, which is being pursued as a Coastal Management Area under the *Oceans Act*.

NRCan hosted "**Geology Rocks**", the 10th anniversary of the **Nova Scotia EdGEO Workshop Program**, at BIO, August 23-25. Thirty-three teachers from schools across the province were immersed in three days of interactive learning through hands-on activities and field trips. The workshop's narrative thread was based on the geological history of Nova Scotia: the first two days focused on rocks and minerals, fossils, and geological time, while the third day offered choices among concurrent sessions on plate tectonics, soil, climate change, and offshore oil and gas. EdGEO, a national program that supports local workshops on earth science for Canadian teachers, is co-ordinated by the Canadian Geoscience Education Network of the Canadian Geoscience Council, and funded by various Earth Science-related associations. The workshops aim to cultivate a heightened awareness and appreciation of our planet by providing educators with enhanced knowledge and classroom resources.

Michael Sinclair co-chaired **a national workshop on marine biodiversity** in Ottawa, October 29-31. Sponsored by DFO, NSERC, and the Alfred P. Sloan Foundation Census of Marine Life (CoML) program, the prime objective of the workshop, which was attended by many of Canada's leading university researchers on marine ecology, was to develop a research outline that would implement the national plan ***Three Oceans of Biodiversity*** (co-ordinated by Ellen Kenchington at BIO), and would lead to a funding strategy. The resulting program will be part of Canada's contribution to the CoML.

The Eastern Scotian Shelf Integrated Management (ESSIM) Planning Office organized a **workshop** to discuss **coral conservation on the Scotian Shelf and Slope**. Held in late October, the workshop was to develop content for a **Coral Conservation Plan** for the Scotian Shelf, with the aim of publicly releasing the Plan in 2005.

EdGeo Workshop group

The workshop focused on the components of a coral conservation strategy (including the overall goals for coral conservation) with in-depth discussion of research needs, particularly the effectiveness of existing management strategies. A summary of the workshop is available from the ESSIM Planning Office, which is located with the OCMD at BIO (essim@mar.dfo-mpo.gc.ca).

In response to recommendations from participants at the 1st and 2nd ESSIM Forum Workshops, in November the ESSIM Planning Office held **workshops to expand opportunities for stakeholder participation in the ESSIM Initiative**. Community workshops held in Liverpool, Ship Harbour, and Port Hawkesbury provided opportunities for coastal communities and other interested parties to learn more about the ESSIM Initiative and to provide input to the future integrated ocean management plan. Each workshop consisted of a series of presentations on key aspects of the plan and the planning process, followed by questions, feedback, and discussion. The proceedings will be available from the OCMD early in 2005.

The OCMD's **ESSIM Planning Office** hosted a **Human Use Objectives Workshop** on December 1-2, to further develop social, economic, and institutional objectives and indicators to complement the ecosystem objectives in the ESSIM Plan. This workshop, involving 40 government managers, industry and academic/technical experts, and NGO representatives, built on the earlier work of a multi-stakeholder working group. The workshop report, available in January 2005, will comprise a core element of the objectives-based management framework in the ESSIM Plan.

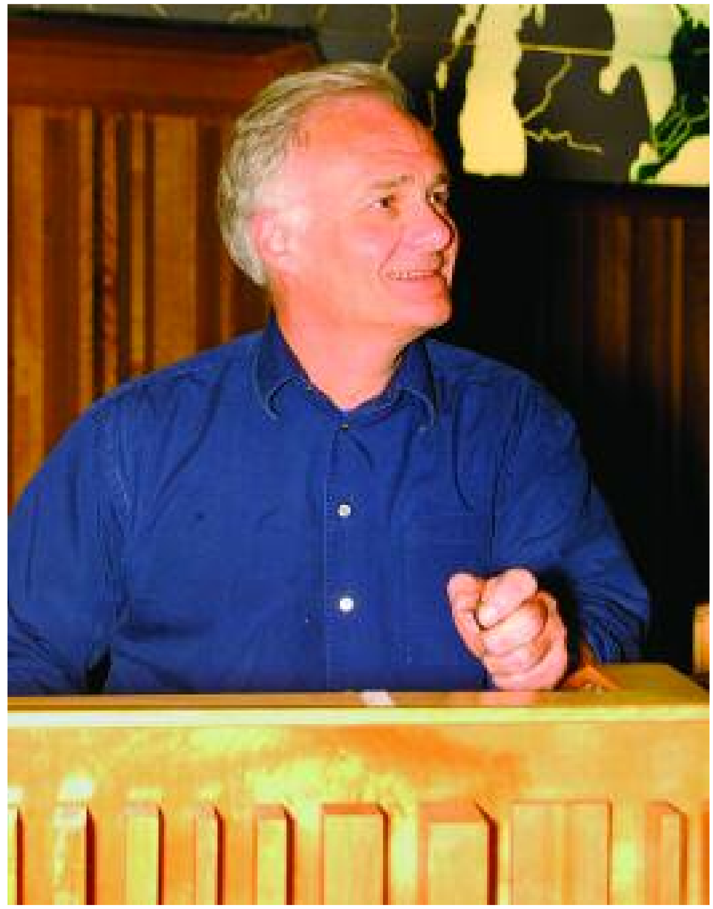
Chaired by Alida Bundy of the Marine Fish Division, **a panel discussion** on **Ecosystem Based Management** was held at BIO on November 24. Presentations were made by Howard Browman of the Institute of Marine Research, Norway, and Bob O'Boyle and Don Bowen of DFO.

A **DFO year-end media event** took place at BIO on December 9. DFO Science Branch presented research at BIO on climate change with an emphasis on the Labrador Sea and Arctic oceanographic studies. Oceans and Habitat Branch provided an overview of oceans management highlights of the year, while DFO Regional Office provided a summary of the performance of fisheries in Scotia Fundy Region.

SPEAKERS AND SEMINARS

On April 1, the Centre for Offshore Oil and Gas Environmental Research, in association with Petroleum Research Atlantic Canada, hosted a presentation at BIO by **Per Gerhard Grini**, General Manager of OG21 (Oil and Gas in the 21st Century), entitled ***Norway's Petroleum R&D Investment Strategy: Environmental and Regulatory Considerations on the Norwegian Continental Shelf***. OG21 is a Norwegian task force developing knowledge and technology to ensure economic and environmentally sound development of the resources on the Norwegian Continental Shelf and to strengthen their industry's global competitive advantage.

Dr. Charles Mayo, Director, Disentanglement Program and Right Whale Habitat Studies at the Center for Coastal Studies in Provincetown, Massachusetts, gave a lecture entitled ***Foraging Ecology of Right Whales: Prey Selection and Strategies*** on April 6. The Center for Coastal Studies focuses on marine mammals and Dr. Mayo has been involved in several successful attempts to free entangled whales.



Dr. Rob Macdonald

Speaker Series

The **BIO Seminar Series** provides 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. During 2004, the Seminar Series featured the following seminars:

***New Directions in Seafloor Mapping and Data Visualization* - Dr. Larry Mayer**, Center for Coastal and Ocean/Joint Hydrographic Center, University of New Hampshire

***Contaminants, Pathways, and Change: The Arctic as a Case Study* - Dr. Rob Macdonald**, Institute of Ocean Sciences, DFO, Sidney, British Columbia

***Hurricane Juan: An Overview of the Meteorology and Oceanography* - Peter Bowyer**, Canadian Hurricane Centre, Environment Canada and **Dr. Will Perrie**, Ocean Sciences Division, DFO

Several groups within BIO sponsor different **speaker series**. These provide a forum for sharing BIO science among colleagues, and often feature outside experts speaking on ocean-related topics. Following are the series with visiting speakers during 2004.

Centre for Marine Biodiversity (CMB) Seminars:

The CMB invites scientists whose research in fisheries, marine ecology, physical oceanography, and related sciences will enhance our knowledge towards the protection of marine biodiversity.

Deep Impact: The Rising Toll of Fishing in the Deep Sea - **Professor Callum M. Roberts**, Environment Department, University of York, England

Benefits beyond Boundaries: The Fishery Effects of Marine Reserves - **Professor Callum M. Roberts**

From Lophelia Reefs to Carbonate Mounds: Understanding Cold-water Coral Reefs - **J. Murray Roberts**, Scottish Association for Marine Science, Dunstaffnage Marine Laboratory, Oban, Scotland

When is it Good Business to Protect Biodiversity and Nature's Services? - **Dr. Peter Kareiva**, Lead Scientist for the Pacific Western Conservation Society, Seattle, Washington

Selecting a Future for Pacific Salmon: Hard Choices and Easy Science - **Dr. Peter Kareiva**

Sponge Reefs on the Western Canadian Continental Shelf: Jurassic Park - **Dr. Kim W. Conway**, Geological Survey of Canada (Pacific), **Dr. Manfred Krautter**, University of Stuttgart, Germany

Changes in the Structure of the Georges Bank Ecosystem - **Dr. Michael J. Fogarty**, National Oceanographic and Atmospheric Association, Woods Hole, Massachusetts

GSC Mud Club:

Mud Club provides an informal opportunity to present findings in marine geoscience by showcasing GSC and DFO research.

Submerging Coasts: the Effects of Rising Sea Level on Coastal Environments - **Professor Eric C.F. Bird**, the University of Melbourne, Australia

A New Geologic Time Scale, with Special Reference to Cretaceous and Cenozoic - **Felix M. Gradstein**, Geological Museum, University of Oslo

Oceans Seminars:

DFO's Oceans and Coastal Management Division organized three **Oceans Seminars** by Australian visitors during 2004.

How Biophysical and Socio-economic Perspectives of Scale and Boundaries in Space and Time may Structure Approaches to Managing Marine Ecosystems - **Richard Kenchington**, Visiting Professor, Maritime Policy Centre, University of Wollongong

Re-zoning Process at the Great Barrier Reef Marine Park: Lessons Learned - **Jon Day**, Director for Conservation, Biodiversity, and World Heritage, Great Barrier Reef Marine Park Authority

Offshore MPAs: The Opportunities and the Challenges - **Peter Taylor**, Director of MPA Development, Department of Environment and Heritage, Canberra

Harvest Fisheries Seminar Series:

The **Harvest Fisheries Seminar Series** began in 2002 and is co-hosted by the Marine, Invertebrate, and Diadromous Fish divisions. The primary purpose is to provide an opportunity to exchange ideas and to hear about research within BIO, as well as research at other institutions. Particularly, staff who will be speaking outside BIO are encouraged to give their presentations at the Institute. The program also features speakers from local universities and visiting researchers:

Marine Biodiversity: A Framework for Inventory and Conservation - **Dr. John Roff**, Canada Research Chair, Environment and Conservation, Acadia University

Mating Systems and the Conservation of Commercially Exploited Species - **Dr. Sheryllyne Rowe**, NSERC Postdoctoral Fellow, Biology Department, Dalhousie University

DNA gets its Teeth into Beaked Whales: Species Identity and Evolutionary Relationships among the Least Known of Cetaceans - **Dr. Merel Dalebout**, Killam postdoctoral fellow, Biology Department, Dalhousie University

Why did Northern Cod off Newfoundland Collapse? - **Dr. Ussif Rashid Sumaila**, Fisheries Economics Research Unit, Fisheries Centre, University of British Columbia

Linking the Internal and External Ecologies of Marine Organisms: Practical Contributions of Sensory Biology to Marine Ecology and Aquaculture - **Dr. Howard Browman**, Principal Research Scientist, Institute of Marine Research, Norway

Ocean Science Division (OSD) Coffee Talks:

The **OSD Coffee Talks** are weekly seminars covering topics in physical, chemical, and biological oceanography. The series provides a forum for both local scientists and visitors.

Plankton and Climate Change: The Continuous Plankton Recorder Survey - **Dr. Chris Reid**, Sir Alister Hardy Foundation for Ocean Science, Plymouth, England

Evidence of Wintertime Subduction at the Subpolar Front of the Japan/East Sea - **Dr. Craig Lee**, University of Washington

Mixed Region Collapse at a Thermocline - **Dr. Bruce Sutherland**, University of Alberta

Recent Development in Ocean Wave Dynamics - **Dr. Don Resio**, United States Army Corps of Engineers

Introduction of a 1-D Coupled Atmosphere-Ocean-Biogeochemical Model: A Canadian SOLAS Project - **Dr. Nadja Steiner**, Canadian Centre for Climate Modelling and Analysis, Environment Canada and the University of Victoria

A Wetting and Drying Scheme for the Princeton Ocean Model - **Dr. Leo Oey**, Princeton University

VISITORS

Derek Hatfield visited BIO on February 16, guest of the Canadian Hydrographic Service. His visit provided an opportunity for staff to hear of his adventures in the ***Around Alone*** race. Derek built and single-handedly sailed his boat, the *Spirit of Canada*, more than 28,700 nautical miles, to complete what has been called "the greatest physical and mental challenge in any sport". He left New York in September 2002 and crossed the finish line at Newport, Rhode Island, on May 31, 2003. During a gale off Cape Horn, Derek was pitched into the frigid ocean and his boat suffered severe damage requiring four weeks of repairs in Argentina, but Derek still managed to achieve 3rd overall in Class II while the *Spirit of Canada* was the fastest 40-foot boat.

Derek Hatfield is shown on his boat, the Spirit of Canada. *Photo by Hal Davies*

Admiral Glen Davidson, Commander of Maritime Command Atlantic, visited on March 3. He was given an overview of the BIO research programs that are of interest to DND and the important collaborative efforts involving the Route Survey Office at BIO.

On March 16, a segment of the film, ***River King***, was shot on the third floor Van Steenburgh building. The film crew spent the day in Ken Lee's lab which, in the movie, represents a forensics lab. Several BIO staff assisted in easing issues related to the filming, the lab, and the 50-member crew.

Public Works and Government Services Minister Reg Alcock visited BIO on April 13. He had visited the Institute as a student at Dalhousie University and was interested to return. Minister Alcock supported the new construction planned for 2004 but under review by the incoming government. Construction on the new laboratory did begin in the autumn.

A group of **15 Foreign Service Officers** (FSOs) visited BIO on April 22. FSOs are with the Department of Foreign Affairs and are assigned to Canadian embassies around the world. BIO scientists gave presentations on Integrated Oceans Management including progress on the Eastern Scotian Shelf Integrated Management and the Canadian approach to Integrated Management, new technologies being used to map and classify the ocean bottom, use of Marine Protected Areas, and Ecosystem Status Reports. The FSOs were particularly interested in the trade and policy implications of BIO research and management activities.

Biologist Trevor Goff points out a tagged Living Gene Bank fish from the endangered inner Bay of Fundy Atlantic salmon population to Fisheries Minister Geoff Regan (right) and Tobique-Mactaquac MP Andy Savoy (left).

Leonard Hill, the US Consul General in Halifax, toured the Institute on May 26 with BIO Director Michael Sinclair and Richard Eisner.

Students and staff of the **International Oceans Institute** (IOI) toured BIO on Oceans Day, June 10. The IOI focuses on the peaceful and sustainable uses of oceans and coasts. Canada's IOI is located at Dalhousie University, where training programs relating to ocean governance are offered for the benefit of coastal communities.

On September 14, the **Honourable Geoff Regan**, Minister of Fisheries and Oceans, visited and received an overview of the Institute's science programs. Bob O'Boyle, Associate Science Director and Coordinator of the Regional Advisory Process, led a discussion on BIO's support of ongoing efforts on integrated oceans management, including science support for environmental assessment (with Ken Lee) and the status of the Scotian Shelf ecosystem (with Ken Frank). A short walkabout followed the discussions, first to the Ocean Circulation Division, where John Loder, Allyn Clarke, Charles Hannah, and others discussed climate change science, earth observations, and coupled oceanographic modelling, then to the Depot where Michel Mitchell and Alex Herman presented some of the Institute's innovation and commercialization of oceanographic instrumentation. The next day Minister Regan learned of the activities of the Diadromous Fish Division (DFD) at BIO when he toured their satellite operation, the **Mactaquac Biodiversity Facility**, for an overview of the Captive Broodstock Rearing and Living Gene Bank programs for Atlantic salmon.

A **French diplomatic party** visited BIO on December 7. **Odile Jouanneau**, wife of the French ambassador to Canada and a project engineer with the Centre national de la recherche scientifiques; **Jean Sarrazin**, Advisor for Science and Technology at the Embassy in Ottawa; and **Claire LaPeyne**, the cultural attaché with the General Consulate in Moncton and Halifax, were given a tour of the Institute by René Lavoie.

Dr. Yvan Hardy, Chief Scientist at Natural Resources Canada, presents Dr. Kenneth Lee (right) with the FPTT Leadership in Technology Transfer Award.

Dr. Brian Petrie accepts the 2004 J.P. Tully Medal in Oceanography. Photo courtesy of the Canadian Meteorology and Oceanographic Society

AWARDS AND HONOURS

Steven Campana of the Marine Fish Division was presented with the **Lifetime Achievement Award** at the ***Third International Symposium on Fish Otolith Research and Application*** in Townsville, Australia. The symposium's Steering Committee presents the award every five years to recognize individuals for outstanding international contributions to otolith science. Dr. Campana was selected for his research advances in fish-age determination and stock identification.

The **Federal Partners in Technology Transfer (FPTT) Leadership in Technology Transfer Award** honours a federal employee whose creativity and exemplary leadership have strengthened government's capacity to transfer technology or knowledge from federal laboratories to those who are able to exploit it most effectively. **Dr. Kenneth Lee**, Executive Director of the Centre for Offshore Oil and Gas Environmental Research, received the 2004 award for his leadership in the development and transfer of innovative technologies and strategies to alleviate the damage of oil spills and enhance recovery of the natural habitat.

Dr. Brian Petrie was awarded the 2004 **J.P. Tully Medal in Oceanography** for his outstanding contributions to oceanography in Canada. His early research led to a clearer dynamical understanding of important physical processes in the coastal ocean; more recently, his collaborative work in monitoring and interpreting the variability of marine ecosytems has led to significant breakthroughs in understanding long-term changes and regime shifts. The medal is awarded annually by the Canadian Meteorology and Oceanographic Society.

Beth Lenentine, Assistant Biodiversity Facility Co-ordinator at the Diadromous Fish Division's Coldbrook Biodiversity Facility, was one of 16 employees nationally chosen to highlight the importance of people who work at DFO, in a ***Real Life DFO feature*** of the department's Strategic Plan. The feature will include her picture with a short description of her job of maintaining a Living Gene Bank of the endangered inner Bay of Fundy Atlantic salmon.

Beluga Award winner, Dr. David McKeown

The **Oceans Association 2004 Beluga Award** was given to **Dr. David McKeown** in recognition of his many innovative engineering developments in both hydrographic and oceanographic research during his 35 years at BIO.

The display area outside the cafeteria provides an opportunity for BIO scientists to showcase their work. Displays are changed monthly, and at year-end the submissions are judged for the **BIO Science Display Award** by a committee representative of all participating groups. Presentations are judged on visual impact, communication value, and science promotion value, among other factors. The yearly winner receives a small trophy, and both first- and second-place finishers receive gift certificates to a local restaurant. NRCan's **Geological Survey of Canada** was the winner of the 2003-2004 award for ***Co-operative Geological Mapping Strategies Across Canada***. **Simon Hanmer**, **Jennifer Bates**, **Rob Fensome**, **Bill MacMillan**, **Phil O'Regan**, and **Graham Williams** were the authors of the display.

Unama'ki Scholarship ceremony:

From left, back: Dr. René Lavoie, DFO; Dr. Michael Sinclair, DFO; Shelley Denny, Unama'ki Institute of Natural Resources; Dr. Tom Traves, President, Dalhousie University; Dr. Bernie Boudreau, Chair, Dalhousie Department of Oceanography; Dr. Gary Bugden, DFO; Dr. Jan Kwak, Dalhousie Dean of Graduate Studies. Front: Shauna Barrington, 2003 Scholarship winner; Erin Breen and Dr. Anna Metaxas, 2004 Unama'ki Scholarship winners, Dalhousie Department of Oceanography
Photo by Daniel Labrie, Dalhousie University

BIO Director, Michael Sinclair (left), with Science Display Award winners: Jennifer Bates, Rob Fensome, and Graham Williams

Integrated Management of Our Watershed/Habitat won second place. This was created through a partnership between **DFO's Habitat Management Division** and **Stewardship and Science Liaison Unit**. Both the Gulf and Maritimes regions of DFO had input, and information from across Canada was shared.

The **DFO Marine Environmental Sciences** group of **Lene Buhl-Mortensen**, **Derek Davis**, **Ursula Grigg**, **Kevin MacIsaac**, **Leslie Pezzack**, and **Elizabeth Vardy** received Honourable Mention for ***Marine Invertebrate Diversity Initiative: Amphipod Workshop 2003***.

The recipients of the **Unama'ki-Fisheries and Oceans Scholarship for 2004-2005** were Dalhousie University professor **Anna Metaxas** and student **Erin Breen** for their project, ***Patterns in Colonization of the Alien Green Crabs in the Bras d'Or Lakes and Consequences for Native Decapods***. The scholarship is awarded jointly by DFO and the Unama'ki Institute of Natural Resources to a Dalhousie team of a graduate student and a faculty member judged to have submitted the best proposal for a graduate research project on a topic related to the natural resources of Cape Breton Island in general and the Bras d'Or Lakes in particular. The researchers undertake to mentor and include in their research activities a high school student from one of the Cape Breton First Nations.

The **Government of Canada Workplace Charitable Campaign 2004** recognized BIO with two **Sunny Awards**; these honour exemplary contributions to the annual campaign. **Rhonda Coll**, DFO Account Executive for 2003 and 2004, was named Female Account Executive of the Year. NRCan, led by Account Executive **Maureen MacDonald**, received a Sunny Award for the best special fundraising events. (*See* ***Community Assistance in 2004***.)

Fisheries and Oceans Canada Awards

The **DFO Distinction Award** is granted to an employee for outstanding achievements and contributions that further the objectives of the department and/or the Public Service. It is based on excellence in service delivery; valuing and supporting people; and values, ethics, and excellence in policy and/or science. The best, most exemplary contributions to DFO among the Distinction Award winners are further honoured with the **Deputy Minister (DM's) Prix d'Excellence**.

DM's Prix d'Excellence:

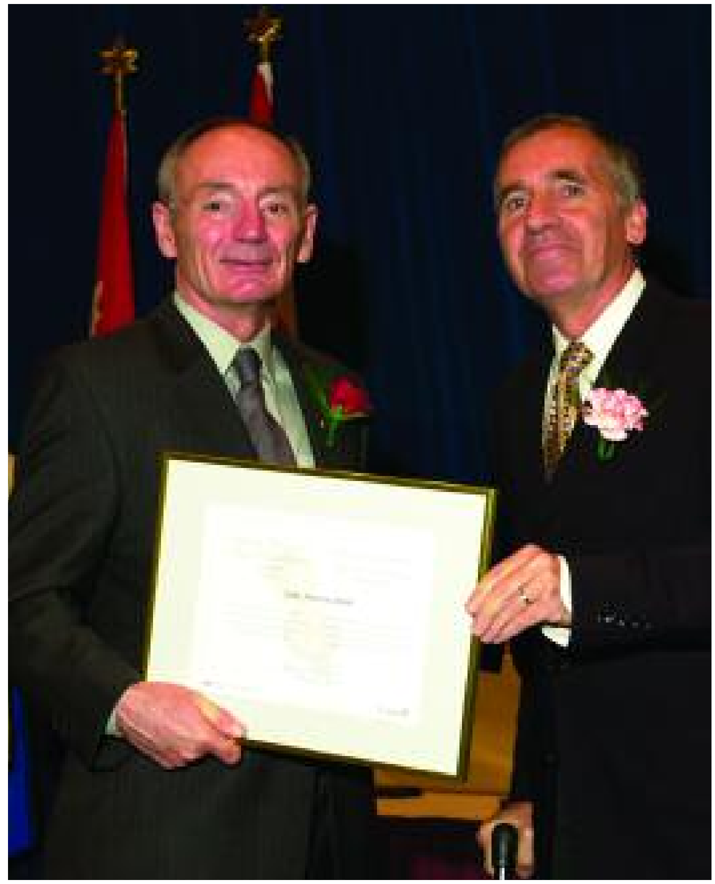
Since 1981, **Dr. Ginette Robert** of the Invertebrate Fish Division has conducted research and produced annual surveys of Scotian Shelf and Georges Bank scallop stocks. She has distinguished herself and DFO by providing excellence in client satisfaction, working horizontally with other sectors and departments, and building strategic partnerships with the private sector. Her professionalism and dedication to the health of scallop stocks have contributed to the economic and social well-being of the thousands of people who depend on the Atlantic scallop fishery. Moreover, Dr. Robert has demonstrated that women scientists can work in close cooperation with fishing captains and crews and conduct scientific surveys on industry vessels.

Through a transitional employment (TE) program, **Douglas Frizzle** and **June Senay** of the Canadian Hydrographic Service (CHS) have helped individuals who are overcoming mental health challenges return to work. Douglas, supervisor of the Electronic Navigation Chart (ENC) unit, recognized the potential of these TE program members and initiated the relationships. June, a multi-disciplinary hydrographer with the unit, was responsible for their training and support, ensuring that they performed in a mentoring environment and delivered a quality product. Douglas and June demonstrated that a creative approach to solving internal human resources issues can result in a teamwork environment that values and supports a diversity of persons, skill sets, and education.

Dr. John N. Smith of the Marine Environmental Sciences Division received the DM's Prix d'Excellence in Science with his colleagues on the Chemical Properties of Water Masses team (Drs. Robie W. Macdonald [Pacific Region] and Luc Beaudin and Charles Gobeil [Quebec Region]). This inter-regional research team undertook two major projects that analyzed organic carbon flux changes and studied the presence of contaminants in Arctic Ocean deep basins. Conclusive data on the accumulation of chemical compounds and lead in deposited sediments have provided the scientific community with a better understanding of trends in global processes in this region over the past decades, and their relation to climate change.

Distinction Awards:

Jim Leadbetter of the Oceans and Habitat Branch has demonstrated integrity and and fairness throughout his long career with the fish



DFO Deputy Minister Larry Murray, left, presents the DM's Prix d'Excellence in Science to Dr. John Smith.

habitat management program, performing work that requires a balance among environmental, legal, policy, and socio-economic factors in the decision-making process. He established the Habitat Program before the present policies were developed and has worked with proponents to implement work processes that ensure adequate protection of fish habitat. A mentor to all staff, Jim is the lead expert in freshwater assessments. His professionalism has resulted in a high standard of commitment to the DFO habitat policy and work to protect fish habitat.

Shayne McQuaid, Oceans and Habitat, has long contributed to excellent stewardship of fish habitat within Maritimes Region. His commitment in time, travel, and effort has resulted in the effective participation of community groups in fish habitat restoration. He mentors staff of the Stewardship Unit working with the diverse groups, and his work always aims to present DFO in the best and most supportive light while striving to make habitat work a good news story.

Trudy Wilson was appointed Regional Departmental Assessment and Alignment Project (DAAP) Coordinator in 2002, carrying out this function along with her regular responsibilities as Assistant Director, Oceans and Habitat. Trudy excelled in working horizontally with all sectors in the Region and with the other Regional DAAP Coordinators and Headquarters colleagues to ensure that Maritimes Region provided input and had complete information. Trudy demonstrated a high level of professionalism and support for Public Service values by making complex information on DAAP accessible to Regional employees.

Joan Hebert-Sellars was nominated by the Oceans and Coastal Management Division (OCMD) for her outstanding service as procurement expert for their division and thus, her contribution to their program delivery. Daily, Joan demonstrates her commitment to

DFO and to her work where her knowledge, empathy to client needs, and willing assistance ensure that the OCMD is receiving the best value for the taxpayer and that the government's procurement policies and practices are upheld.

With his in-depth knowledge and curiosity about technological architectures, **Tobias Spears** of the Informatics Branch has provided leadership in developing innovative solutions in the delivery of digital information to DFO's external clients. Also, he has contributed significantly to DFO; for example, his discussion paper on the management and support of shared computer libraries used in national computer applications was well received by the Services Committee team addressing issues involved in the national application deployment process and the enhanced infrastructure service delivery initiatives.

Throughout his career, **Mark Lundy** has earned the respect and friendship of the inshore Bay of Fundy scallop fishers with whom he has worked; his relationship with the industry fosters their acceptance of scientific advice towards management of the fishery. Mark's personal commitment to participate in the annual Digby Scallop Days Festival provides educational information to the public and opportunities to speak with fishers in an informal situation. Each year, festival organizers have awarded him a plaque to acknowledge his contribution.

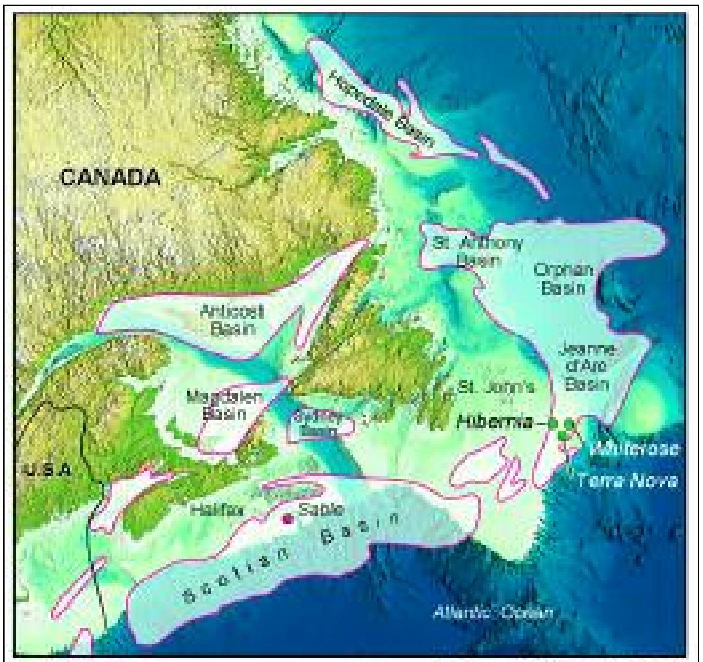
For the past 15 years, **Dr. Barry Hargrave** has provided outstanding leadership for regional scientific research and coordination of national research on the environmental interactions with finfish aquaculture. He has been proactive in discussing this research with the aquaculture industry and provincial regulatory agencies, and played a major role in providing scientific advice to facilitate the preparation and screening of Environmental Impact Statements (EIS) aquaculture site development under the *Canadian Environmental Assessment Act*. Throughout his career, Dr. Hargrave has demonstrated scientific excellence, as well as the importance of multi-regional and multi-disciplinary research.

BIO Research and Advice for Oil

Towards Safe and Environmentally Sound Petroleum Exploration, Development, and Regulation

John Loder (DFO), Kenneth Lee (DFO), Gary Sonnichsen (NRCan), Paul Macnab (DFO), and Don McAlpine (NRCan)

Research and advisory activities at the Bedford Institute of Oceanography provide important information toward development of Canada's offshore oil and gas reserves in a way that will minimize risks and adverse environmental effects. Focal areas are assessments of offshore hydrocarbon reserves, seabed stability, and geohazards by NRCan's Geological Survey of Canada (GSC) Atlantic; descriptions of the physical ocean environment and evaluations of the potential impacts of oil and gas activities on biota and fisheries by DFO's Science Branch; and the development of integrated management strategies by DFO's Oceans and Habitat Branch. Activities include instrument development, field and laboratory experiments, computer modelling, and interpretative studies to understand ocean ecosystems and their sensitivity to disturbances. BIO researchers provide scientific advice to industry, regulators, environmental emergency responders, and others involved in decisions regarding safe and sustainable strategies for managing and protecting Canada's ocean resources.



Sedimentary basins off Atlantic Canada with potential hydrocarbon reserves are delineated by pink. Existing production fields are indicated by solid circles—gas (red) and oil (green).

In this overview, we provide examples of the wide range of BIO activities in Atlantic Canada related to oil and gas development, from estimating the type and distribution of petroleum resources, to protecting ocean ecosystems.

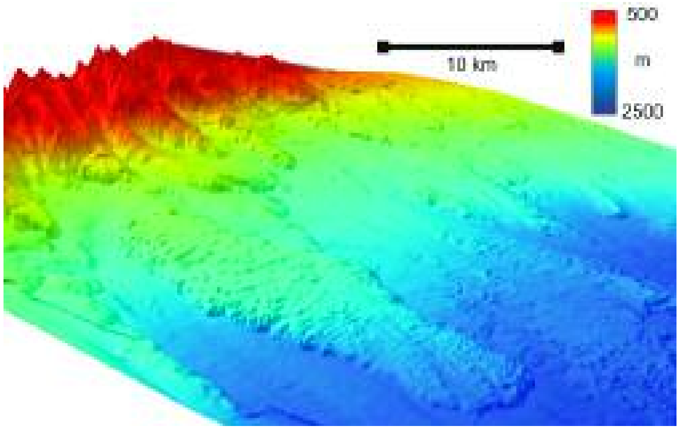
SUBMARINE PETROLEUM DISTRIBUTIONS: Why, Where, and How Much?

Oil and gas are mostly derived from the remains of microscopic plants and animals that lived in ancient seas, sank to the bottom upon dying, and were wholly or partly incorporated into the bottom sediments. As more and more sediment accumulated, the underlying sediments and organic matter were buried further and subjected to heat from the overburden pressure and the earth below. The sediment was converted to rock and the organic matter component was cooked and slowly converted to petroleum. Generally, animal-derived material produces oil; plant-derived material produces gas.

Since 1959, petroleum industry exploration on the continental shelf and slope off Atlantic Canada has revealed large proven and potential oil and gas deposits. These deposits are found in sedimentary basins up to 25 km thick that were formed in response to continental plate tectonic forces when Africa and Europe separated and moved away from North America between 250 and 100 million years ago. Regional variations in organic matter type have led to gas being the main product found off Nova Scotia and oil the main product found off Newfoundland and Labrador.

NRCan geoscientists at the GSC, often in partnership with industry, provincial, and university colleagues, analyze industry seismic survey data, as well as core and cutting samples from exploration wells, to assess the oil and gas potential of frontier basins from Georges Bank to Baffin Bay. These assessments are used by regulatory agencies, such as the Canada-Nova Scotia and Canada-Newfoundland and Labrador Offshore Petroleum Boards (OPBs), and by federal and provincial energy policy-makers. The oil and gas industry uses the information and interpretations to reduce risk in exploration and to help identify potential areas for further evaluation.

and Gas Activities:



Submarine landslide (foreground) on the Scotian Slope imaged from 3D seismic data (provided by EnCana Corporation)

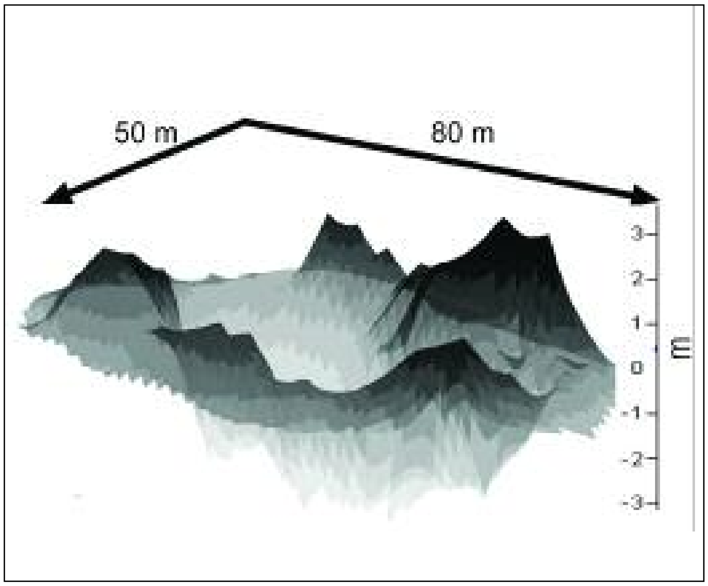
A large dry-dock iceberg drifting southward in offshore pack ice

Waves and the CCGS Hudson *near the Hibernia Gravity Based Structure on the Grand Banks*

SEABED STABILITY AND HAZARDS:
Can Petroleum be Extracted Reliably?

One risk that concerns geoscientists at BIO is the stability of the seabed overlying petroleum basins. This has important economic, environmental, and safety consequences for offshore exploration, production, and transportation facilities. The GSC Atlantic and its partners carry out field studies to identify the types of material on the seafloor and their mobility, the potential for the occurrence of submarine landslides on the continental slope, and the effects of sediment transport (erosion and infill) associated with waves and currents. Three-dimensional maps of landslide debris fields can be obtained with advanced seismic survey and computer visualization techniques, providing important information for exploratory drilling.

Another focus for GSC Atlantic seabed studies is the frequency and effects of seabed scouring by keel-dragging icebergs on the Newfoundland Shelf and the Labrador Shelf. Where and how often



Schematic of a recently mapped pit created by an iceberg on the Grand Bank in 2000, with depth in meters do these scours occur? How damaging are the effects? These questions have serious cost and risk implications for facilities placed on the seabed. The data from these studies are used in the formulation of design parameters for the construction of offshore structures used in our coastal waters.

THE PHYSICAL OCEAN ENVIRONMENT:
Factors Affecting Safe Operations

The Northwest Atlantic coastal waters often provide a harsh working environment for the oil and gas and other marine industries. Physical environmental factors such as waves, winds, icebergs, sea ice, and currents can affect safety and environmental vulnerability during exploration, production, and transportation operations. DFO Science has research programs on the observation and prediction of waves, sea ice, icebergs, and currents in Atlantic offshore areas with active petroleum interest. Waves studies, carried out in collaboration with a number of organizations, are focused on the development and validation of improved prediction models for various locations in the NW Atlantic (where deep-water wave heights of 30 m have been observed in recent years), and on the use of satellite data for broad-scale observations of winds and waves.

Ridged ice floe under study by a DFO helicopter-based research team

Research personnel servicing instrumentation on an offshore ice floe

Waves sweeping across the Hudson's *foredeck during a storm*

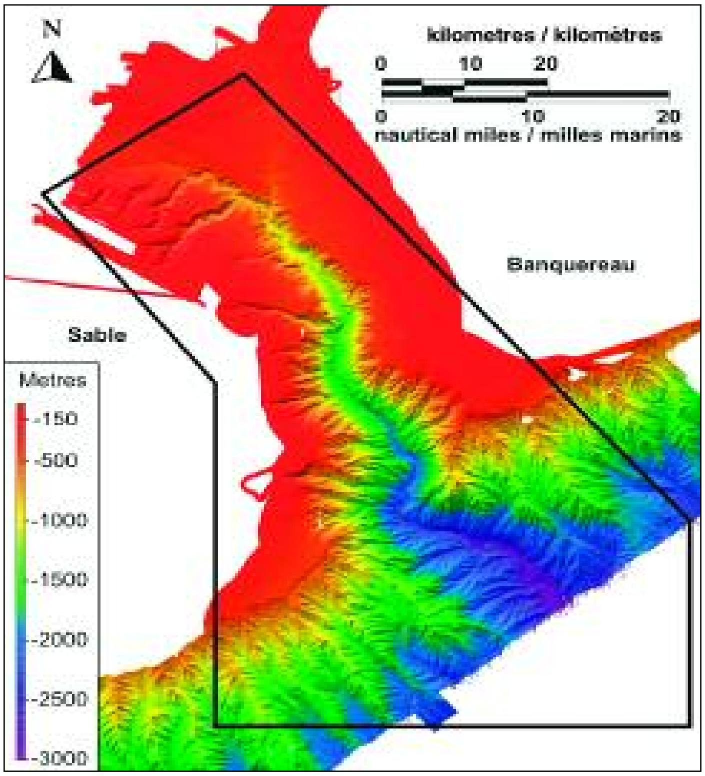
During the past two decades, BIO has developed and used novel satellite-transmitting instruments for tracking and measuring the properties (e.g., thickness) and distribution of sea ice, as well as improved ice-ocean prediction models which have been transferred to Environment Canada's Canadian Ice Service and others for use in ice forecasting on the Labrador and Newfoundland shelves. Recently, an iceberg population prediction technique was developed which is being used to provide industry and others with one- and two-month forecasts of the number of icebergs that will drift south of 48°N into the oil production region on the northeast Grand Bank.

Another research activity in recent years, carried out in partnership with several oil and gas companies, has been current measurement programs in frontier deeper-water exploration areas on the continental slope. Current-meter moorings deployed for multi-year periods on the Scotian Slope off Halifax, and in Flemish Pass and Orphan Basin off Newfoundland, are providing information on currents, temperature, and transport variability associated with features such as Gulf Stream rings and the Labrador Current. These features are particularly important to loadings on drill strings—and hence to design and drilling operations—in water depths greater than 1000 m.

BIOLOGICAL RESOURCE DISTRIBUTIONS:
Are Sensitive or Valuable Ecosystem Components at Risk?

Concurrent with efforts to minimize risks to oil and gas activities, BIO scientists are working to ensure the protection of the marine environment and its biological resources. Regulatory agencies, such as the National Energy Board and the federal-provincial OPBs, issue permits for offshore oil and gas activities, drawing on advice from DFO and other government departments. To minimize and mitigate adverse environmental impacts, it is necessary to delineate and better understand the ecology of unique or sensitive habitat areas, such as The Gully Marine Protected Area (MPA) to the east of Sable Bank and the important haddock spawning area on Western (Sable) Bank on the Scotian Shelf.

Coordinated studies by the NRCan's GSC Atlantic and DFO's Science, and Oceans and Habitat branches, with support from the Canadian Coast Guard and DFO Informatics, are providing databases and maps of biological resources and their environment. DFO's Virtual Data Centre provides seasonal maps of the distribution of fish and marine mammals, and species at risk (e.g., corals). Its web-available Oceanographic and BioChem databases provide access to archived information on currents, temperature, plankton, nutrients, and contaminant levels. This information offers a baseline for the assessment and monitoring of potential changes in ecosystem health associated with industrial operations. Coordinated efforts at BIO in these areas provide industry, regulators, and public interest groups



Colour-coded bathymetry, obtained from a high resolution multi-beam survey, showing the steep and rugged topography in The Gully MPA (outlined by the polygon), an ecologically unique area that is an exclusion zone for offshore oil and gas operations

with information needed for the assessment of proposed exploration and production activities. Industry is supportive of DFO's mandated role under the *Oceans Act* and the *Species at Risk Act* since it reduces their risk of being denied approval to proceed with further work following significant investment in exploratory operations.

ENVIRONMENTAL IMPACTS: *How Harmful are Seismic Surveys and Operational Discharges?*

Seismic surveys are routinely conducted by the offshore oil and gas industry to define subsurface geological structures and determine the location and size of hydrocarbon reserves. While numerous surveys have been conducted in the coastal waters of Canada, scientific knowledge is limited in some key areas, and environmental concerns remain over the potential impact of noise generated by some of the airguns used in these surveys. During 2004, a coordinated effort was made to provide scientific information for the establishment of guidelines for the impacts assessment of proposed seismic operations. This included a series of review articles to provide up-to-date information to decision makers on the measurement and prediction of sound propagation, biological effects, and mitigation procedures. In addition, two scientific field studies were conducted in collaboration with industry and academic partners during actual survey operations to validate existing sound propagation models, and to assess the impact of seismic noise on marine mammals, including the northern bottlenose whale, a species at risk in The Gully MPA area, and snow crab, a commercially important species off the western coast of Cape Breton. These studies addressed both region-specific and national concerns, and were managed by DFO's recently created Centre for Offshore Oil and Gas Environmental Research (COOGER). With its secretariat located at BIO, this group is the leading national and inter-agency coordination of DFO's environmental research programs related to offshore oil and gas.

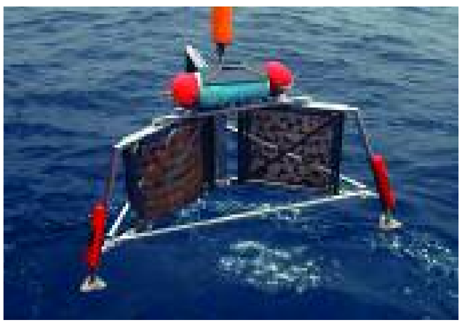
Another major environmental concern with offshore oil and gas activity has been the potential for adverse impacts of discharges of waste fluids, muds, and cuttings associated with drilling operations, particularly to organisms on or near the seabed. Over the past decade, studies have been conducted in the BIO laboratory to identify the concentration of various drilling wastes that may have detrimental biological effects on commercial fisheries species, and in the field to determine the effects of discharges on scallops and mussels moored near drilling rigs. This work has required the development of new laboratory and field instruments and techniques to identify both acute (e.g., short-term lethality) and chronic (e.g., reduced growth rates and reproductive success) biological responses.

Offshore oil or gas production is now underway at several sites in Canada's coastal waters. An emerging concern is potential impacts from the operational discharge of production waters, the largest waste stream by volume. They are primarily comprised of waters that are extracted with the hydrocarbon reserves along with some waste process chemicals (e.g., corrosion inhibitors, emulsion breakers). A number of these waste products are of environmental concern, including hydrocarbons, heavy metals, inorganic nutrients, and process chemicals. Regional studies are being conducted by DFO Science to identify how the composition of production waters varies from one geological formation to another,

Deployment of an Ocean Bottom Seismometer to record sound levels from airguns and marine mammal vocalization

A northern bottlenose whale alongside a research vessel in The Gully area

Deployment of a moored bottom tripod to measure sediment concentrations and other variables in the benthic boundary layer near the Hibernia structure



A bottom tripod with caged scallops and mussels being deployed in the vicinity of a drilling platform

the primary contaminants of concern, and the physical-chemical processes that control the extent of their distribution and biological availability following their discharge. The results of this work (like those from drilling mud impacts studies) are used by regulators to establish improved waste treatment guidelines for oil and gas operations.

Physical environmental factors, such as ocean currents and mixing, play an important role in the impacts of discharges from offshore operations through their influences on both the fate (drift, dilution, biogeochemical pathways) of the discharges and the distribution of marine organisms. A significant advance in this area has been the development of predictive environmental impact assessment models. Models for discharged drilling muds and production waters, which draw on observed or predicted ocean currents and laboratory measurements of the effects of specific constituents within the discharge streams on particular organisms (e.g., scallops) and ecosystem dynamics (e.g., interaction among zooplankton, phytoplankton, bacterioplankton) have been developed. These provide quantitative estimates of the potential impacts at particular drilling sites. These and other BIO research programs have defined new approaches and technologies for impacts assessment and Environmental Effects Monitoring programs that are accepted and used by both the regulatory agencies and the offshore oil and gas industry on a national and global scale.

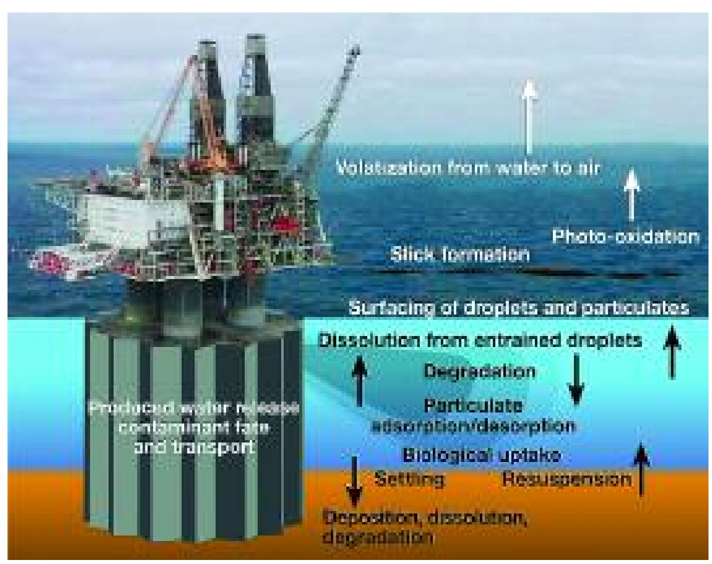
Flow-through tanks used in laboratory experiments of drilling-mud effects on sea scallops

Laboratory analyses for contaminants and chemical processes associated with discharged production waters

Seabed pipeline-route surveys, and sediment distribution and transport studies by GSC Atlantic also provide valuable input to the mapping of biological resources and assessment of their vulnerability to impacts from oil and gas activities, particularly in The Gully region.

ACCIDENTAL SPILLS: Minimizing Risks and Impacts

Despite improvements in safety standards and in engineering technology, it is likely that accidental spills will occur in future operations associated with offshore oil and gas activities. Research at BIO includes the development of standards and methods to minimize environmental and human risks associated with accidental spills. Studies include the development of protocols for toxicity evaluation of drilling fluid and mud formulations to be used in offshore operations. Since the 1970 *Arrow* spill in Nova Scotia's Chedabucto Bay, DFO Science has maintained ongoing studies on oil spill countermeasures and methods to monitor habitat recovery. A wave tank facility has

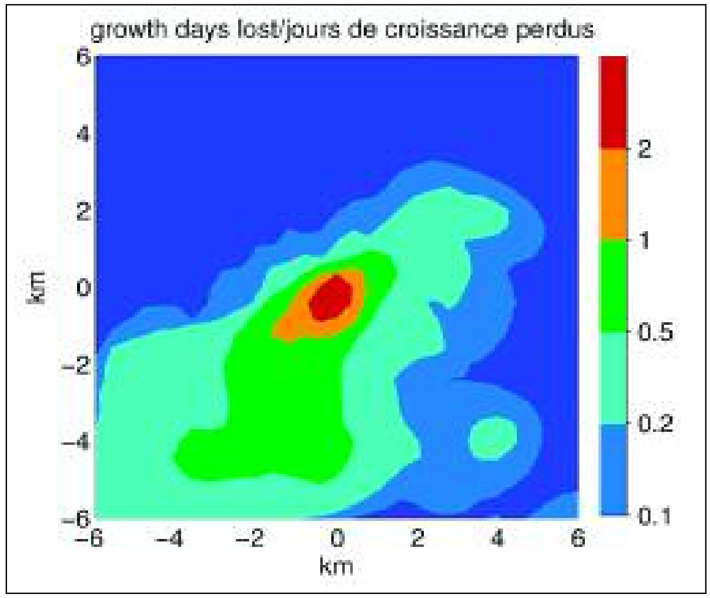


Schematic representation of the fate and contributing processes for production waters from Hibernia oil production platform recently been constructed by engineers at BIO to conduct studies with the U.S. Environmental Protection Agency on the effectiveness of chemical oil dispersants and the potential effects of dispersed oil in the water column. Results from these studies will be used to establish guidelines for product selection and use by oil spill response teams.

Studies are also being conducted to identify the primary components in residual oil responsible for detrimental effects, for use in predictive models for environmental risk assessment, and to provide guidance to spill response operations.

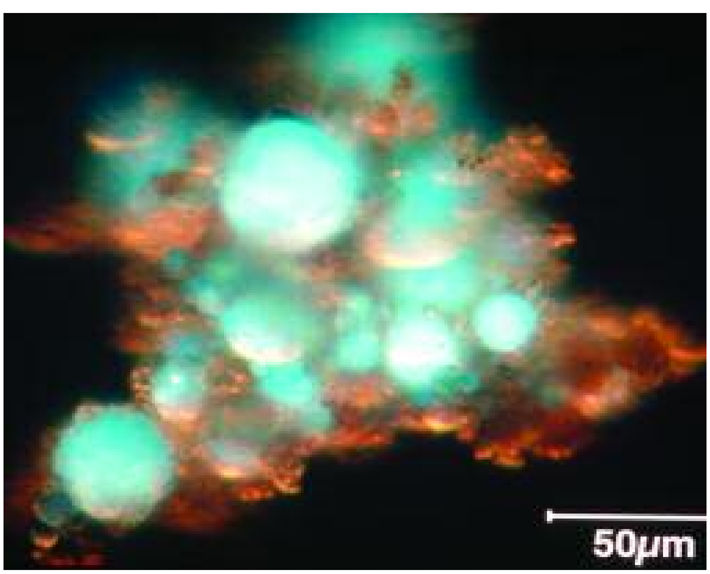
INTEGRATED OCEAN MANAGEMENT:
How to Manage Multiple Uses of the Ocean

Canada's oceans and marine resources are of great socio-economic importance to many industries and communities, and include many treasures to be preserved for future generations. BIO's Oceans and Habitat Branch leads integrated ocean management and planning in coastal and offshore areas of the Maritimes Region, in support of Canada's *Oceans Act* and *Fisheries Act*. This includes the Eastern Scotian Shelf Integrated Management (ESSIM) initiative which is the most advanced integrated ocean management project in Canada. ESSIM draws on scientific information and seeks to build a consensus-based approach to decision making that balances ecosystem concerns and human use of the marine environment. It provides a forum to consider multiple-use conflicts, collaborative approaches, and dialogue among scientists, regulators, and a broad community of ocean users (e.g., oil and gas, fishing, transportation, conservation). The ESSIM region includes The Gully MPA, and areas of oil and gas exploration and production on nearby Sable Bank.



Model prediction of the total number of growth days that would have been lost by scallops in the vicinity of the North Triumph site (0,0 km) on Sable Bank due to drilling discharges in 1999

The wave tank for chemical oil dispersant studies at BIO



Microscopic image of oil droplets in sediment

DFO's Oceans and Habitat Branch also provides advice and leadership in the development of policies and procedures for environmental impacts assessment, as well as reviews of environmental assessments for proposed marine activities, in support of the Canadian Environmental Assessment Act. Assessment reviews are provided to the OPBs and other regulatory agencies, based on Expert Opinions from DFO's Science Branch. This includes all phases of oil and gas development from initial seismic exploration to the decommissioning of production facilities.

CONCLUSION

In conjunction with other agencies, the coordinated efforts of many people at BIO are providing critical information and advice on a range of issues related to the safe and environmentally sound development of petroleum resources off Atlantic Canada. Most of these activities have national or international implications or involvement, as the Canadian and global communities seek new cost-effective energy sources that are compatible with preserving our planet's marine ecosystems and other marine activities of socio-economic importance. With its diverse and extensive expertise, BIO provides national as well as regional leadership in helping to balance resource development and environmental stewardship.

Acknowledgements: Many of the research programs at BIO related to oil and gas development have been carried out as part of the federal interdepartmental Program on Energy Research and Development (PERD) and/or through partnerships with other agencies, industry, and universities. Photographs and graphical displays for this article have been provided by Gary Grant, David Mosher, and John Shaw of NRCan; Peter Cranford, Adam Drozdowski, Charles Hannah, Stan Johnston, Tim Milligan, and Simon Prinsenberg of DFO; and by Kee Muschenheim of Acadia University.

Science Activities

Four-dimensional Modelling of Carson Basin, Grand Banks: Why and What Did We Learn?

Hans Wielens

In geological terms, a basin is a confined area with sediments that share a common history. One such is the Carson Basin, close to and southeast of the oil-producing Jeanne d'Arc Basin which contains the Hibernia and Terra Nova oil fields (Figure 1). When Hibernia was found, the other basins on Grand Banks were left minimally explored. The 200x100 km Carson Basin started to form when North America rifted away from Africa 200 million years (Ma) ago in the late Triassic era. Rifting formed a valley in which desert-like sands were deposited. Then an ocean named the Thetis Sea flooded the area. Because of the hot, dry climate there was repeated evaporation of the sea water, leaving a salt layer about 2 km thick. This was covered by several kilometers of shale, sandstone, and limestone. Crustal heating from the onset of the next rifting phase, which split Grand Banks and Iberia 65 Ma ago, uplifted the area. Parts of the basin emerged from the sea and were eroded, and the westernmost areas lost almost all their sediment above the salt.

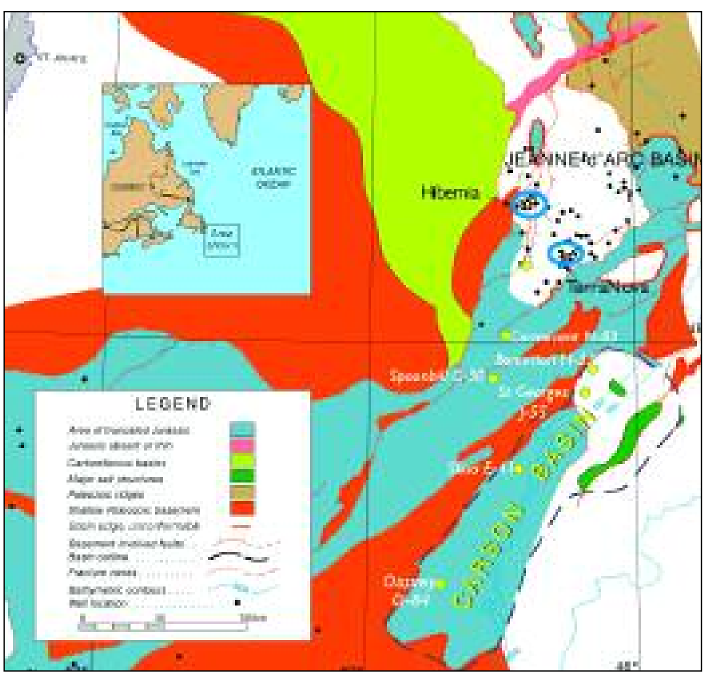


Figure 1: Location geological map showing Carson and Jeanne d'Arc basins in relation to Newfoundland

After this upheaval, the area sank again and more sediment was deposited in an ongoing process.

A basin may contain three rock types important to oil and gas fields: seal, reservoir, and source rocks. Seals such as shales are impermeable to oil and gas. Most rocks contain small, connected pores that are filled with water: rocks with more than 10% pore space are called reservoirs. Oil and gas originate from a source rock, which contains more than 1.5% of unoxidized, "compacted" organic matter, such as cell walls of algae, phytoplankton, bacteria, and plant remains.

When plankton dies in absence of oxygen it is preserved as source rock. This happens only in deeper parts of geologic basins, especially in those formed by rifting. When a source rock becomes buried deeper by younger sediment, it warms. Burial also converts the organic material into very large, complex molecules. The warming accelerates vibration of these molecules, until, at about 90°C, molecular bonds start to break. The molecule falls apart into smaller components which are oil and gas; the source rock now enters maturity. Oil and gas are lighter than water and move up through the pore water until they are trapped by a seal, such as shale or salt. Usually these traps have a dome shape that oil exploration companies try to find with seismic exploration.

While the domes are attractive drilling targets, not every dome contains oil and gas. Crustal processes, and especially salt in this area, can form domes: salt is quite plastic when warm, and lighter than most other sediments. Thus, it tends to rise and push the overlying sediment up and aside.

Seismic information is used to guide oil and gas exploration. A seismic line is like an ultrasound image of the rock layers below. If we have crossing lines, a rock layer can be mapped and constructed in three dimensions (3-D). By mapping several layers, we can reconstruct layers of different age and composition above each other. A 3-D image is formed that shows the domes.

Based on seismic information, four wells were drilled on the western, high flank of the Carson Basin but no oil or gas was found. No source rock was present in any of the four wells, although a late Jurassic (152 Ma old) source rock shale is present in the Jeanne d'Arc Basin, in the North Sea (adjacent to Grand Banks at that time), and in many locations worldwide—global conditions apparently were right for plankton blooms in the late Jurassic.

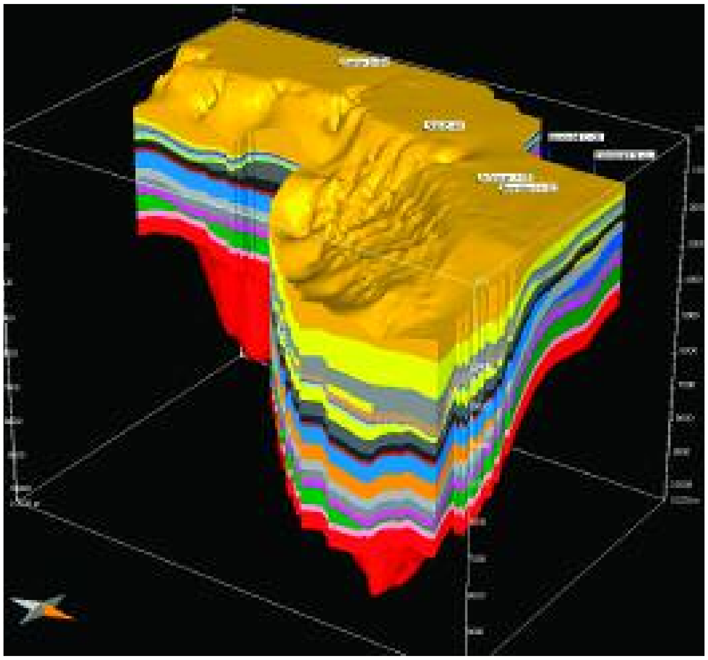


Figure 2: Southwest 3-D view of the model layers in the Carson Basin: Red = basement; green = salt; blue = limestone; pink = dolomite; grey = shale; orange = siltstone; yellow = sandstone. The well locations are in blue at the lower-left bottom of the name tags. The orange arrow points north. (Image generated by Petromod software.)

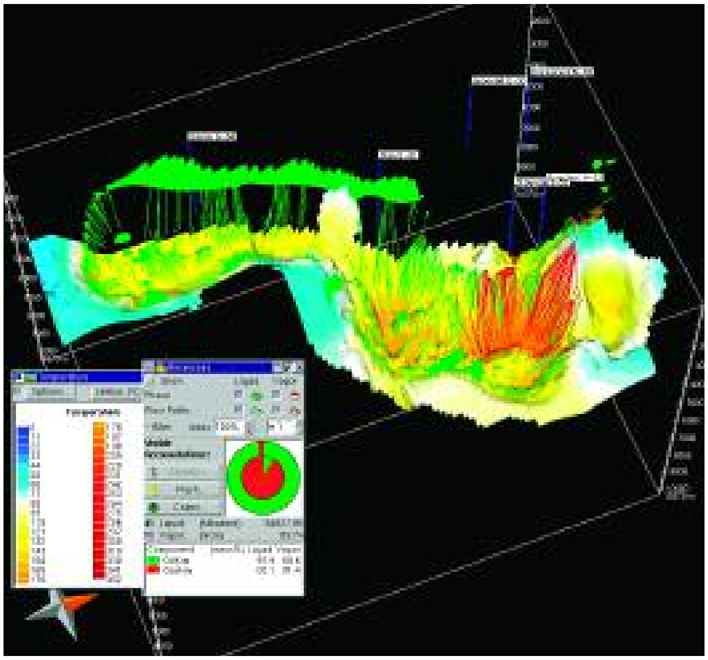


Figure 3: Shown is a view down to the SW of the source rock layer, overlain by the temperature at 62 Ma ago. Only the yellow to pink areas were warm enough to generate oil and gas. Oil is bright-green and gas is red and both float above the layer; solid colour shows filled reservoir; and lines show migration routes. Temperature scale and oil/gas compositions are in insets. Note that the wells missed the reservoirs. (Image generated by Petromod software.)

From our work on several types of microscopic fossils and their ages, we know that about 152 Ma old siltstone rocks are found in two of the Carson wells, but they were formed in an oxygen-rich, coastal environment. Thus, there are not source rocks here. However, because source rocks occur in Jeanne d'Arc Basin nearby, and several other basins that formed during this global rifting event, it is probable that source rock is also present in the deeper parts of Carson Basin, east of the wells.

The geology of basins is a complex, four-dimensional system, of which at best we can see only small three-dimensional parts. A geologist has to add the fourth dimension—time—and synthesize the history of the basin since its inception. Many of the geological processes, such as compaction of sediments or formation of oil and gas, can be described with surprisingly simple formulae. A basin can be divided into more or less homogeneous cells that are about 2x2x2 km, and the geological processes calculated for each cell, including its effect on neighbouring cells. Calculations for one cell can be done with pen and paper, but for the 500,000+ cells in a basin, a computer is more time-effective.

That is the idea behind basin modelling. The more precise the input, the better the modelling results will be. That means serious questioning of every bit of information and its effect on the other factors. The need to synthesize all geological knowledge of a basin is why the Geological Survey of Canada (GSC) started to use four-dimensional (4-D) modelling. The GSC Atlantic acquired the world-class specific software, Petromod, from IES Germany. This program calculates also many other parameters over time, such as composition and amounts of oil and gas, their subsurface and surface properties, reservoir pore percentage, and amount of connection among pores, pressures, and temperatures.

Carson Basin was the first basin to be 4D-modelled. Seismic data were converted into a computer model, as shown in Figure 2. Because the geological history is included, the computer model shows basin formation through time. When the program is asked to show oil in green and gas in red, the trapped oil and gas are shown, as well as their migration paths from the source rock (as similarly coloured lines), as in Figure 3. There, the source rock layer is shown, overlain with the temperature at 62 Ma ago. Sandstone, the common reservoir rock in this area, is shown in Figure 4 in yellow. It is clear that the oil moved up and into it, and now is trapped where the sandstone layer thins to

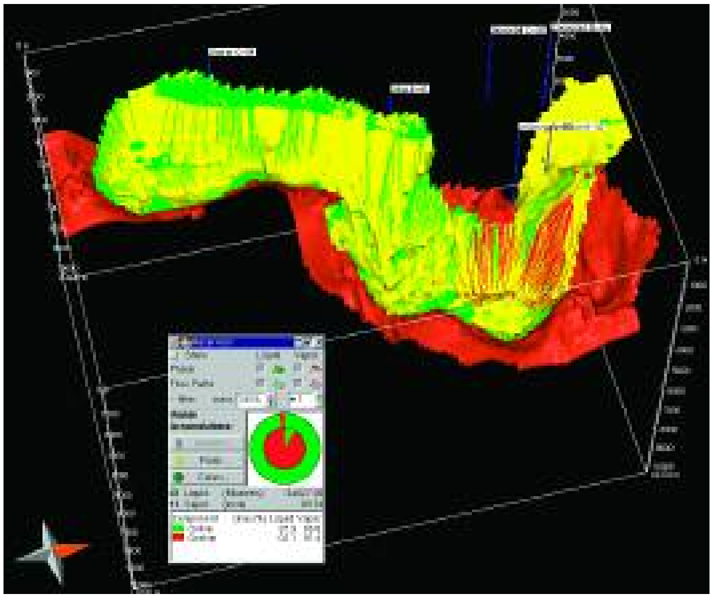


Figure 4: Source rock layer is brick-coloured, and reservoir (sand) layer, yellow. Oil and gas are as in Figure 3. Both are trapped mainly in the western part of the sand, where it decreases to zero thickness, and in a few domes elsewhere. (Image generated by Petromod software.)

zero thickness in between impermeable shales.

What have we learned from this model? We believe there is a source rock, based on the integrated thinking required for the model. With a source rock and the temperature history in this basin, there likely is a viable petroleum system (combined reservoir, source, seal, trap, and the right timing of trap and oil formation) where previously there appeared to be none. By taking conservative parameters from the source rock in the Jeanne d'Arc Basin, the model shows that billion-barrel oil fields, similar in size to Hibernia, are possible. Further, to our surprise, we learned that the higher heat flow associated with the rifting matured the source rock about 125 Ma ago, and the maturation stopped at 65 Ma ago. That means that no oil and gas are now being generated and that it is less likely that dome-like traps younger than 65 Ma old contain oil and gas. Many structures are younger, until fairly recently formed by moving salt.

What is the benefit of the modelling for Canada? We now believe that this basin, rather than being "dry", may contain economically-viable amounts of oil and gas. Thus we have reduced the risk for exploration companies and shown that attractive targets exist here. Further detailed exploration will create jobs, and if found, oil and gas might provide wealth and royalties for Canadians and their governments.

Mixing and Phytoplankton Dynamics on the Inner Scotian Shelf

Blair Greenan, Brian Petrie, Glen Harrison, and Neil Oakey

Phytoplankton are the fundamental energy source for life in the ocean. These cells use the sun's energy to convert carbon dioxide, water, and dissolved salts into organic compounds through photosynthesis. The rate of carbon formation by phytoplankton is referred to as primary productivity. Water temperature, variations in the light field and adaptations that phytoplankton make to these variations, availability of nutrients, and species composition all affect primary productivity.

A strong burst of primary production sustained for several weeks in late winter/early spring is referred to as the spring bloom. The spring bloom is marked by high levels of chlorophyll, one of the major functional products of photosynthesis. On the Scotian Shelf (Figure 1), the upper illuminated layer of the ocean (euphotic zone) generally has enough sunlight for photosynthesis but typically is low in nutrients during most of the year because of consumption by phytoplankton during the spring bloom. The deeper waters are a reservoir of nutrients, and the primary supply pathway for the euphotic zone. Vertical mixing in the ocean can play an integral role in primary production by transferring nutrients from the deeper to the more shallow waters. Mixing results from external forces such as surface winds or from oceanic processes such as tides and internal waves. During winter when light levels are too low to allow significant primary productivity, strong and frequent storms over the Scotian Shelf increase vertical mixing and build relatively high concentrations of nutrients at shallow depths. The subsequent stratification in spring, as the surface warming trend begins, and the increase in light levels lead to the spring bloom. This is largely "new production", i.e., production that uses inorganic nutrients stored near the surface or transferred from the deeper waters. After the bloom, reduced production is fuelled primarily by recycled nutrients within the shallow layer, nutrients derived from the decay of plant material, or from excretions of zooplankton that have eaten the phytoplankton. However, short-term mixing events related to increased wind stress on the ocean surface from passing weather systems during the summer and fall seasons may lead to local increases in "new" primary productivity. Our ability to monitor the impact of these short-term events has been limited to this point.

Most methods used to calculate marine primary productivity require chlorophyll observations. For September 1997 to the present, estimates of chlorophyll concentrations in the upper ocean for the Canadian east coast are available as semi-monthly composites of Sea-viewing Wide Field-of-view Sensor (SeaWiFS) satellite images from the Biological Oceanography Section of the Ocean Sciences Division, DFO at *(http://www.mar.dfo-mpo.gc.ca/science/ocean/ias/remotesensing.html)*. The SeaWiFS images for the Halifax Section show significant cross-shelf and interannual variability (Figure 2). For example, the 1999 bloom on the outer shelf peaked in winter (mid-February) while in the following years this occurred in March-April. The 2003 spring bloom was much stronger than the four previous years in the sample. In terms of cross-shelf variability, during the 1999 spring bloom chlorophyll concentrations >4 mg m^{-3} were sustained in the coastal and outer shelf regions, while only a weak bloom occurred over Emerald Basin.

Following the spring bloom, short-term events lasting two weeks or less are evident in all five years. Do these short-term events make a significant contribution to the overall production on the shelf? Factors such as cloud cover and low satellite angle make it difficult to use SeaWiFS imagery to study chlorophyll variability on the Scotian Shelf on time scales shorter than two weeks. The annual median chlorophyll concentration for the near surface layer of the central Scotian Shelf, which includes Emerald Basin and Station 2 of the Halifax Section, is 1.6 mg m^{-3} with a range of 0-8 mg m^{-3} and a standard deviation of 1.5 mg m^{-3}. While much of this variability is caused by spring and fall blooms, the biweekly differences indicate that there is a significant contribution from events lasting less than two weeks. This is indicated by the average biweekly difference over the entire period of 0.4 mg m^{-3}, with a maximum of 4.5 mg m^{-3} and a standard deviation of 1.4 mg m^{-3}.

To determine if events lasting less than two weeks are important to the overall primary production on the shelf, a mooring program was carried out in October 2000 to measure physical, chemical, and biological variables at short time intervals. The goal was to allow us to study events that occur at intervals as short as one day. On September 30, 2000, two moorings were deployed at Station 2 (Fig. 1) on the Halifax Section where the water depth is 150 m. One mooring had a SeaHorse moored profiler equipped with a CTD (measuring conductivity, temperature, and depth) and fluorometer (measuring chlorophyll concentrations). SeaHorse is a positively buoyant platform developed at BIO (Hamilton et al., 1999) that uses surface wave energy and a one-way clamping mechanism to enable it to descend along the mooring wire until it reaches a docking position at about 120 m. It remains at that depth until a preset time interval has elapsed, at which point the clamp on the mooring wire is released and SeaHorse ascends smoothly to the surface at ~0.5 m s^{-1} measuring temperature, salinity, chlorophyll, and depth. The

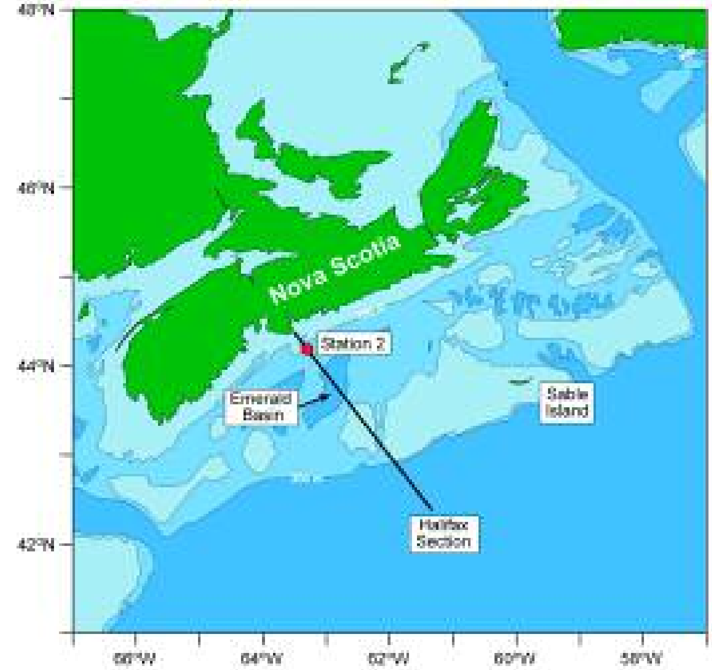


Figure 1: Scotian Shelf bathymetry is indicated by the shading with darker blue representing deeper water. Two moorings were deployed at Station 2 on the Halifax Section in fall 2000 to study high-frequency variability.

SeaHorse cycled between 7 and 120 m every two hours. The second mooring, about 200 m from the SeaHorse mooring, included an upward-looking acoustic Doppler current profiler (ADCP) at 80 m in a streamlined sub-surface float. The ADCP measured water velocity every 15 minutes, in 2 m intervals between 6 and 76 m.

The results (Figure 3) show a subsurface chlorophyll maximum at

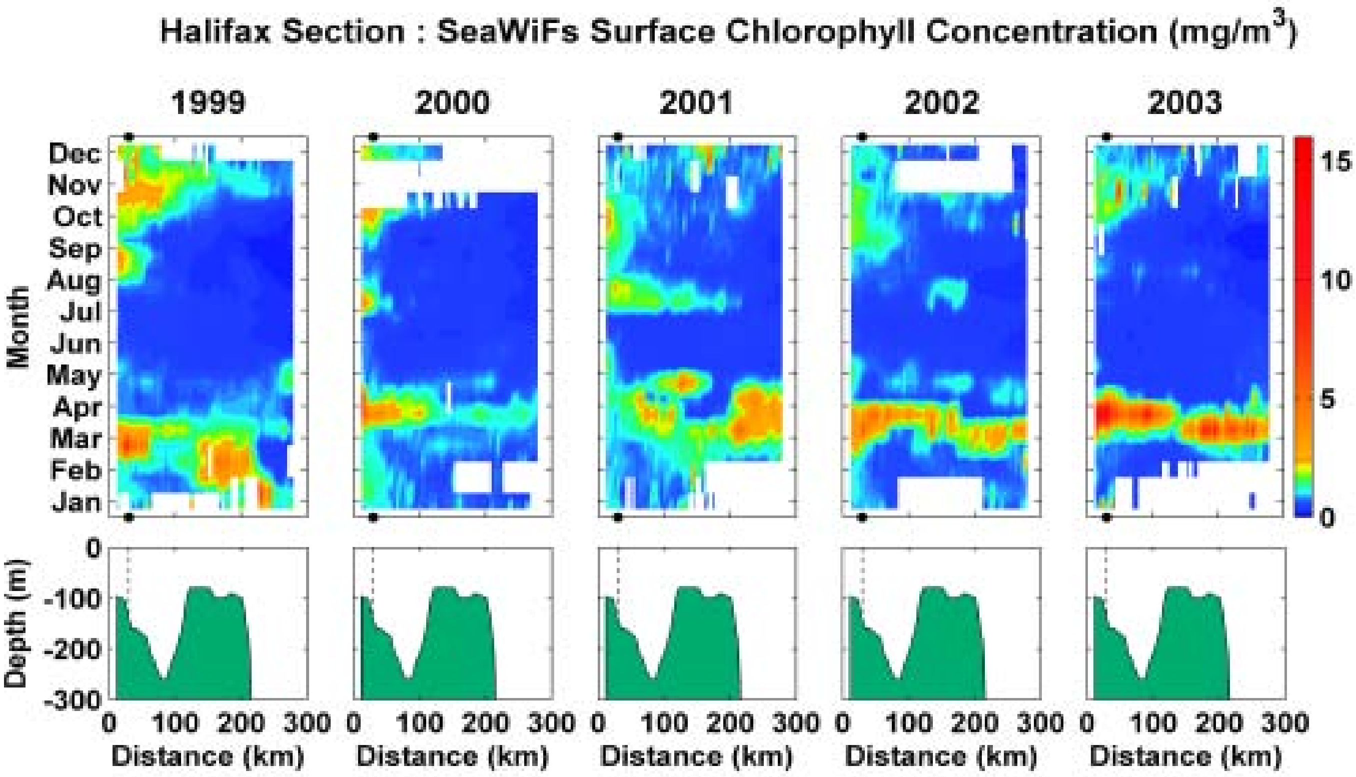


Figure 2: Surface chlorophyll concentration from SeaWiFS ocean colour satellite imagery: the concentration can be determined from the color bar on the right. The x-axes of the plots represent the cross-shelf distance from the coast (see Fig. 1). The depth to the bottom is shown below each panel. The black dot on the upper and lower horizontal axes of each panel indicates the location of Station 2 where moorings were deployed in the fall 2000. The vertical axes of the chlorophyll plots represent each mid-month of the year.

a depth of 40 m from September 30 to October 9 (Fig. 3e). This sub-surface chlorophyll maximum coincides with the strong, vertical density and nitrate change at the base of the ocean mixed layer (OML): a surface layer of water with nearly uniform density, (Fig. 3c and 3d). The strong density change at the base of the OML suppresses vertical mixing and diffusion of nutrients from the deeper water into the nutrient-depleted surface waters; consequently, phytoplankton can grow only at the base of the OML where there are some nutrients and sufficient light. At the mid-point of the mooring deployment the sub-surface bloom disappears, only to be followed by a stronger bloom at the surface.

The physical variables provide insight into the cause of the change in phytoplankton abundance and distribution. The data indicate that from October 9-15 some physical process caused levels of constant temperature, salinity, density, and nutrients to rise by approximately 20 m. The process is known as "coastal upwelling", whereby sustained winds along the shore from the southwest to the northeast cause surface water near the coast to move offshore. On the inner Scotian Shelf, the high-nutrient deep water moves upward replacing the surface water that moves offshore. This replenishes the nutrient inventory in the euphotic zone in the inshore region and enables the phytoplankton to flourish. During this process, the change of velocity with depth, measured by the ADCP, increases due to the increased wind stress at the surface, and the density stratification is reduced. The increased shear and reduced stratification lead to a further enhancement in the vertical transfer of nutrients through increased mixing and diffusion.

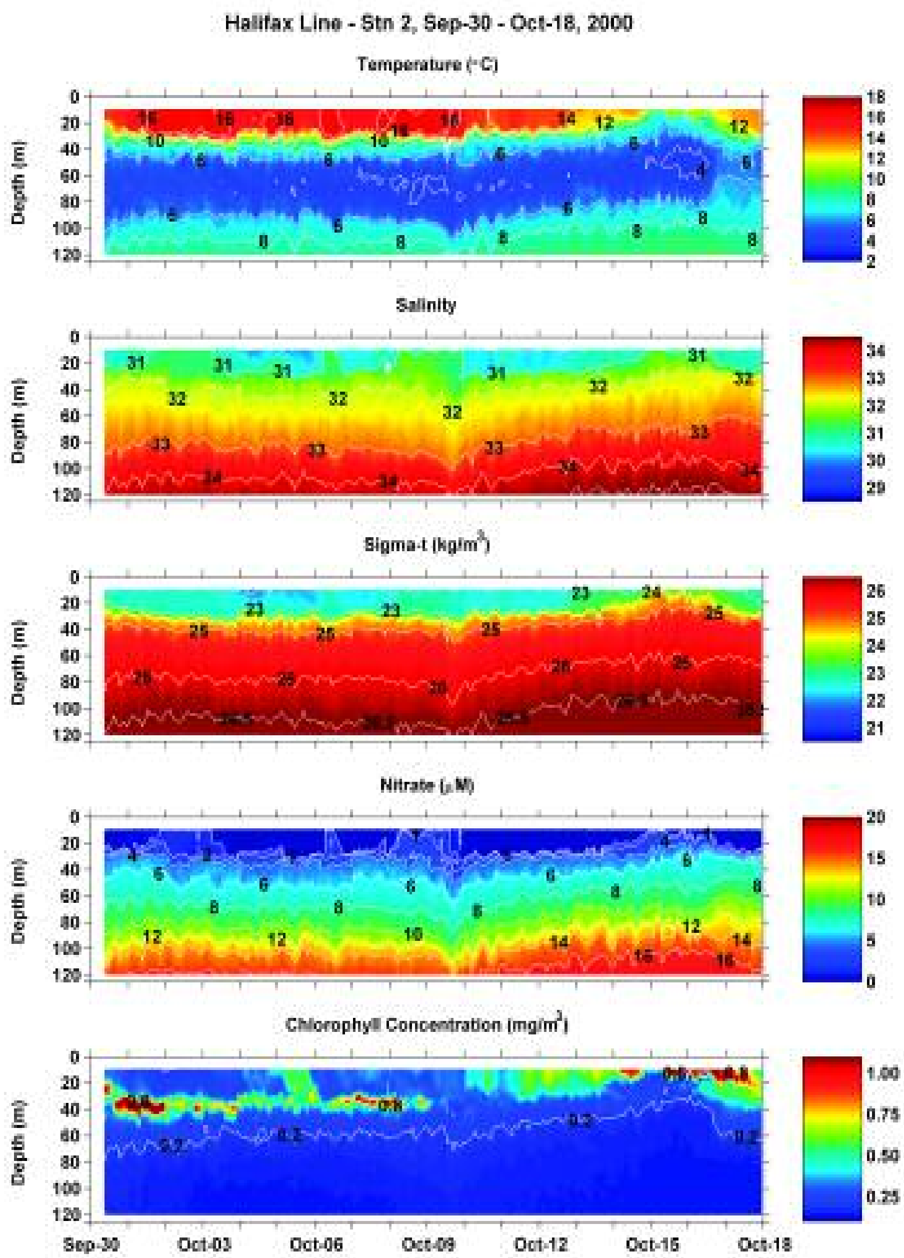


Figure 3: a) Temperature, b) salinity, c) density (sigma-t), d) nitrate, and e) chlorophyll concentrations measured with the SeaHorse moored profiler at Station 2, Halifax Section for the period September 30-October 18, 2000. The range of each can be determined by the colour bar on the right. The nitrate panel is based on water samples taken on September 30, October 7, 17, and 25. The strong correlation between nitrate and salinity allowed us to fill in the gaps (Greenan et al., 2002).

The data provide a compelling case for a strong role of coastal upwelling and wind-forced mixing in the production of fall bloom on the inner Scotian Shelf. However, it should be noted that horizontal advection can also play an important role in the changing hydrographic properties at the mooring site. To further support the role of coastal upwelling, SeaWiFS ocean colour satellite imagery shows that this process occurred all along the Nova Scotia coast from Louisbourg to Cape Sable during fall 2000. This imagery also provides evidence of bursts of higher chlorophyll levels during summer and large spatial differences within and between years. Therefore, the bloom is not a smoothly varying annual cycle but an intermittent process with significant variability in time and space. The timing and duration of phytoplankton blooms on the Scotian Shelf, affected strongly by physical processes, may have significant consequences on subsequent secondary and fisheries production (Platt et al. 2003).

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A Satellite Link to Shrimp Growth in the North Atlantic

Peter Koeller, Cesar Fuentes-Yaco, and Trevor Platt

The northern pink shrimp, *Pandalus borealis* (hereafter called shrimp), has become one of the most important fishery resources in the North Atlantic, with a 2004 catch of nearly half a million metric tons and a landed value approaching CAN $1 billion. The unprecedented increase in shrimp abundance during the 1990s has been linked to environmental factors such as temperature and to ecological changes, principally the decrease of shrimp predators like cod, *Gadus atlantica*, and other groundfish species (Figure 1).

The rise of the coldwater shrimp industry has not been without problems—large catches have led to an oversupply of shrimp and a decrease in prices. In addition, since the early 1990s, shrimp sizes have been decreasing steadily over a wide geographical area ranging from the Scotian Shelf to West Greenland (Figure 2). This is of both economic and biological concern. Because prices are directly related to shrimp size, the size decrease has exacerbated the oversupply problem. On the biological side, since the number of eggs a female produces is directly related to her size, the size decrease has resulted in fewer eggs produced per female, on average. This could eventually contribute to a population decline. The collapse of cod stocks was preceded by a decrease in individual fish size-at-age and at the age of maturation. Could the decreasing shrimp sizes be an early indication of a similar fate for shrimp? Understanding the factors causing the decrease is the key to answering this question.

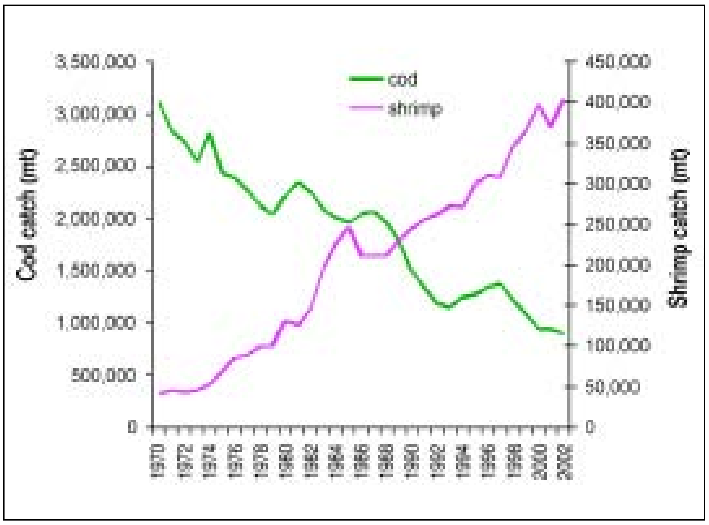


*Figure 1. Commercial catches of cod and shrimp (*Pandalus borealis*) in the north Atlantic, 1970-2002*

Several factors are implicated in the shrimp size decline, including the fishery itself. Shrimp fishermen are interested in the largest, most valuable individuals in the population. By cropping off the largest females the fishery will decrease their average size. This appears to have occurred, despite relatively low exploitation rates, i.e., the fraction of the total stock removed by the fishery. However, size decreases have occurred not just in the female fraction of the population, but also in the smaller males, which the fishery avoids. Evidently, other factors are also involved. Principal among these is food availability. Assuming a constant but limited food supply, the shrimp population increases of the 1990s would have resulted in less food available per shrimp, leading to slower growth and smaller sizes. Water temperature increases during the same period probably added to this problem. The metabolic requirements of coldblooded animals like shrimp are linked to temperature—warmer temperatures mean more food is required to produce the same amount of growth. If the food supply remains constant, warmer temperatures will decrease growth and shrimp sizes (Figure 3).

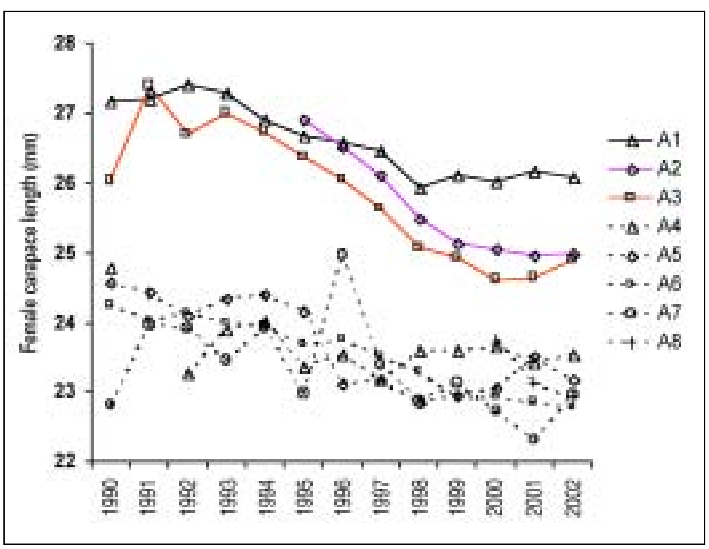


Figure 2. Chart shows the decrease of female carapace lengths on the Newfoundland Shelf (1990-2002). Note that shrimp in the northern areas (A1-3) are much larger than those in the mid-shelf or southern areas (A4-8). The large shrimp in and near Hudson Strait (A2-3) experienced the greatest size decreases.

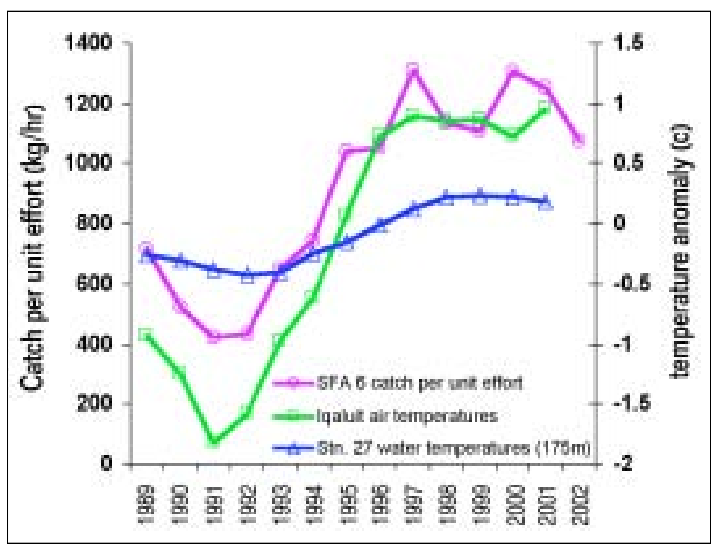


Figure 3. Shrimp density from commercial fishing vessel catch per unit effort in Shrimp Fishing Area 6 (SFA 6 corresponds to A7-8 in Figure 5) and annual mean temperature anomalies at Station 27 (5 year means, 175 meter depth) and air temperatures at Iqaluit.

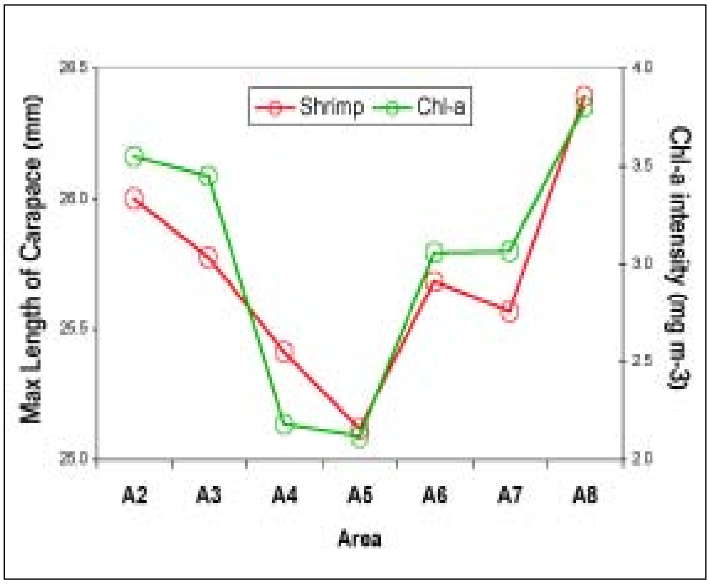


Figure 4. Average maximum size from survey samples and maximum Chlorophyll-a intensity by area for 1998-2003

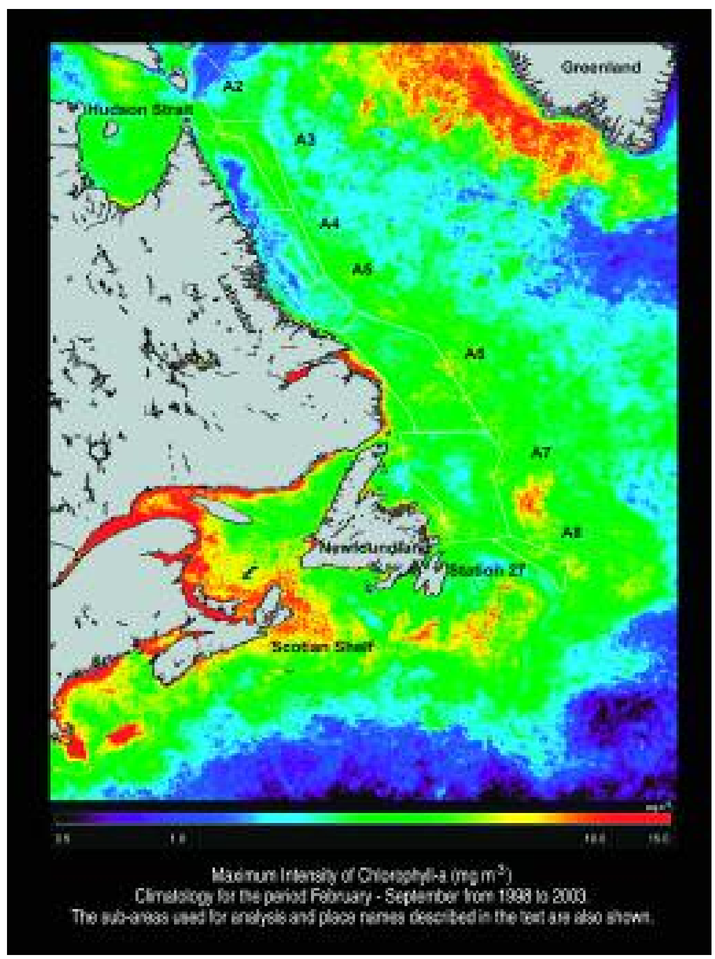
Fishery biologists can measure most of the parameters implicated in the shrimp size decrease. Carapace lengths in the population and the catch from research vessel surveys and fishery observer samples can be used to estimate fishery effects. Changes in water temperatures can be determined from ongoing monitoring programs. However, food availability, arguably the most important factor determining growth, has remained unmeasured at the large scales required—until recently. An important food source for young shrimp is phytoplankton, the microscopic plants growing near the surface of the ocean. Older shrimp also feed on the decomposed phytoplankton, or detritus, which reaches the bottom. The amount of phytoplankton in the surface waters can now be determined from satellite images of ocean colour, essentially the "green-ness" of the water.

Demonstrating a link between phytoplankton abundance, as determined by satellite imagery, and shrimp growth is complicated by difficulties in determining growth rates. Shrimp cannot be aged like fish because they have no bony hard parts with annual rings that can be counted to determine age, so it is difficult to tell how long it took a 10 cm long shrimp to become that large. In general, shrimp get larger with latitude: the farther north, the larger the shrimp (Figure 2). Biologists usually assume this is because growth is slower in colder northern waters. According to this view, shrimp are larger farther north because they are older and take longer to grow to these larger sizes, not because they grow faster in the same time period. This assumption ignores differences in food availability. However, the link between shrimp growth and food availability can be tested on the Newfoundland Shelf where water temperatures are known to remain relatively constant with latitude during the summer growth period—latitudinal changes in size are therefore more likely to be due to differences in food availability.

We divided the Newfoundland Shelf into sub-areas that encompass shrimp distribution, then calculated the average maximum shrimp size and the intensity of the chlorophyll maximum in each sub-area. These were significantly correlated for years for which both measurements are available (Figure 4). The results strongly suggest that the geographic differences in shrimp size on the Newfoundland Shelf are at least partly due to geographic differences in food availability caused by differences in phytoplankton production.

What causes these geographical differences in plankton production? The northern Newfoundland shelf (areas A2-A3 in Figure 5) is known to be an area of enhanced phytoplankton production due to higher nutrient concentrations originating from mixing processes in Hudson Strait. This decreases to a minimum near mid-shelf (A4-A5), and increases again in the south (A6-A8) due to other oceanographic processes. The regional differences in maximum phytoplankton bloom intensity on the Newfoundland-Labrador shelf are clearly seen in Figure 5, which also suggests that food may be more limiting to shrimp growth off Newfoundland than elsewhere in the northwest Atlantic, like West Greenland.

Could changes in plankton production characteristics have contributed to decreased growth in addition to the warmer temperatures and increasing shrimp abundance in the 1990s? The greatest size decreases occurred in the productive northern areas which harbour the largest shrimp (Figure 2) suggesting that these areas experienced a greater change in phytoplankton production pattern. For example, more freshwater runoff into Hudson Strait from increased atmospheric temperatures (Figure 3) and ice melt in the 1990s could have led to increased water column stability, resulting in decreased mixing of nutrients into the surface layers, lower primary production, and less food for shrimp. Whatever the cause, the availability of satellite data now makes it possible to consider changes in food availability in testing such hypotheses.



Port Sampling in the Maritimes Region of DFO

Peter Comeau and Bob Branton

The DFO Maritimes Region Port Sampling Program was developed at the St. Andrews Biological Station (SABS) in the mid-1940s to collect length, age, and catch data from commercial fish landings throughout the Maritime Provinces. In order to conduct assessments on fish stocks, fisheries scientists require data on the fish populations as well as data on the quantity, size, and age of fish captured in the commercial fisheries. The data and biological samples are processed and combined with other sources of population data to complete fish stock assessments that provide scientific advice on harvest levels.

In the 50 years the program has been in existence, there have been a number of changes in how it has operated. One very important and time-consuming responsibility of the port sampling technicians for many years was to determine the quantities of fish of each species being landed by the commercial fishery within the sampling area. This was accomplished by maintaining a good rapport with the fishing industry: fishermen and processors were willing to tell them what types and amounts of fish they were catching. In recent years, through the use of log books and dockside monitors, this is no longer a large part of a port sampler's job.

Port technician removing otoliths (small bone in head) from a silver hake

One aspect of the job that has remained the same has been the need to collect biological data from fish landed by the commercial fishery. In conjunction with stock assessment biologists, port samplers determine a target number of samples for the various fish stocks in the area. The technician tracks fishing activity and meets vessels as they return to port with their catch. The technician selects a random sample (250-300 fish) from the catch and each fish is then measured. Depending on the species, further information is collected such as materials used in age determination (otoliths

Port samplers meeting at St. Andrews Biological Station, 1974: back: Ted Sollows, Darrel Lyon, Bill Smith, Peggy Stewart, Ralph Halliday (project leader), Jim Martin. Front: Murray Fraser, Russell MacPherson, Charlie Monaghan, Winni Chaisson, Rex Hunter

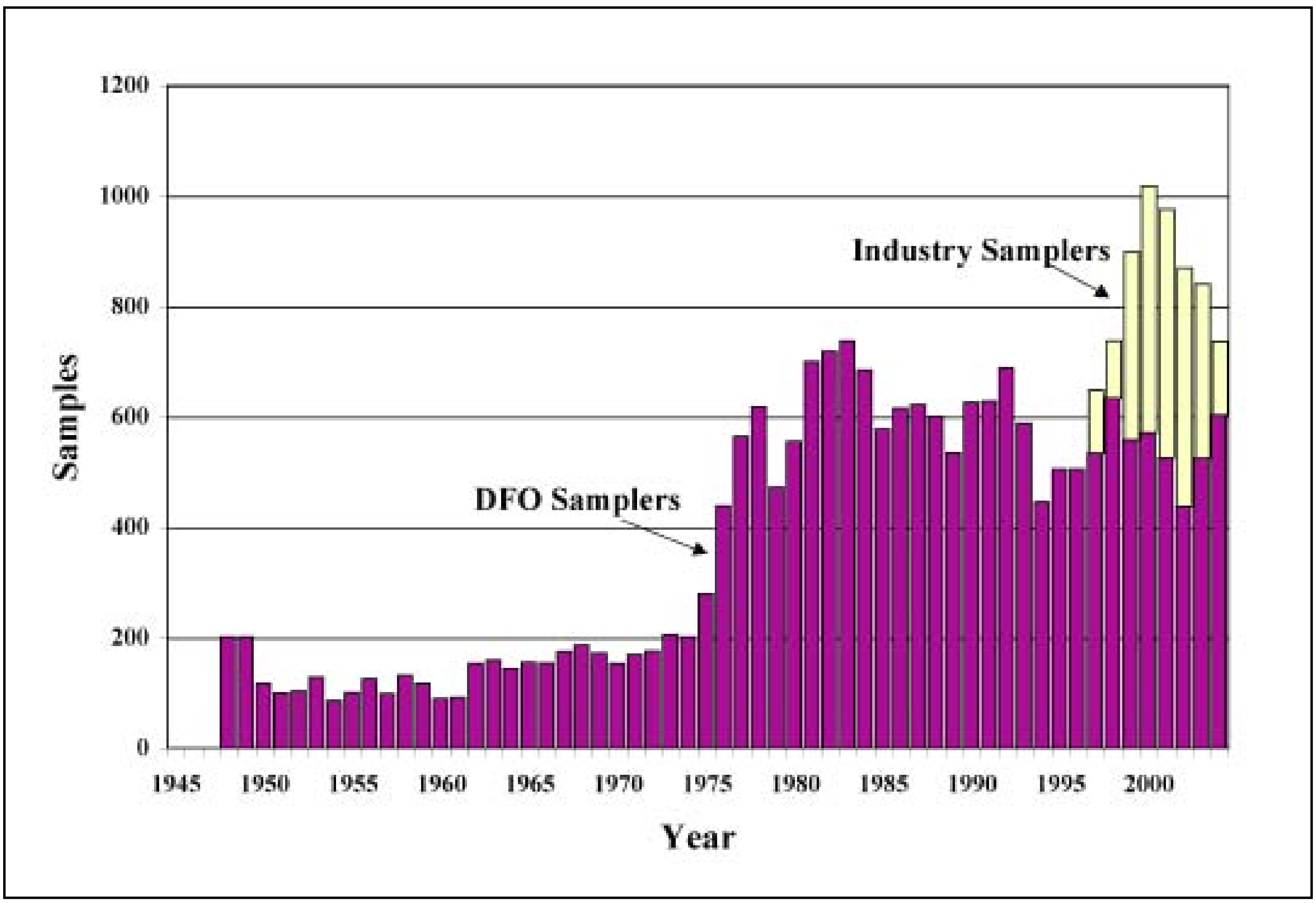
Gilbert Donaldson (DFO port technician) trains Susan d'Entremont (industry sampling technician, now with DFO) how to sample silver hake on the Dennis Point Wharf in Pubnico, 2000.

and/or scales), gender ratio, gonad maturity stage, individual fish weights, liver weights, and gonad weights. The basic tools of the trade—measuring board, forceps, and knives—have remained the same over the years although the materials used have improved to keep up with health standards in fish plants. For example, measuring boards have gone from wood to aluminum; knives have changed from wooden to plastic handles, with stainless steel blades.

Other ways in which the program has changed are in the size of territory covered by the program and the number of technicians in the field. At one time, Maritimes Region samplers were responsible for all of New Brunswick, Prince Edward Island, and Nova Scotia. With the creation of the Gulf Region, this area has been reduced to the coast of Nova Scotia from Bay St. Lawrence to the Bay of Fundy, and the south coast of New Brunswick. The declining number of field technicians has been a response to both the territory reduction and to the way in which the fishery operates. In 1977, with the introduction of the 200-mile-limit and the creation of the Marine Fish Division, the sampling program transferred from SABS to BIO. The number of port sampling technicians has gone from 10 full-time in the early 1970s to one full-time and two part-time samplers in 2004. The use of computers has also changed the way the program operates. In the early days of the program, all data was sent to SABS to be entered onto punchcards. Starting in the mid-1980s, the samplers were able to enter the data they collected directly into the database at BIO from their field offices.

Despite the reduction in field-based technicians, the program has been able to maintain sampling levels in recent years. This has been accomplished through a number of alternative sources of samples that now can be used because of changes in how the fishery is conducted. We have arrangements with the fishing industry to provide additional samples, in particular with Blue Wave Fisheries in Port Mouton and the Scotia Fundy Mobile Gear Fishermen's Association in southwestern Nova Scotia. As well as these sampling arrangements, new developmental and exploratory fisheries, such as the dogfish fishery, provide samples as part of the scientific requirements of their joint project arrangement. We have also supplemented samples by deploying SABS or BIO technicians into the field for short periods of time.

Although the Port Sampling program has changed a great deal over the years, it still provides a vital part of the data required for the assessment of the health of fish stocks. The data generated through the sampling program provide a time series of the biology of fish in our region that spans almost 50 years and is the oldest database at the Marine Fish Division at BIO. Stock assessment scientists use these data in the production of Stock Status Reports, Research Documents, and scientific publications. Data are accessed through the Marine Fish Division's Virtual Data Centre. The role of our DFO field technicians will likely change further to incorporate more of a supervisory and quality control role for industry-based technicians, but they will continue to provide an important service to our understanding of the fishery and the biology of the fish stocks.



Number of samples collected per year by DFO and industry-based samplers

Atlantic Whitefish: At Home and Alone in Nova Scotia

R.G. Bradford

*Figure 1. Atlantic whitefish (*Coregonus huntsmani*)*

Imagine if existence on Earth, for you and all of your kind, was confined to the area visible from the brow of a low hill. That is the reality for Atlantic whitefish (*Coregonus huntsmani*) (Figure 1), survivors, once widespread, of an ice age now resident in three small Nova Scotia lakes, and endangered. Our assistance is required for their survival.

Atlantic whitefish belong to the whitefish subfamily Coregoninae, an abundant and taxonomically and ecologically diverse group of fishes that inhabit the arctic and temperate regions of the northern hemisphere. In North America, the genus *Coregonus* diverged more than one hundred thousand years ago into the groups known today as the lake whitefishes and the ciscoes (lake herrings). The Atlantic whitefish is a relict species of the progenitor form that existed prior to divergence. Endemic to Canada, and with no recorded occurrences outside of Nova Scotia, Atlantic whitefish are an important component of biodiversity: locally, nationally, and globally.

Like many of the freshwater dependent fishes of eastern Canada, Atlantic whitefish likely survived the last episode of North American glaciation through retreat to one or more refugia. In concert with the growth and advance of the continental ice sheet, sea level fell as glaciers stored increasing quantities of water. It is thought that conditions suitable for persistence of freshwater species existed along the seaward edge of one or more of the exposed Scotian Shelf banks.

The geographic extent of the dispersal of Atlantic whitefish to eastern North American rivers upon retreat of the glaciers approximately ten thousand years ago likely never will be known. By the time of their first description in 1922 as a unique form of whitefish, Atlantic whitefish exhibited a disjunct distribution restricted to two southwestern Nova Scotia rivers, the Tusket-Annis and Petite Riviere (Figure 2). Genetic and demographic factors indicate the species must have occupied a broader contiguous distribution at an earlier time. The relative roles of natural versus human factors in determining their documented distribution are not known. Speculative interpretations refer to the naturally acidic character of many Nova Scotia river drainages, construction by early colonists of dams lacking fish passage, and indiscriminant harvesting. What is certain is the alarming reduction in area of

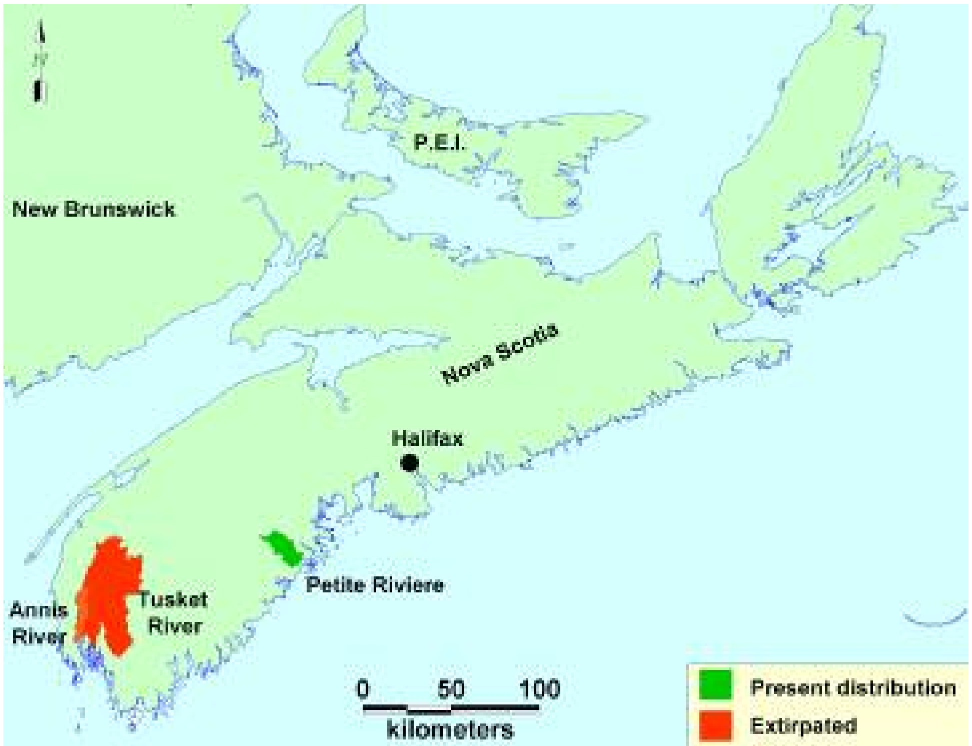


Figure 2. Rivers for which Atlantic whitefish presence has been documented

Figure 3. Satellite image shows the three lakes that define the present global distribution of Atlantic whitefish. Minamkeak Lake was diverted into the Petite Riviere in 1903. Note the relatively undeveloped character of the land surrounding the lakes in relation to the wider area of the image. Source: www.terraserver.com

occupancy of, and loss of ecological diversity within, the species that has occurred during the past several decades.

The Tusket-Annis population appears to have been entirely anadromous, whereas both anadromous and wholly freshwater resident fish were reported from the Petite Riviere. Atlantic whitefish were last reported in the Tusket-Annis system in 1982. Life-cycle closure is now certain only for the wholly freshwater-resident population within the Petite Riviere, which exhibit low genetic diversity symptomatic of past instances of extreme low abundance. There is no evidence from recent field surveys of the existence of previously undiscovered populations.

Survival of Atlantic whitefish since 1982 has been wholly contingent on persistence within the approximately 16 km^2 of aquatic habitat defined by three lakes within the Petite Riviere system (Figure 3). It is perhaps fortuitous that water quality within these same lakes receives exceptional protection owing to their role as the municipal water supply for the Town of Bridgewater. These lakes are not accessible from the sea because of the presence of a dam which lacks a fishway. A recent illegal introduction of non-native smallmouth bass (*Micropterus dolomieu*) into one of the three lakes, and their likely colonization into the remaining lakes, casts uncertainty on the status of the Atlantic whitefish residing there, and by extension, of the species.

The Atlantic Whitefish Conservation and Recovery Team has been active in recovery planning since 1999. Recovery planning is generally oriented around reduction of risk to species survival through range expansion, namely: 1) repatriation of anadromous Atlantic whitefish to the Tusket-Annis rivers, 2) restoration of the anadromous run to the Petite Riviere, and 3) creation of alternate populations elsewhere in southwestern Nova Scotia. The likelihood that any of these objectives will occur in the future through natural colonization of new habitat is poor. Species recovery can be effected only through a combination of direct human intervention and concerted societal action.

Recent field and laboratory research provides encouragement that recovery is feasible. It is highly probable, for example, that Atlantic whitefish naturally colonized one of the three lakes where the species occurs (Fig. 3) following diversion of the lake in 1903 into the Petite Riviere.

Creation of additional lake resident populations elsewhere may therefore be possible. Strays from the Petite Riviere lakes are known to have wintered at sea in recent years. Experiments underway at Dalhousie University indicate that the remnant population of Atlantic whitefish has maintained tolerance to full seawater. Thus, the freshwater resident fish may be suitable donor stock to re-establish the anadromous runs. Research at DFO's Mersey Biodiversity Facility has demonstrated, through repeated successful spawning and rearing of Atlantic whitefish in captivity (Figure 4), that stocking could be a robust conservation tool to assist with fulfillment of recovery objectives. A mating program to maintain fitness of the offspring has been developed with the assistance of the Marine Gene Probe Laboratory, Dalhousie University.

Recently listed as an endangered species under the federal Species at Risk Act (SARA), Atlantic whitefish now receive extraordinary protection that includes prohibitions against harm to either the individuals or their critical habitat. Protective measures already effected include closure of the three Petite Riviere lakes to angling during times when Atlantic whitefish are susceptible to capture, and the banning of fishing with bait in these lakes during the open angling season. Accurate field identifications by conservation officers are supported with criteria developed in collaboration with Acadia University to distinguish Atlantic whitefish from other whitefish species. Research to support definition of critical habitat in the context of water quality, forage, and thermal preferences is nearing completion. Research over the next few years will include the tracking of individual wild fish to improve understanding of the habitat requirements of Atlantic whitefish.

Although of indisputable conservation benefit, the prohibitions against harm under SARA necessarily restrict options for establishing additional populations elsewhere in southwestern Nova Scotia. Presence of Atlantic whitefish could potentially adversely affect normal use and enjoyment of personal property or local resources, both commercial and recreational fishing, or shoreline property use, for example. In addition to the ecological and biological suitability factors, due consideration to socio-economic factors during selection of candidate stocking sites will be required.

Successful implementation of any of the recovery objectives ultimately rests with public receptiveness and stewardship at the community level. Communication and stewardship initiatives already enacted include initiatives by Nova Scotia Power Inc. to assess habitat quality within the Tusket-Annis rivers and to raise awareness of Atlantic whitefish at the local level. Complementary activities by Bluenose Coastal Action Foundation, Nova Scotia Department of Agriculture and Fisheries, Nova Scotia Museum of Natural History, South Shore Naturalist Society, and Tusket River Environmental Protection Association, have yielded additional communication products intended to increase public awareness of the Atlantic whitefish generally and of the threats posed by the illegal stocking of non-native fish species and deleterious land- and water-use practices.

The call to action has been answered at every level of government and by industry, academia, and environmental organizations. We are hopeful that the public will recognize the intrinsic value of accommodating the needs of a species in need of help.

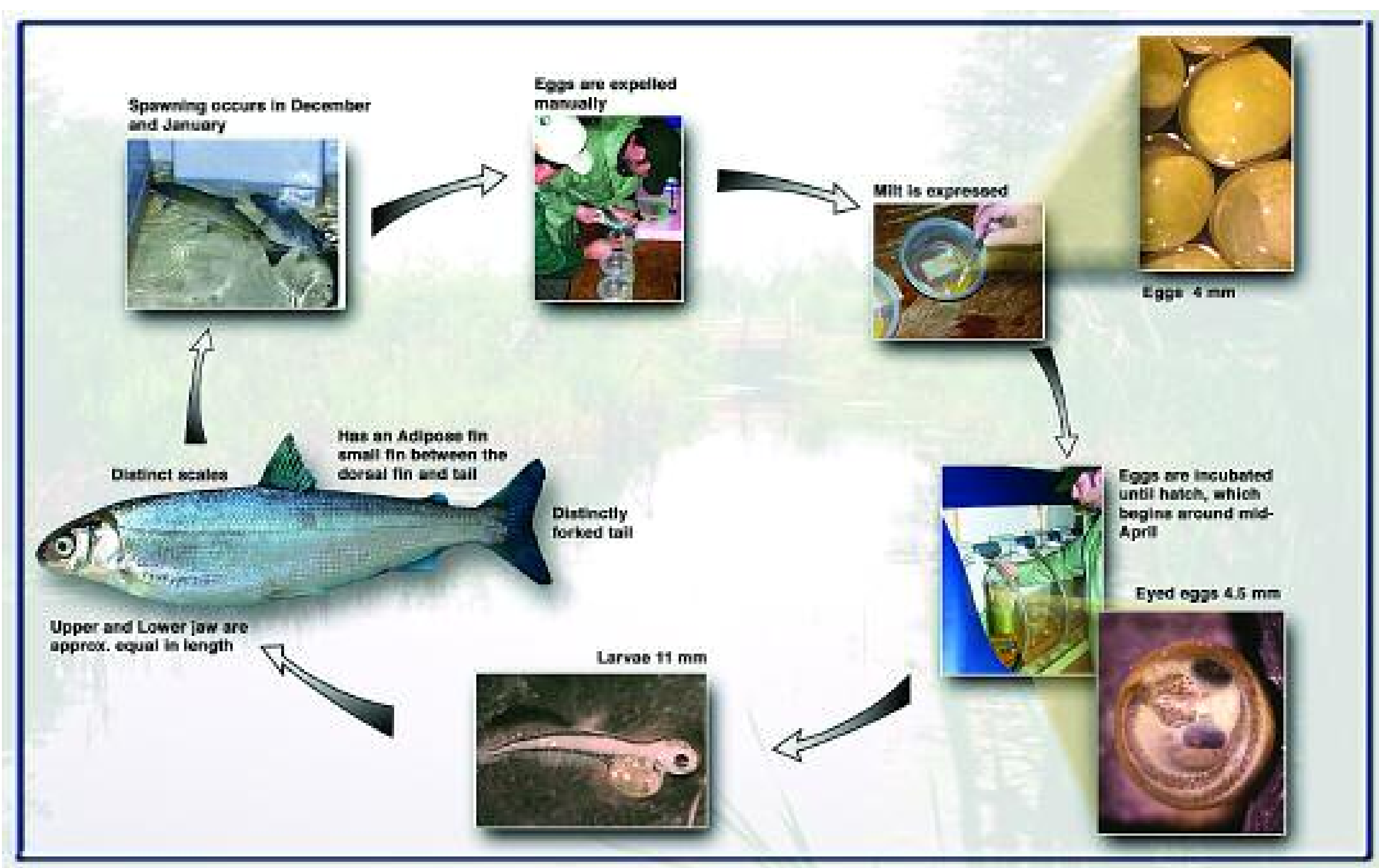


Figure 4. Captive rearing experiments at the DFO Mersey Biodiversity Facility

Measuring Freshwater Transports Through the Canadian Archipelago: Addressing the Climate Change Question

Jim Hamilton and Simon Prinsenberg

The Arctic Ocean is unique among the world's oceans because of its vast ice cover. Almost half of this ocean is capped year-round with a layer of ice that averages 3 m in thickness, and the ice-covered area is nearly doubled over the long winter season. There is evidence that the perennial portion of this ice cap is shrinking, and open-water conditions are persisting longer in the seasonally covered areas of the Arctic Ocean. Such changes have an impact on the local ecosystem and the people depending on it. Furthermore, ice cover insulates the atmosphere from the ocean, and reflects solar radiation into space with minimal heating affect; there is concern that a loss of ice cover could accelerate regional warming and result in further melting, not only of sea ice, but also some of the vast glaciers of Greenland and the Canadian Archipelago. The resulting release of fresh water from both of these sources may have significant, farther reaching effects. Global circulation patterns connect the world's oceans, redistributing heat and salt, thereby having a significant impact on climate. In the upper Atlantic Ocean, warm, salty water moving northward from the equator becomes heavier when cooled by Arctic air, and sinks to generate a deep southward return flow. If there is increased export of this lighter fresh water from the Arctic Ocean into the surface waters of the North Atlantic, it may inhibit this convection process, thereby altering this large-scale ocean circulation pattern.

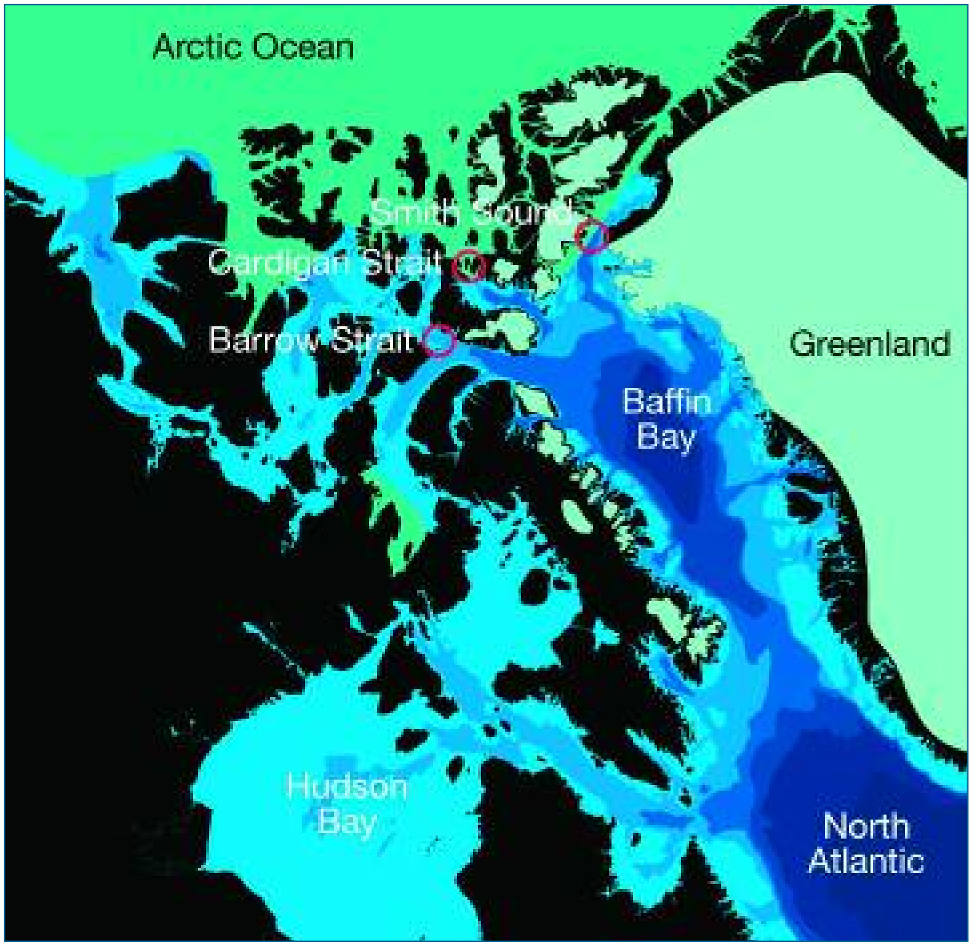


Figure 1. Map shows the Canadian Archipelago and surrounding waters with pathways connecting the Arctic Ocean to the Atlantic, including the Barrow Strait study site. Perennial sea ice is shown in dark green while glaciers are shown in light green.

To understand the response of the Arctic Ocean to global warming, it is necessary to have knowledge of its many components and their interconnections. With the potential impact of increased melting on global ocean circulation, the freshwater cycle in the Arctic is a primary concern. The principal sources of new fresh water into the Arctic Ocean are river runoff, inflow of slightly fresher Pacific water through Bering Strait, and precipitation. These are balanced by exports of fresh water (in ice and liquid form) through Fram Strait along the east coast of Greenland, and export through the three main passages of the Canadian Archipelago into the Northwest Atlantic Ocean. None of these parameters is easy to quantify accurately, but our knowledge is improving with the application of new tools and techniques for making the required measurements. Until recently, transports through the Canadian Archipelago have not been well quantified. A research program that started in 1998 has provided the opportunity to develop the required specialized instrumentation, and to obtain a six-year time series of current, salinity, and temperature data through Barrow Strait (Figure 1). These data have been used to calculate freshwater transports through this strait, and with the extended time series, have allowed us to quantify the seasonal and inter-annual variability of this parameter.

Unique aspects of the polar ocean environment have required development of specialized instrumentation and techniques to collect the data needed for this study. One challenge was measuring ocean current direction where our proximity to the north magnetic pole renders compasses in commercially available current meters useless because of the small horizontal component of the earth's magnetic field there. The technique developed to overcome this difficulty uses a precision heading reference system to measure the orientation of an upward-looking acoustic Doppler current profiler (ADCP) mounted in a streamlined underwater buoyancy (SUB) package (Figure 2). SUBs are a patented technology previously developed by BIO staff. The SUB ensures alignment with the flow, thereby reducing the time that the power-hungry precision heading reference needs to be on for each five-minute current profiler sample. The modest battery requirement allows for the complete instrument assembly to be a manageable, self-contained unit. These units serve as the top buoyancy in several of the sub-surface moorings in our array across Barrow Strait (Figure 3), providing detailed current speed and direction measurements, and ice drift over a 75 m depth interval. These moorings, and others, also support CTD instruments for measuring salinity, temperature, and depth, while yet another mooring in the array measures ice thickness. Since 2003, an ADCP with an extended range of 250 m has been used at one site. A deployment of this instrument is shown in Figure 4.

Ice covers the mooring location for ten months of the year. Ridges that form when ice is driven together by currents and winds can reach down to 20 or 30 m and sweep through the mooring area, presenting a real hazard to any equipment in this near surface layer. For this reason, none of our conventional moorings extend into this high-risk ice zone. Yet, it is in this near-surface layer that we can expect to see the freshest water, since it is lighter than the saltier water below. Since a principal goal of the study is to determine freshwater transport through the Strait, instrumentation was also developed at BIO to make these upper ocean salinity measurements. Icycler (Figure 5) consists of a winch in the main float of a mooring, which reels out a CTD float once a day using sonar to detect both the depth of the ice and a safe reel-out distance. When not profiling, the CTD float is reeled in below any danger of ice impact. A year-long record from Icycler is also shown in Figure 5. Through August to mid-October, water in the upper water column is 1-5 ppt (parts per thousand) fresher than at the 30 m level. The lack of data above 10 m from mid-March to mid-May suggests that an ice ridge formed and remained over the mooring until break-up commenced. Some of the data gaps earlier in the record are caused by ice avoidance, but others are a result of mooring knock-down in high currents.

Figure 2. Mooring deployment preparations showing one of the instrumented buoyancy assemblies: the acoustic Doppler current profiler protrudes through the top of the package, while the compass is the silver cylinder mounted in the tail.

The six-year series of comprehensive data we have now collected and analyzed, has allowed us to determine transports through Barrow Strait to a greater certainty than has been possible for any of the pathways that connect the Arctic Ocean to the Atlantic Ocean. We have found that the average freshwater flux through Barrow Strait is 1500 km^3/year, which is about 20% of the total freshwater export out of the Arctic Ocean, and substantially greater than previously thought. Seasonal variability is high as might be expected, with summer seeing the greatest freshwater transports, but more interesting is the substantial differences from year to year. We find that the annual freshwater transport can vary by as much as a factor of two from one year to the next. It seems then, that detecting a trend

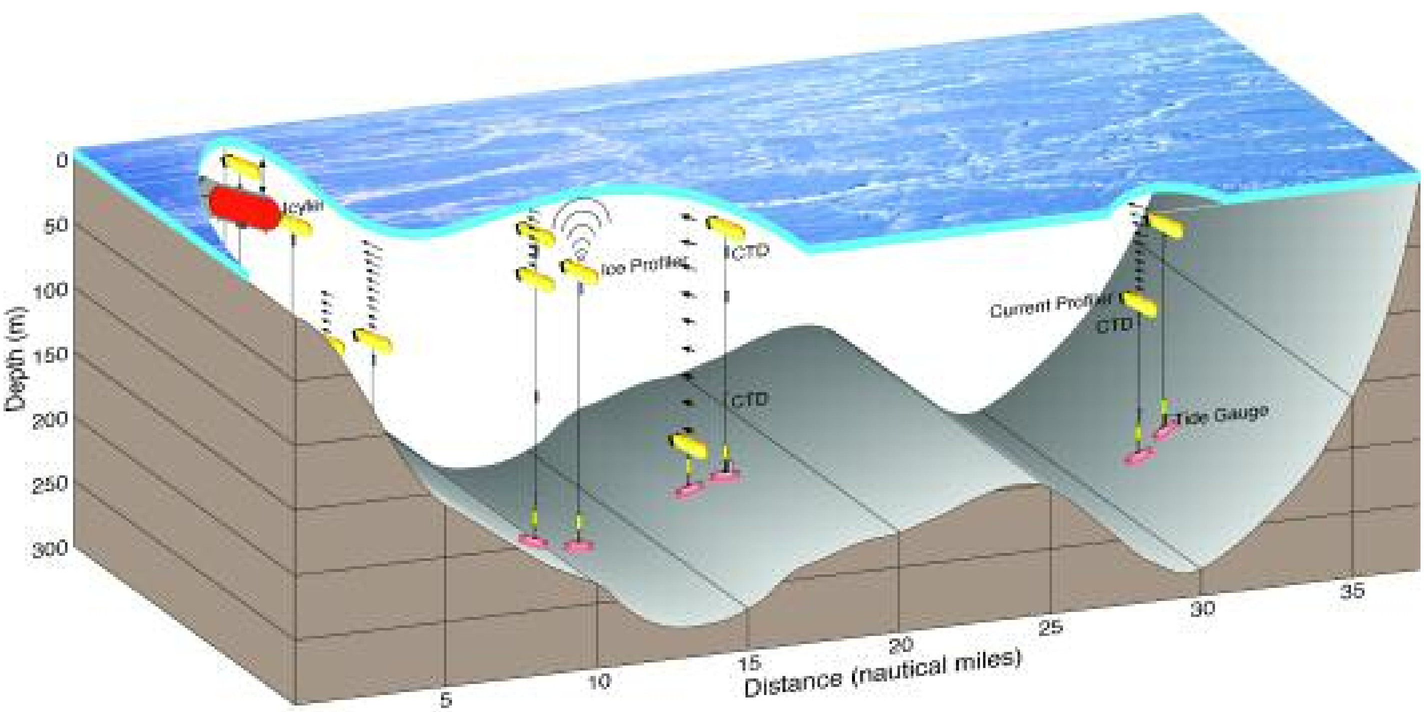


Figure 3. The instrumented mooring array across Barrow Strait

Figure 4. Deployment of an instrumented mooring

Figure 6. A mooring recovery

Figure 7. Part of the Barrow Strait team, from back to front: Bosun Gilles Gaudet and Seaman Eric Frenette, CCGS Des Groseilliers; Murray Scotney and Brian Beanlands, BIO

caused by increased ice cap melting will require a longer time series than we have collected to date. But correlations of the inter-annual variability we see in Barrow Strait with other components of the Arctic Ocean climate system are now being investigated. Slowly varying atmospheric patterns have a strong influence on the weather in the region, and likely generate oceanic response as well. Finding the links between the different components of this intricately coupled system will put us in a better position to predict how this sensitive part of the world will respond to climate change, and how changes there will affect the global ocean and climate systems.

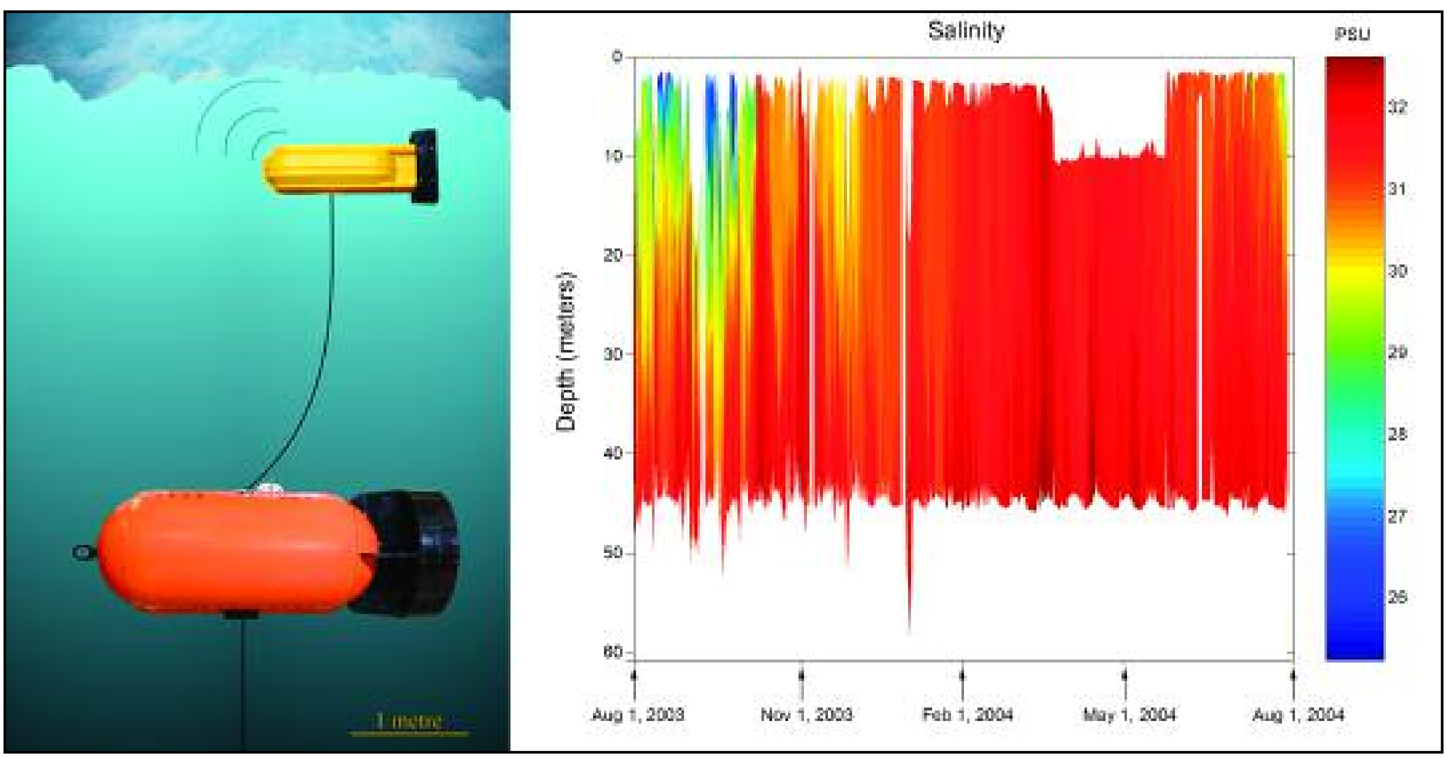


Figure 5. The "Icycler" Profiler, and a yearlong salinity record collected by the prototype in 2003-2004

The Petitcodiac Causeway: What Went Wrong?

Tim Milligan, Gary Bugden, Kristian Curran, Brent Law, and Murray Scotney

In June 1948, the Parliament of Canada created the Maritime Marshland Rehabilitation Administration (MMRA) which embarked on several major construction projects intended to preserve the region's dykelands. Based in Amherst, Nova Scotia (NS), the 70-member staff of the MMRA began applying modern engineering techniques to the traditional problems of dykeland construction and maintenance. Draglines and power shovels replaced the dyking spade and draft animals. Over the next 20 years, the MMRA ensured the protection of 18,000 hectares of tidal farmland in Nova Scotia and 15,000 hectares in New Brunswick (NB), building 373 kilometres of dyke in the process.

Construction of large tidal dams in the Shepody, Annapolis, Avon, Tantramar, Petitcodiac, and Memramcook rivers was seen as a major accomplishment of the MMRA. These giant concrete and steel aboiteaux, completed by the late 1960s and early 1970s, were designed to prevent tidal inundation of marshlands upstream, thus eliminating the need for many kilometres of dyke and smaller aboiteaux. At the same time, causeways provided a cheap alternative to costly bridges. Unfortunately, the benefits of these control structures did not come without a price.

Figure 1. The Petitcodiac River causeway under construction: downstream is to the left. The mudflat is growing at the same pace as the causeway is extended.

The causeways across the Avon River at Windsor NS and the Petitcodiac River at Moncton NB (Figure 1) had very negative impacts on the downstream side, where the disruption of tidal flow resulted in such high sedimentation rates that new mudflats were created almost as fast as the causeway was constructed. The extent and speed of formation of the mudflats were unexpected in both cases. At Moncton, the location of the causeway was moved inland so shipping to the city would not be disrupted. Within a year of completion, the cross sectional area of the Petitcodiac River at Moncton shrank by up to 80% as the entire system started to fill with sediment. Since the creation of the causeway, fish passage in the Petitcodiac has been hampered, leading to the extinction there of some species and a severe decline in others.

Scientists from DFO's Marine Environmental and Oceans Science divisions at BIO became involved with the Petitcodiac River as part of an Environmental Impact Assessment (EIA) conducted to consider alterations to the causeway that would permit the free movement of fish in the river. At the beginning of the EIA process a workshop was held to examine the value of computer modelling as the basis for the EIA. At the workshop it soon became apparent that there was little or no hard data available on the Petitcodiac River system and that much of the discussion on the hydrodynamics and sediment dynamics in the river was speculation. As a result, a research program to better understand the Petitcodiac River system was begun in the spring of 2002.

The upper reaches of the Bay of Fundy have some of the highest tides in the world. Also found there are some of the world's highest concentrations of suspended sediment. Sediment concentrations in the Petitcodiac regularly exceed 10 kg m^{-3} and can reach 400 kg m^{-3} near features such as tidal bores. (Normal coastal suspended sediment concentrations are closer to 0.001 - 0.01 kg m^{-3}.) Following construction of the Petitcodiac causeway these unusual conditions combined to produce sweeping changes to the environment.

The simplest approach to estimating the large-scale impact of an engineering work on sediment dynamics in a river or estuary is to consider a cross section through which a volume of water passes. Water flowing through a channel will generate a shear stress on the bottom proportional to the speed of the flow. The erosion and deposition of sediment in an estuary responds to the magnitude of this shear stress. A channel is in a state of equilibrium when no long-term changes in the area of a channel cross section take place, or in other words, the erosion and deposition of sediment are in balance. If the volume of water passing through the cross section is reduced, for example by the insertion of a causeway, then to maintain the same current speed and thus shear stress the area of the section will have to decrease. Reduced flow means less ability to resuspend sediment causing the channel to fill until the current speed increases and the bottom shear stress once again reaches equilibrium with the sediment.

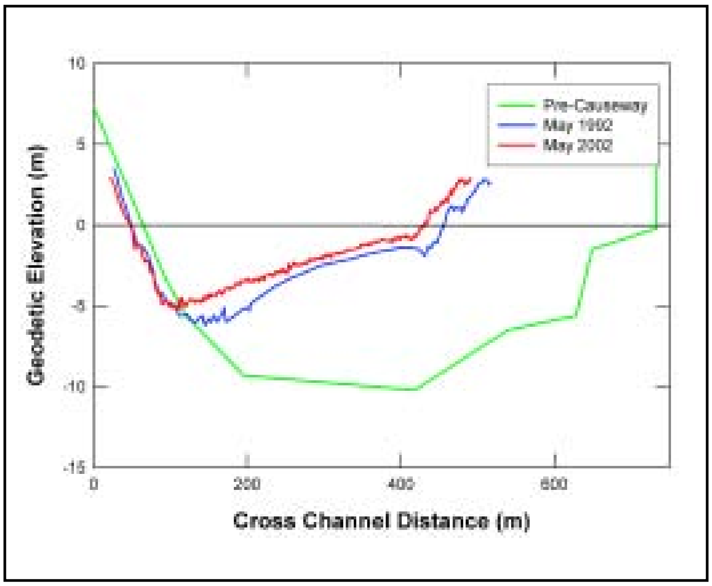


Figure 2. Cross-channel depth profiles from a section 15 km downstream of the causeway show the continuing decrease in channel cross-sectional area since causeway construction.

Figure 3. Sediment sample collected during causeway construction showing the layers deposited during each tide

In the case of the Petitcodiac, the tidal prism—the volume of water that passes through the cross section on every tide—dominates the flow. The characteristic tidal current speed through an estuary cross section may be estimated using only the geometry of the estuary and details of the tidal period and amplitude. Characteristic current speeds calculated for several Petitcodiac River cross sections, using parameter values both before and after causeway construction, revealed two things. Current speeds were much higher prior to causeway construction and, even though the cross sections have narrowed significantly since construction, the calculated current speeds have still not regained their pre-causeway values. This implies that the bottom shear stresses have not yet reached their equilibrium values, even after more than 30 years. Channel cross sections measured in 1992 and 2002 reveal that sediment is still, as predicted by the simple model described above, accumulating more than 15 km downstream of the causeway (Figure 2). There is no evidence that even this simple calculation was made for the Petitcodiac prior to causeway construction. Apparently post construction flows were estimated to be sufficient to resuspend and remove any deposited sediment. Shipping to the "port" of Moncton was not expected to be affected.

A second important factor also appears to have been overlooked. At the extreme suspended sediment concentrations encountered in the Petitcodiac, the individual sediment particles combine very rapidly to form aggregates or "flocs". These flocs have much higher settling velocities than the unaggregated particles. High floc settling velocities, on the order of 10 metres per hour, allow most of the material in suspension to accumulate on the bottom during slack tide. Recent studies on the Amazon Shelf, the Eel River in California, and the Po River in Italy show that in areas with very high concentrations of mud, sediment can accumulate on the bottom and resist resuspension even at very high current speeds. If a lot of sediment is available, then concentrations near the bed can grow high enough to suppress turbulence. Up to a 60% decrease in turbulence in sediment-rich suspensions

Figure 4. View downstream from the causeway showing the extensive new mud flats a year after causeway completion

Tidal bore at Moncton in winter

has been observed in the laboratory. When turbulence is suppressed, sediment becomes trapped near the bottom forming a mud-water slurry or "fluid mud". The effective density difference between the fluid mud and the overlying water can suppress the turbulence enough to prevent resuspension.

In the Petitcodiac, the Bay of Fundy provides an unlimited supply of sediment, brought upstream on the tide. As flow decreased during construction, more sediment would deposit during slack water. Higher sediment concentrations during resuspension events accelerated flocculation, which in turn led to greater deposition at slack water. Very soon, near-bed concentrations of sediment reached the point where fluid mud stabilized the water column preventing resuspension by the tidal currents. The result was the deposition of up to 2 cm of sediment near the causeway on every tide (Figure 3). Within a year several kilometres of the Petitcodiac were filled with mud (Figure 4).

The lack of appreciation of both the complicated sediment dynamics and the importance of maintaining critical flow speeds appears to be the reason for underestimating the environmental impacts of the causeway. The main objective of the MMRA at the time of causeway construction was the creation of farmland on the "rehabilitated" marshes. The impacts of the construction on the interconnected components of the Petitcodiac River ecosystem appear to have been neglected. The problems encountered following causeway construction, which continue to this day, clearly demonstrate the perils of attempting to manipulate one segment of a natural system in isolation. It is now broadly recognized that human activities in coastal ecosystems can have significant and long-lasting effects. Many of these activities can have non-linear or threshold effects, such that small changes in one part of the system can have unanticipated effects elsewhere. This makes predictions difficult and uncertain.

To answer the question posed in the title—what went wrong?—it seems that sound science and good judgment were missing at the time. Present scientific research and ocean management studies at BIO aim toward the sustainable use of natural resources by increasing the ecological sensitivity and content of management practices. Integrated Coastal Zone Management (ICZM) and Ecosystem Based Management (EBM) are two concepts in which stakeholders and regulators reach general agreement on the best mix of conservation, sustainable resource use, and economic development. EBM attempts to determine the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function during exploitation. It is acknowledged that both of these concepts require sound science to ensure informed management decisions. Had such concepts as ICZM and EBM existed during MMRA's time, the problems created by the Petitcodiac causeway might have been foreseen and avoided. By integrating science with management we hope to avoid another Petitcodiac.

BIO Science in Partnership

Where are the World's Largest Tides?

Charles T. O'Reilly (Canadian Hydrographic Service [CHS], BIO), Ron Solvason (CHS, Canadian Centre for Inland Waters, Burlington), and Christian Solomon (CHS, BIO)

Areas of large tides and their associated large currents have always provoked interest. The reasons include tidal power, tourism, navigation, the rich habitat of the extensive intertidal zone, and the scheduling of day-to-day coastal zone activities. Traditionally, the "World's Largest Tides" were believed to occur at Burntcoat Head, at the head of Minas Basin in the Bay of Fundy. However, over the past several decades, many people have held that the tides in Ungava Bay are equivalent to, or even greater than, the record Fundy tides. The issue has been fueled by media interest and has remained controversial because insufficient measurements were made at both sites after the debate erupted. Since 1998, new observations have been made at both sites using modern instrumentation. The CHS has completed the analysis of new tidal observations collected at Gauge Point in Leaf Basin, Ungava Bay. To resolve the question, these data are compared with analysis of new and old data from Burntcoat Head and Cobequid Bay.

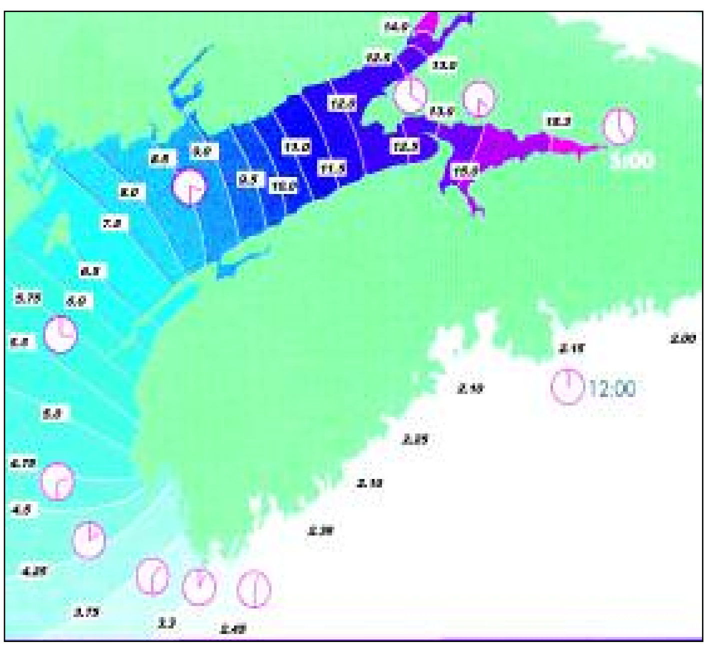


Figure 1. Minas Basin, Bay of Fundy

BACKGROUND

Oceanic tides are harmonic oscillations of the sea surface caused by the gravitational attraction between the sun, earth, and moon (Forrester, 1983). These oscillations are modulated by:

- **the relative alignment of the sun, earth, and moon:**
  -full and new moons produce maximum or "spring" tides,
  "destructive" misalignment occurs at quarter moons, producing minimal or "neap" tides,
  -the spring/neap pattern repeats twice a month;

- **the distance of Earth from the moon:**
  -the lunar gravitational pull is enhanced during the nearest approach (perigee) of the moon, in its elliptical lunar orbit, and is minimized during the farthest approach (apogee);

- **the distance of Earth from the sun:**
  -a similar variation occurs at the perihelion (point nearest the sun) and the aphelion (farthest point) of the solar orbit, but is much less than the lunar effect due to the great distance of the solar orbit;

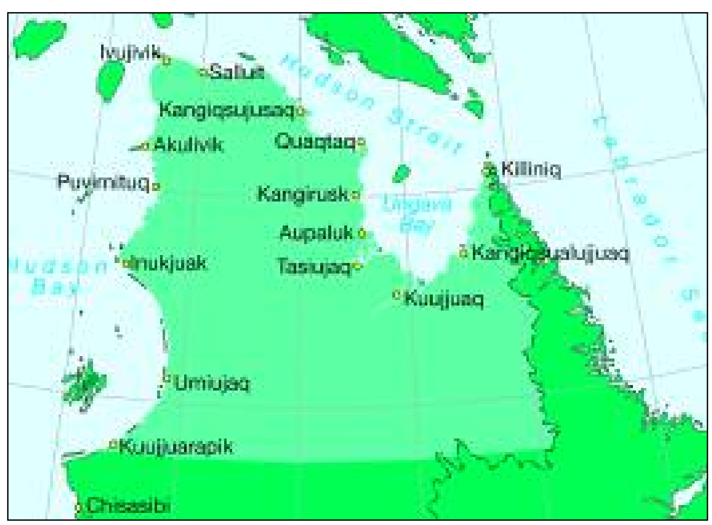
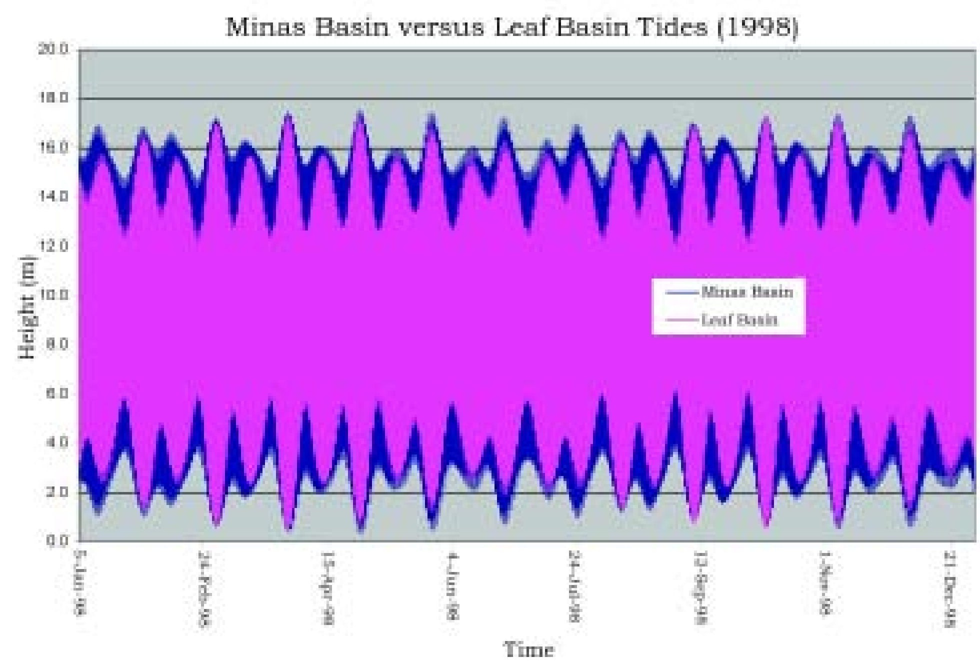


Figure 2. Leaf Basin, Ungava Bay



Burntcoat Head, Minas Basin

- *16.3 m range recorded in November 1998*
- *highest predicted extreme 17.0 m (+/- 0.4 m)*
- *lunar forcing appears dominant resonance feature*

Leaf Basin, Ungava Bay

- *16.2 m range recorded on March, 2002*
- *highest predicted extreme 16.8 m (+/- 0.4 m)*
- *lunar forcing was less, and solar forcing was more pronounced than in Minas Basin*

Figure 3. Annual predictions during period of Highest/Lowest Astronomic Tides

- **solar/lunar declination:**
  -the declination of the moon, when above or below the plane of the earth's equator, causes unequal daily tides. When the moon is on the equator, daily heights tend to be equal;

- **the precession of the lunar-ecliptic planes over an 18.6 year cycle:**
  -the multi-year variation caused by this precession in annual tidal extremes is typically less than 0.1 or 0.2 m, but can exceed 0.5 m in areas of extreme tides.

A minimum of 200 observation days is required to estimate accurate extreme tidal ranges. In the early 1950s, observations in Ungava Bay indicated very large tides, greater than 50 feet (15.2 metres), but the data were extremely poor, unsubstantiated, and too sparse for proper harmonic analysis. Bay of Fundy tides have been measured more frequently, but inadequately in most places, and only for very short periods. An exception is at Saint John, New Brunswick, where long-term observations indicate that the tides are getting larger by as much as a few decimeters per century. This is compatible with geologic evidence that Fundy tides have grown from normal coastal ranges to their present size in very recent millennia and are continuing to do so (Amos et al 2004).

METHODOLOGY

To determine the largest tidal range, only pure tidal motion over a 19-year period was considered: no barometric, wind, or other non-tidal influences. The other selection criterion was using the maximum high to adjacent low tide, i.e., an individual event, as opposed to highest tide in one event and lowest in another.

Both sites were gauged with submersible Aanderaa Water Level Recorders. These instruments use highly accurate sensors (oscillating quartz crystals) to measure total hydrostatic pressures and water temperatures, which are recorded at regular intervals. The pressures are converted to equivalent water level heights after applying factors for water temperature, salinity, and local gravity. This equipment gives an excellent measure of the tidal contribution to change in water level height. With care, measurements to within centimeters are possible in areas of large tides.

Figure 3 shows superimposed tidal predictions from both sites for 1998. This year experienced the Highest and Lowest Astronomic Tide during the 18.6-year precession of the lunar/ecliptic planes. From the predictions, it is apparent that on average, Minas Basin experiences higher tidal ranges, but that during extreme conditions, both sites are comparable.

CONCLUSIONS

- Both sites have measured tides significantly larger than anywhere in the world.

- Extreme values are only estimates.
- Neither site has ever been measured during extreme highest tides (occurs next in 2014).
- This controversy is mainly a tourism issue—all about "bragging rights".
- Further resolution will require very expensive field surveys, and regardless of findings, the truth may never be totally accepted.

The results obtained from analysis of the data in Ungava Bay indicate a maximum predicted tidal range to be 16.8 meters over the 19-year period from 1998 to 2016. The maximum predicted range in Minas Basin was 17.0 meters for the same period. The estimate of accuracy at both sites was determined to be plus or minus 0.4 meters (95% confidence). As both computations essentially agree within the limits of the error boundaries, the contest was concluded to be a draw. Both sites now share the official accolade, "World's Largest Tides".

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Towards a New Benthic Habitat-Mapping Paradigm

Vladimir Kostylev

Until recently, our knowledge of the seabed was mostly fragmented and constructed from "snapshots" scattered through space and time. These were bottom grab-and-trawl samples taken by various scientists with different objectives and, less often, photo and video observations. Most theoretical and experimental work in marine ecology was carried out in easily accessible intertidal or shallow subtidal zones, while most of the ecological studies of the deep-ocean floor were descriptive only. Despite the incomplete understanding of deep-water ecosystems, it has become apparent that human society impacts the seabed through increased fishing, mining, and hydrocarbon exploration. These adverse impacts are most profound on the continental shelves and at water depths less than 300 m.

Our challenge is to balance resource exploitation by humans against preservation of living and non-living seabed resources. This objective is difficult to achieve without a complete depiction of the seabed and better understanding of ecological processes there. Compared to terrestrial land management, where decision making is supported by satellite and photo imagery and is founded on a long history of ecological studies, seabed managers are facing two major problems: technology gap and theory gap.

Throughout the last decade, great technological advances have been made in acoustic mapping of the seafloor using high-resolution multibeam sonars, which yield geo-referenced, three-dimensional depictions of seabed morphology. Analysis of the acoustic signal obtained from multibeam sonar also allows us to deduce sediment properties, and, when used in conjunction with other geophysical instruments and augmented by geological sampling, the technology allows the production of highly accurate maps of seabed morphology and texture. These novel depictions of the seabed led to advancement of our understanding of the seafloor structure and dynamics, and have stimulated new theories and hypotheses. Benthic ecology, in particular, highly benefits from these technologies. The high-resolution habitat-mapping approach was implemented by Natural Resources Canada in the Gulf of Maine—on Georges, Browns, and German banks, and the results were useful for gaining insights into seabed ecology and for optimization of fishing strategies on these banks. Unfortunately, only a minor part of our continental shelf is currently mapped in high resolution.

The theoretical gap in our understanding of seabed ecosystems is based on the diversity of research needs and interests of science groups studying the oceans. Until recently, the knowledge had not been assimilated or summarized in an ecologically sound framework and had not been presented in a manner helpful to seabed managers and decision makers.

Three years ago, DFO, NRCan, and university scientists discussed the possibility of developing a classification scheme for the benthic habitats of the Scotian Shelf using a series of physical variables. In this interdisciplinary framework of habitat mapping we addressed these key questions:

> Which areas of the seafloor are the most sensitive to human impacts?
>
> How do we balance resource exploration and fisheries with available ecosystem services?

These questions were answered through detailed mapping and characterization of the seafloor environment based on current understanding of biological, geological, and oceanographic patterns and processes on the Scotian Shelf.

The ecological framework for the Scotian Shelf habitat classification was based on the consideration of the effects of the physical environment on life history traits of benthic species. Knowledge of life histories is important for seabed management when considering the likelihood of recovery of populations following a destructive event. Traits of benthic species, such as longevity, time to reach sexual maturity, frequency of reproduction, ability to re-colonize substrates, and timing of critical life phases, should all be considered before any disturbance is imposed on the species. For example, populations of longer-lived species are more sensitive because they will be replaced more slowly: if disturbance is more frequent than the time to reach sexual maturity or their cycle of reproduction, then population recovery from an impact is not likely. Risk to populations increases also if a species has restricted habitat requirements. One such group of species is deep-sea corals, which grow extremely slowly, exist for hundreds of years, and reproduce irregularly.

Life-history traits are the cornerstone of the habitat template hypothesis developed by T.R.E. Southwood in the 1970s. The hypothesis was based on the reasoning that characteristics of habitats, through selective forces such as biotic and abiotic factors, affect the fitness of individual organisms by modifying their growth rate, survival, fecundity, etc., in ecological time. This leads to the selection of an optimum combination of traits/tactics and to evolution of optimal life-history strategy. Each adaptation, however, has a cost: heavily armoured animals cannot move quickly; in animals with high fecundity, juvenile survival is low; species with high tolerance (e.g., lichens) have low competitive ability; and species adapted to a unique habitat (e.g., through co-evolution) risk death with the disappearance of a specific habitat.

The traits are selected by two major forces: the *disturbance* and the *adversity* of the environment (Figure 1). The disturbance factor reflects intensity of habitat destruction or alteration, or of durational stability of habitat in general. The adversity factor is related to the environmental stressors on the physiological functioning of organisms, that thus limits growth and reproduction. So it is reciprocal to the scope for growth. This disturbance-adversity template defines and constrains the life-history characteristics of species, without imposing uniformity of the traits. Ecosystems, like species, may be arranged in patterns against habitat template, where ecosystem character is a mix of population strategies and their interactions. In evolutionary perspective, an adverse environment will select species for their tolerance to the extremes of physical factors. A disturbed environment will favour short-lived species, which can quickly colonize an area and leave offspring.

DFO, in cooperation with NRCan, has made significant progress in understanding the ecology and structure of seafloor habitats of Eastern Canada by applying the habitat template model. Cooperative habitat mapping was carried out through interdepartmental agreements, as well as through informal linkages among scientists from different disciplines. The concept was implemented as a numerical model and mapped on the Scotian Shelf. The disturbance factor was defined from a number of physical variables mapped on the shelf, such as water depths, grain size, and strengths of tidal and wave-generated currents, expressed as a ratio of the total tide and wave-generated currents to a critical shear stress for the observed sediment grain size (Figure 2). The adversity (or scope for growth) factor of the template considers average bottom water temperature, productivity regime, vertical stratification, variability of environment, and other stressors affecting the amount of energy available for growth and reproduction of benthic communities (Figure 3). The model has been mapped in the Geographical Information System; it is easily adjustable to any geographic location and type of marine environment and has direct implications for seabed management.

The benefit of this approach is in combining a number of environmental variables in an ecologically meaningful manner. A map thus produced is more useful than a set of disparate maps depicting separate physical factors. For example, maps of natural disturbance could be used to predict risk of human disturbance—habitats and communities adapted to natural disturbance, such as shallow sandy bank tops, will be at a lower risk of adverse impacts than stable (e.g., deep-water) habitats. An adversity map could be

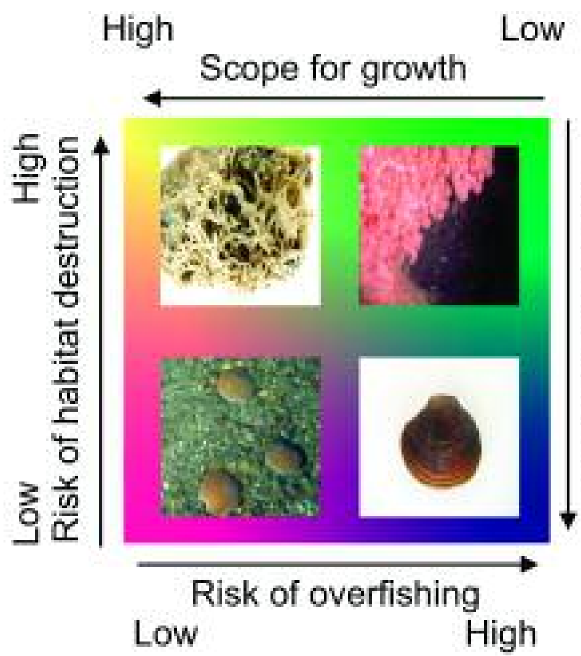

Figure 1.Template for seabed habitat classification and management: natural disturbance (right) and scope for growth (top) axes are descriptive, characterizing processes occurring on the seabed; risk of habitat destruction (left) and risk of overfishing (bottom) axes are prescriptive, serving as guidelines for management decisions.

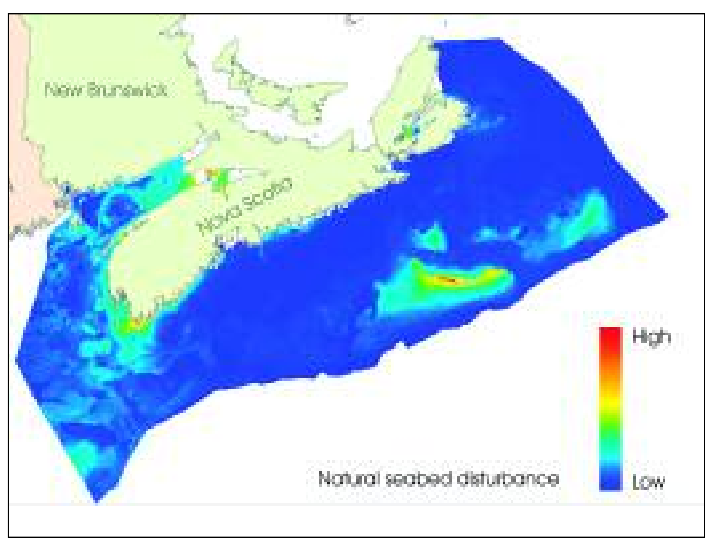

Figure 2. Intensity of natural seabed disturbance on the Scotian Shelf: calculations are based on known distribution of seabed grain size, and climatology of tidal and wave-generated currents. Risk from man-made habitat destruction is higher where the natural disturbance rate is low. Red = highly disturbed habitats; Blue = stable habitats

used to show which areas may have populations with fast recovery rates from fishing impacts and areas in which populations may be slow to recover or not recover at all. In particular, populations in less productive environments, having less energy for growth and reproduction, are at higher risk of extinction than the populations dwelling in highly productive environments. These maps can act as a guide for defining areas of concern, and will be important in considering the likelihood of recovery of populations following a destructive event.

The benthic habitat-mapping projects carried out at BIO will provide products that can be used for integrated seabed management, for example, to plan installation of structures on the sea floor and for the resolution of conflicts regarding sea floor use. This will allow a balance between the competing demands of resource exploration and of conservation. The data, expertise, and mapping solutions will meet a broad range of needs of governments, First Nations, ocean industries, other resource users, environmental interest groups, coastal communities, and university researchers.

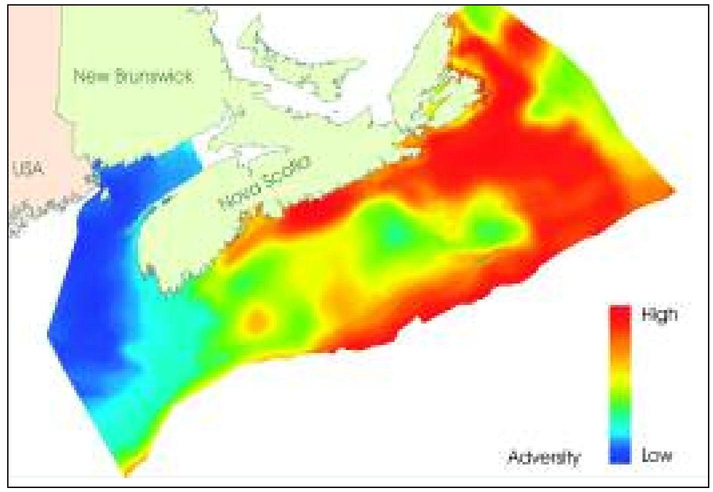

Figure 3. The image shows the adversity of the seabed environment (reciprocal of the scope for growth) based on chlorophyll concentration in the water column, vertical stratification, temperature variability, and mean bottom temperatures. The Gulf of Maine is mostly not adverse, because of high productivity and vertical water mixing, while most of the Eastern Scotian Shelf is adverse, because of physiological stress limiting population growth.

Monitoring The Gully Near-Bottom Acoustic Environment During an Exploration Seismic Survey

Norman Cochrane and Charles Hannah

The oceans are becoming an increasingly noisy home for sea creatures, due to ocean-related industrial activities and increased ship traffic. Recent observations off California suggest background noise levels in the ocean have increased almost ten-fold since the mid-1960s. For vocalizing marine mammals, such as whales, sound is an important tool for finding food and for social communications. Artificial noise could be especially harmful to an endangered species struggling for survival.

Three contributors to anthropogenic sound in the oceans have recently come under increased scrutiny: hydrocarbon exploration (seismics) and production, shipping-related noise, and military sonar activities. In Atlantic Canada, seismic exploration is of particular concern. Modern seismic explorations use large airgun arrays towed a few metres below the surface to generate and direct sound downwards in search of reflections from deep petroleum-bearing strata. Large quantities of sound are also radiated in other directions, sometimes detectable within the water column at hundreds and even thousands of kilometres from their source. Reportedly, exploration activity on the Scotian Shelf has been detected in the middle of the North Atlantic.

For the late spring and summer of 2003, the hydrocarbon exploration company Marathon Canada Ltd. commissioned a seismic survey of two lease blocks on the Scotian Slope (Figure 1). Survey lines were to approach within 4.5 km of the boundary of the Scotian Shelf Gully Marine Protected Area (MPA) and within about 16 km of the MPA's Gully Whale Sanctuary, the year-round home of the northern bottlenose whale (NBW), which is listed as endangered by the Committee on the Status of Endangered Wildlife in Canada. While environmental assessment modelling predicted that sound intensities reaching the Sanctuary would be acceptable, the propagation models contain simplifying assumptions and must assume in advance the detailed characteristics of the sound source as well as the sound speed structures within the ocean which strongly govern sound intensities at long ranges from the source.

The Gully Seismic Research Program was undertaken to directly measure sound levels, to test predictions, and to assess any observ-

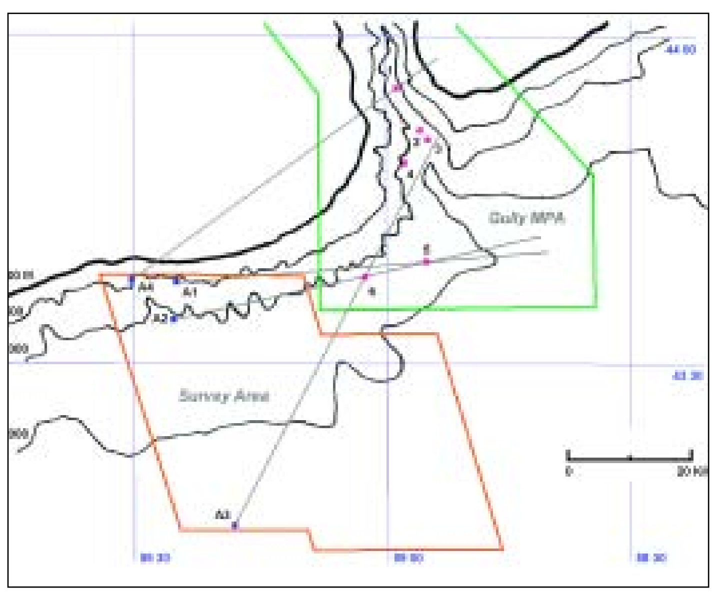

Figure 1. The Gully Seismic Research Program experiment area: Cortland and Empire Leases (west to east) are outlined in orange; boundaries of The Gully MPA are in green; Ocean Bottom Seismometer locations are numbered 1–6. Four modelled profiles (grey lines) radiate from seismic source locations A1–A4.

able responses of the NBW population to seismic sound. This was a joint initiative by industry, government, and academia to monitor sound in The Gully ecosystem, coordinated by the Centre for Offshore Oil and Gas Environmental Research (COOGER) under the overall leadership of Dr. Kenneth Lee of DFO Science. The acoustic component involved near- and long-range ship-based measurements of near-surface (upper 200 m) sound levels by JASCO Research Ltd., and extensive near-surface sound level and speed observations by researchers from DFO's Institut Maurice Lamontaigne and the University of Quebec at Rimouski. It also included sightings and recordings of marine mammals in the vicinity of The Gully. The DFO Ocean Physics group at BIO were tasked with measuring and analyzing the near-bottom sound field within the MPA, as described below.

Due to severe time constraints, it was decided to deploy hydrophone-equipped Ocean Bottom Seismometer (OBS) instrument packages at fixed locations to listen for both seismic signals and marine mammal vocalizations. Three new OBS packages were designed and constructed, and three additional OBS instruments from the Geological Survey of Canada (GSC)/Dalhousie University standing pool were upgraded to a similar status by OMNITECH Electronics in Dartmouth. Design specification was conducted by Dave Heffler of the GSC in consultation with DFO's Ocean Physics Section. The latter was also responsible for subsequent OBS instrument calibration.

After several delays, six OBSs were finally deployed (Fig. 1) from CCGS *Edward Cornwallis* by contract to GeoForce Ltd. All instruments were configured to record sounds up to about 2 kHz continuously. OBS #1, #2, and #3, deployed in the known NBW concentration area, were additionally equipped with a "click detector" channel to capture high frequency NBW click-type vocalizations extending to above 20 kHz. Rushed development of sophisticated equipment invariably results in problems: OBS #2 and #3 failed on deployment due to flooded connectors, while a glitch in OBS #4 resulted in only a partial data set. The start-up delays precluded planned close scientific survey vessel approaches to the MPA. Instead, OBS recording was confined to the regular survey in the western half of Cortland block (Fig. 1); nevertheless, useful data were obtained.

Sound levels at OBS #5 (Figure 2) and #6 were markedly enhanced during seismic shooting. Levels at OBS #1, and especially #4, were lower due to the shielding effect of locally downslope bathymetry. Comparison of the direct hydrophone and click detector outputs from OBS #1 revealed a multitude of low frequency, click-like signals fairly confidently ascribed to sperm whales. Occasional distinctive click vocalizations appeared on the click detector channel alone, with characteristics previously associated with the NBW. A comparative analysis of 14 hours of data during seismic shooting and a similar length of non-seismic section by Marjo Laurinolli, an investigator with considerable prior experience with marine mammal sounds, revealed that assumed NBW click vocalizations were statistically more frequent during the seismic periods. However, the short stretch of applicable data precluded drawing a firm causal connection with the seismics.

A major goal was to determine whether seismic sound levels far from the source can be accurately predicted from theory. Prediction requires both a source model providing an accurate representation of the impulse emitted by the airgun array and a transmission loss model describing how the impulse is modified in transit to the observation point. A source model for the 3090 cu. in. *Ramform Viking* airgun array was developed in-house. Using a frequency-based transmission loss model, specifically the "RAM" parabolic equation model developed at the U.S. Naval Research Laboratory, predicted seismic acoustic levels were calculated (sample computation, Figure 3) and compared to observed levels at five frequencies between 25 and 400 Hz for four contrasting sections as marked in Fig. 1.

Analysis showed that individual acoustic levels were not especially well predicted. Since the (signed) differences between predicted and observed levels average to only 4 dB our general approach seems validated, but the large magnitude of individual differences, averaging about 10 dB, give cause for concern. The large individual differences probably indicate that the full complexity of the acoustic generation-transmission-reception process was not being captured by the models. One problem area stems from observing very near the

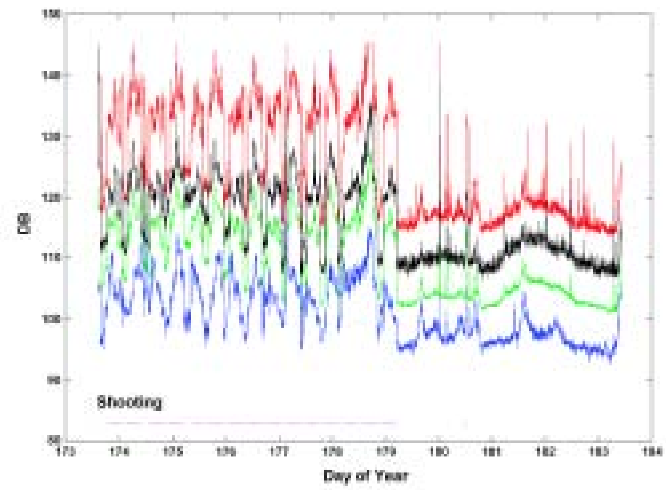

Figure 2. Broadband acoustic levels at OBS #5 in decibels relative to a reference pressure of 1 µPascal (dB re 1 µPa) over entire recording period
Traces:
Red: Maximum acoustic pressure amplitude observed within consecutive 300 second (s) intervals; Green: RMS (root mean square) amplitude over same interval; Black: Maximum RMS amplitude in any 1 s interval within the larger 300 s interval
Blue: Minimum RMS amplitude in any 1 s interval as previous
Magenta horizontal lines indicate active shooting periods (shooting was suspended between survey lines). Day 173 corresponds to 0000Z 23 June 2003.

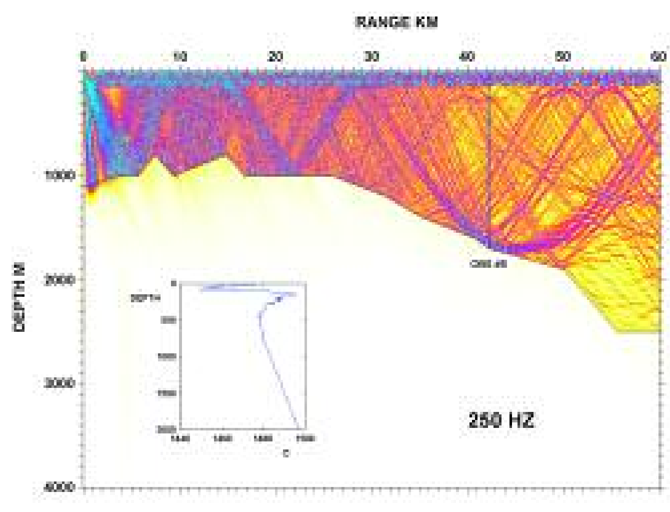

Figure 3. Shown are modelled acoustic intensities at 250 Hz along the profile originating at source location A2 in Figure 1.
Intensities increase from yellow to cyan. Normal cylindrical spreading losses with range have been removed. Insert shows vertical profile of sound speed (c).

bottom—a major acoustic discontinuity which has the potential to render sound levels very sensitive to local bottom properties. Also, modelled sound ray paths deeper than several hundred meters were frequently isolated and narrow, making direct ray impingements at an OBS a somewhat hit-or-miss process dependent on the precise deep sound speed profile. These two factors could largely account for the individual discrepancies. The model results did show that acoustic levels at the OBS locations in 1000–1700 m water depths should be relatively insensitive to seasonable variations in the sound speed profile in the upper water column, provided the relevant sound paths do not cross the shallow continental shelf. More extensive model comparisons may better elucidate the accuracy of predicted seismic sound levels.

Theoretical modelling of elementary sophistication does not appear to be a fully adequate substitute for direct sound monitoring in deep-water, very near-bottom environments. Future instrumental developments could include intelligent high-bandwidth, real-time signal processing internal to the OBSs, enabling vocalizing animals to be more reliably classified for behavioural studies. Four or more simultaneously recording OBSs would allow the tracking of click origins in three-dimensional space, facilitating more-focused behavioural studies. Multiple OBS-like recorders suspended from deep-water moorings would open the entire water column to acoustic monitoring. When combined with real-time processing and a satellite telemetry capability, a moored system could allow warnings of excessive sound levels to be telemetered immediately to responsible authorities.

This work was supported by Petroleum Research Atlantic Canada, the Environmental Studies Research Fund, funding under SARCEP (DFO's Species at Risk funding program), and NRCan's Geological Survey of Canada (Atlantic).

Blue Mussels: Canaries of the Sea

Gareth Harding[1], Steve Jones[2], Peter Wells[3], Jamie Aube[4], Guy Brun[4], Peter Hennigar[3], Christian Krahforst[5], Natalie Landry[6], Jack Schwartz[7], J. Stahlnecker[8], Darryl Taylor[9], Bruce Thorpe[10], Louise White[11], and Peter Vass[1]

The premiers of Nova Scotia (NS) and New Brunswick (NB) and the governors of Massachusetts (MA), New Hampshire (NH), and Maine (ME) signed the *Agreement on the Conservation of the Marine Environment of the Gulf of Maine* in December 1989. This agreement established the Gulf of Maine Council (GOMC) on the Marine Environment whose mission is to maintain and enhance environmental quality in this region. The same year the GOMC created the Environmental Quality Monitoring Committee (EQMC) to provide information on the health of the Gulf of Maine. This committee was created with staff from various provincial, state, and federal departments, including DFO, and interested scientists from universities. The EQMC set out to provide information on the status, trends, and risks of contaminants to the Gulf of Maine ecosystem and indirectly to human health in the region. The information could then be used and acted upon by regional resource and environmental managers. This project has been funded by the United States (US) Environmental Protection Agency through the US Gulf of Maine Association, Environment Canada at Dartmouth NS, the State of Maine, and the National Oceanic and Atmospheric Administration (NOAA), Washington DC.

The monitoring committee decided that the most feasible approach was to use mussels as indicators of the contaminant levels accumulated in the biosphere. Mussels have the advantage of being widespread and immobile once their larvae have settled, and mussel tissue is therefore representative of the levels of contaminants retained from filtering large quantities of sea water for microscopic plankton over several years. Another advantage of mussels is that they are cultivated for consumption and that the findings can therefore be related directly to issues of human health. After a two-year feasibility trial, a gulf-wide study for mussel tissue contaminants, hereafter known as Gulfwatch, was initiated in 1991 (Figure 1). A benchmark station was established in each jurisdiction (state or province) and sampled each fall, and 33 other stations were sampled at least every third fall. These stations were designed to follow temporal changes in a wide variety of sit-

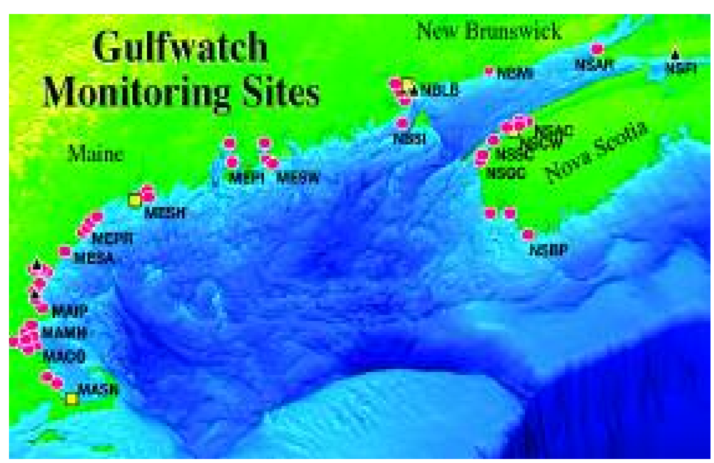

Figure 1. Chart of the Gulf of Maine showing mussel sampling sites

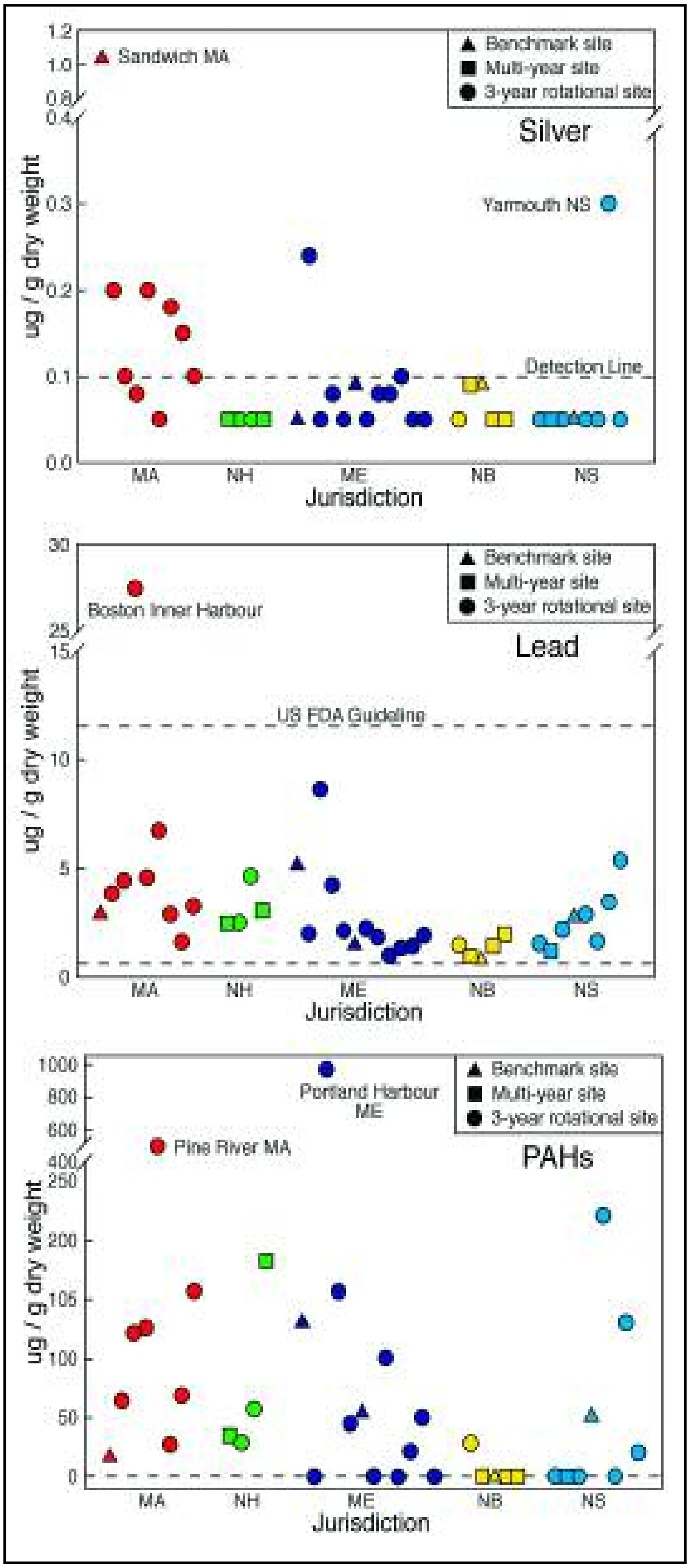

Figure 2. Geographic distribution of nine-year median silver, lead, and PAH concentrations in mussel tissue, shown clockwise around the Gulf of Maine

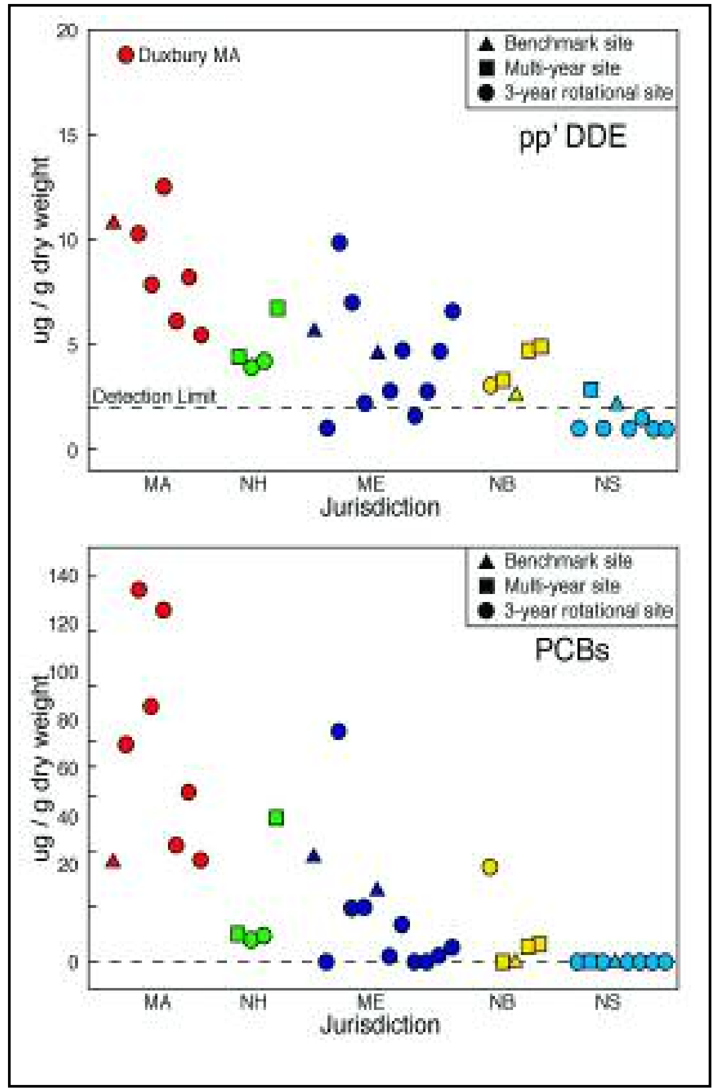

Figure 3. Geographic distribution of the nine-year median pesticide p,p-DDE and PCB concentrations in mussel tissue, shown clockwise around the Gulf of Maine

uations, from polluted harbours to pristine headlands. Eighteen other sites were sampled on a less frequent basis to extend our spatial understanding of contaminant distribution. Ten trace metals (silver, aluminum, cadmium, chromium, copper, iron, mercury, nickel, lead, and zinc); 24 polyaromatic hydrocarbons (PAHs); 24 polychlorinated biphenyls (PCBs); and 17 chlorinated pesticides (CH) were routinely analyzed. Four replicates were taken at each site. The condition of the mussels was estimated from the ratio of the wet weight to estimated volume of the individual.

Many of the metals or compounds analyzed had local “hotspots” or regions of higher concentration such as silver in Massachusetts and Yarmouth NS, lead in Boston Harbor MA, and high molecular weight PAHs at Pines River MA, Portland Harbor ME, and Broad Cove NS (Figure 2), but in general, most analytes had remarkably similar tissue levels around the Gulf. The source of hydrocarbons in mussels at Broad Cove NS is thought to be local contamination from a creosoted wharf, whereas the source of silver in Yarmouth harbour is unknown. The pesticide p,p-DDE and PCB values show a decreasing spatial trend from the southwest (Massachusetts) to the northeast (Nova Scotia) (Figure 3). In general, higher concentrations of contaminants were associated with denser human populations and proximity to large rivers. Unfortunately, the body index used to test the condition of the mussels turned out to be more responsive to the nutritional aspects of a site than the levels of contaminants, thus mussels were found to be proportionately plumper in Boston Harbor.

Trend analysis of the contaminants measured at the benchmark sta-

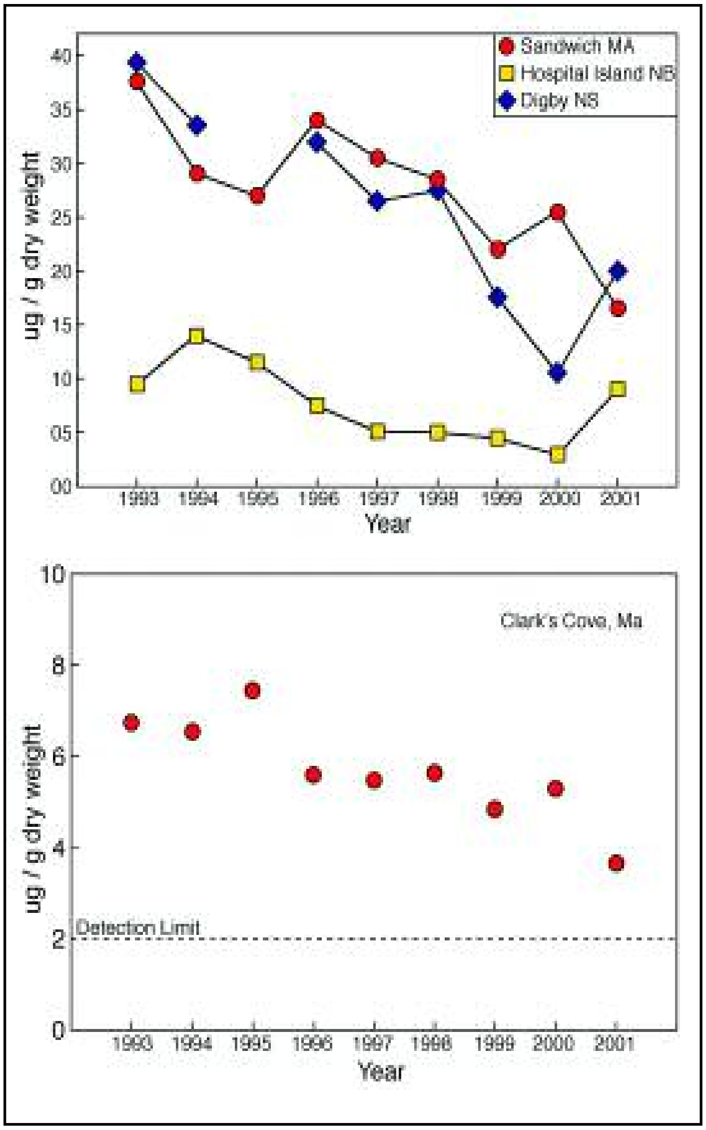

Figure 4. Declining temporal trends of annual median lead concentrations at Sandwich MA, Hospital Island NB, and Digby NS, and annual median p,p-DDE concentrations at Clark's Cove ME, between 1993 and 2001

tions annually from 1993 to 2001 failed to show a general gulf-wide change in any of the contaminants. Locally, the results are encouraging in that none of the contaminants measured were found to be increasing in mussel tissue. However, we would have expected declines in contaminants such as CH pesticides and PCBs which have been either restricted in use or banned in North America for decades. This probably indicates atmospherically borne input from Central America. Lead levels are declining at Sandwich MA, Hospital Island NB, and Digby NS (Figure 4). Mercury levels are declining at the Hospital Island and the Niger River sites in New Brunswick. Chromium and iron levels are declining at Sandwich and Digby. The pesticide p,p-DDE was found to be declining in mussel tissues collected at Clark's Cove ME (Fig. 4). High molecular weight PAHs appeared to be declining at Digby. It is difficult to explain any of these observed declines in terms other than local phenomena since there is no regional trend.

The present program is considered to be a great success in that it has motivated scientists from Canada and the US to collaborate in documenting the environmental health of this large and shared valuable ecosystem. Plans beyond 2005 are to maintain long-term monitoring of our original contaminants at a reduced number of sites, to initiate further biological effects monitoring, and to increase the number of types of contaminants monitored such as dioxins/furans, organotins, toxaphenes, pharmaceuticals, and emerging categories of contaminants.

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Web sites:

Gulf of Maine Council on the Marine Environment:
http://www.gulfofmaine.org/

Gulfwatch website: http://www.gulfofmaine.org/gulfwatch/

NOAA National Status and Trends Program:
http://nsandt.noaa.gov/

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8. Marine Department of Environmental Protection, Augusta ME
9. Nova Scotia Department of Environment, Halifax NS
10. New Brunswick Department of Fisheries and Aquaculture, St. George NB
11. EQMC Coordinator, Halifax NS

Special Programs

The International Ocean-Colour Co-ordinating Group (IOCCG)

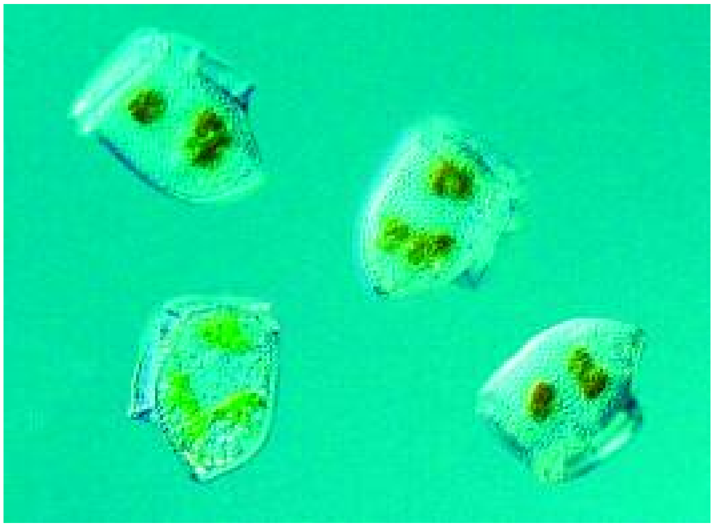
Venetia Stuart and Trevor Platt

The International Ocean-Colour Co-ordinating Group (IOCCG) was formed in 1996 to promote international co-operation in various aspects of ocean-colour science and technology, including the acquisition, calibration, distribution, and utilization of ocean-colour data from various satellite missions. The IOCCG also has a strong interest in capacity building and provides training opportunities in the use of ocean-colour data to students from developing countries. The IOCCG Committee consists of international experts in the field of ocean colour, with representatives from both the science community and international space agencies. Dr. Trevor Platt of DFO's Biological Oceanography Section chairs the group and DFO hosts, at BIO, the IOCCG Project Office, which is staffed by Project Scientist, Dr. Venetia Stuart.

Remote sensing of ocean colour from space provides information on the concentration of chlorophyll-a (a green photosynthetic pigment found in all phytoplankton cells) in the surface ocean waters, thus allowing scientists to estimate the abundance of phytoplankton.

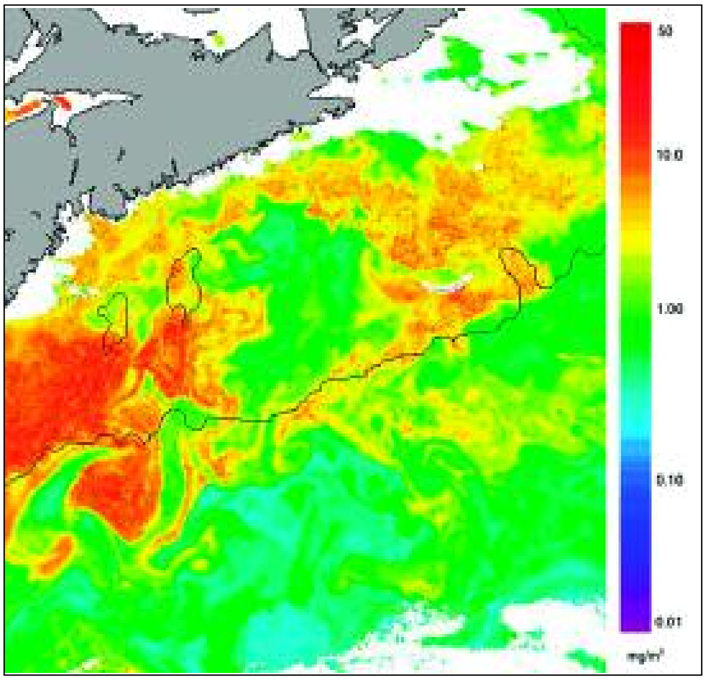
Ocean-colour data can also be used to determine the concentrations of coloured dissolved organic matter and total suspended material. This information can be used to investigate biological productivity in the oceans, to understand the global carbon flux, to examine how human activities influence the oceanic environment, and to manage the coastal zone (including fisheries management). Three major ocean-colour sensors are currently providing ocean-colour data on a global scale: the National Aeronautics and Space Administration (NASA's) SeaWiFS and MODIS sensors, and the European Space Agency (ESA's) MERIS sensor. Other countries such as India, Korea, Argentina, and China also have ocean-colour missions, but the data are not freely available.

SeaWiFS ocean-colour sensor



*Phytoplankton cells (*Dinophysis sp.*)*

One of the IOCCG Terms of Reference is to promote the long-term continuity of ocean-colour data sets by building a multi-sensor, multi-year ocean-colour archive to examine mid- to long-term changes in phytoplankton biomass. A number of issues need to be addressed before this can be done, including the calibration of each sensor, inter-calibration between different instruments, algorithm differences, and data-binning issues. Some of these issues are currently being addressed by scientific working groups set up by the IOCCG. The end product of these working groups is usually the publication of a scientific report. To date, four such reports



This example of a processed ocean-colour image shows different concentrations of chlorophyll off the Scotian Shelf on April 10, 2004. The image was captured by NASA's SeaWiFS ocean-colour sensor. A large phytoplankton bloom (red) can be seen along the South Shore. White patches are clouds and the thin black line represents the 200 m depth contour. Data was collected and processed by the Remote Sensing Unit of BIO.

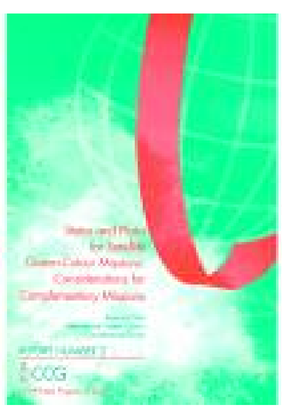
have been published by the IOCCG dealing with topics such as requirements of ocean-colour sensors in various oceanic regimes, remote sensing of ocean colour in coastal waters, and applications of ocean-colour data. These reports have been used extensively by managers and agencies, as well as by students and scientists around the world.

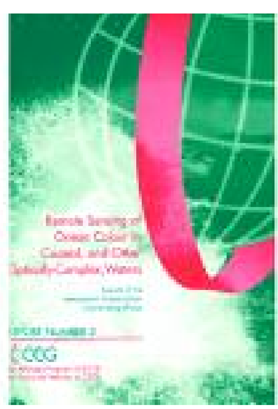
Another important goal of the IOCCG is to broaden the user community for ocean-colour data, especially in developing countries, through ocean-colour training courses and workshops. To date, the IOCCG has sponsored and co-ordinated 10 specialized ocean-colour training courses in Chile, India, Thailand, Turkey, and South Africa, providing comprehensive training to over 280 students from approximately 60 different countries. Another intensive training course will take place in Uruguay in April 2005. These courses are aimed at undergraduate and postgraduate students as well as university lecturers and researchers. Last year, the IOCCG sponsored four students to receive hands-on training onboard the Japanese research vessel, R/V *Mirai*, during its cruise around the Southern Hemisphere (July 30, 2003–February 22, 2004). As part of its training initiatives, the IOCCG also offers a Fellowship Programme aimed at providing young scientists from developing countries the opportunity to gain valuable training experience at an institute outside their home

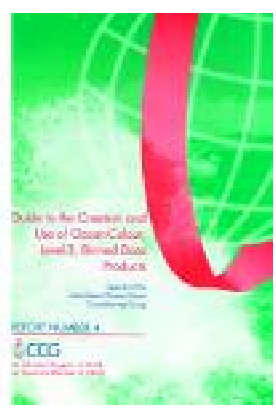
Some of the students and crew aboard the Japanese R/V Mirai *during its Southern Hemisphere cruise*

country. To date, nine students have been sponsored under this program, two of whom came to BIO to receive their training. The IOCCG is meeting a real need in the user community through these capacity-building initiatives, which, as well, have helped facilitate liaison and co-operation among students from various developing nations.

The IOCCG maintains a comprehensive website (http://www.ioccg.org) which provides a wealth of information on many aspects of ocean colour including sensors, publications, conferences, training opportunities, ocean-colour data, and employment opportunities. The IOCCG Committee meets once a year to co-ordinate the ongoing activities of the group, and to plan new initiatives: the 10th annual Committee meeting takes place on Margarita Island, Venezuela, in January 2005. Activities of the IOCCG are dependent upon financial contributions from national Space Agencies (NASA, ESA, the Canadian Space Agency, the Japanese Aerospace Exploration Agency, the Centre National d'Études Spatiales [France]) and other ocean-colour related groups (the Intergovernmental Oceanographic Commission, the National Oceanic and Atmospheric Administration [USA], and the Joint Research Centre [European Commission]), and upon infrastructure support from BIO and the Scientific Committee of Oceanic Research.







Technical Support Highlights

Research Voyages in 2004

Donald Belliveau

Researchers at the Bedford Institute of Oceanography utilize the following research vessels, which are operated by the Canadian Coast Guard (CCG), Maritimes Region:
CCGS *Alfred Needler*, a 50 m offshore fisheries research trawler;
CCGS *Hudson*, a 90 m offshore research and survey vessel;
CCGS *Matthew*, a 50 m coastal research and survey vessel; and
CCGS *J.L.Hart*, a 20 m inshore research vessel.

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

The CCGS *Alfred Needler's* principal role is in stock assessment surveys. Data collected during the annual multi-species ecosystem surveys are a primary source of information for DFO fish and invertebrate stock assessments conducted by the Maritimes, Gulf, and Quebec regions. The data are used also for fisheries research programs. As the Needler was still undergoing repairs after the fire of the previous fall, the February and March annual winter ecosystem surveys on Georges Bank and the Scotian Shelf were conducted from the *Wilfred Templeman*, the *Needler's* sister ship, based in St. John's, Newfoundland and Labrador (NL). The Needler was expected back from repairs/refit to start the July Scotian Shelf survey. Unfortunately, further delays in the repair/refit precluded using the Needler. As the east coast research trawler fleet is scheduled to be reduced from three vessels to two, the St. John's-based *Teleost* was already scheduled to conduct simultaneous surveys with the *Needler* for the summer and fall as part of an inter-comparison experiment. Maritimes Region scientists from BIO and the St. Andrews Biological Station conducted the annual Scotian Shelf survey in July on the *Teleost*. Scientists from the Institut Maurice Lamontagne, Quebec Region, conducted the annual Northern Gulf of St. Lawrence survey in August on the *Teleost*; the *Needler* was available for a small part of the survey. The southern Gulf survey in September was also conducted primarily on the *Teleost*. The *Needler* continued to be plagued by breakdowns. The final cruise of the year, to study benthic ecology on the Scotian Shelf in October, was lost to a combination of breakdowns and the Public Service strike.

CCGS *Hudson* had a busy year with cruises scheduled from April to December. The first cruise of the year was a short trip to service

CCGS Matthew

moorings on the edge of the Scotian Shelf. The annual spring Atlantic Zone Monitoring Program (AZMP) sampling was completed next and included the spring sampling for Norwate, an international research program studying the distribution of zooplankton, which had been deferred from last year. In May, the vessel sailed to the Labrador Sea to service oceanographic moorings and conduct conductivity-, temperature-, and depth-related hydrographic survey operations as part of Canada's contribution to global climate studies. This was followed by a trip out of St. John's to service moorings in Orphan Basin and the Flemish Pass off Newfoundland. In June the vessel returned to Orphan Basin for a deep-water seismic study by NRCan scientists. NRCan continued to use the vessel in July with cruises to study gas hydrate deposits in the Salar Basin and sediment dynamics on Sable Island Bank. The *Hudson* was then scheduled for a six-week period of paint and preservation work. Delays in the painting caused the loss of a cruise to study the effects of production wastes around the Hibernia platform. The Public Service strike resulted in the cancellation of the final cruise of a three-year program to explore the relationships between groundfish and their seabed habitats on Emerald, Western, and Sable Island banks, and a portion of the Maritimes Region fall AZMP cruise. From mid-October to early December, oceanographers from BIO, the Institut

Maurice Lamontagne, and the Northwest Atlantic Fisheries Centre conducted cruises to obtain the autumn AZMP physical and biological oceanographic dataset and the Gulf of St. Lawrence ice forecast dataset. The season concluded on December 7 when the ship was docked at BIO for the winter.

CCGS *Matthew* began its season in early April with gear mobilization and trials in Halifax Harbour. The first cruise was in support of NRCan seabed mapping in Placentia Bay, NL. A seabed mapping cruise to support the benthic habitat study mentioned above was cancelled upon the recommendation of the captain, as he did not feel the *Matthew* was safe to use more than 50 nautical miles offshore. NRCan used the vessel for a study of coastal sediment stability off northern New Brunswick (NB). CHS started their annual cruises to update charts around Prince Edward Island, NB, and NL in June. Unfortunately, the *Matthew* ran aground off Cow Head, on the western coast of Newfoundland, on July 17. Serious damage was incurred on the hull and the new multi-beam sonar transducer was lost. The vessel returned home and was removed from service for the rest of the year.

The smaller inshore fisheries research vessel, the CCGS *J.L.Hart*, also had a busy season supporting research programs in the Bay of Fundy area. This vessel is 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.

As in previous years the vessels were very busy providing BIO scientists with platforms from which to conduct their research. The officers and crews were great to work with, and the scientists appreciated their interest in the research programs.

BIO Revitalization Gains Momentum

Brian Thompson

Construction begins on the new Level II Laboratory facility

Building activity in 2004 represents a milestone for the long-term BIO Revitalization Program. Major design work for the new Level II laboratory was completed, and during July, tenders were called for Phase I of the project. Phase I consists of excavating and constructing the foundation, erecting the building envelope, floors and interior partition walls, and relocating a number of utilities. On November 5, 2004, a contract was awarded to Avondale Construction Limited; by Christmas, excavation for the new facility was well underway.

Phase II of the new laboratory will include mechanical and electrical systems, laboratory casework, security systems, interior finishing, and final fit-up. Although there will be some variations among the individual labs, the overall design concept is based on standard modules. When completed, the building will provide BIO scientists and technicians with 72 new lab units, a collegial work area, chemical storage facilities, and freezer space. Occupancy is proposed for 2006.

During 2004, the Vulcan Building (north) was the focal point of extensive construction. At that site, Phase I of an essential restoration project was completed. This involved reconfiguring and modernizing technical workshops, as well as upgrading the electrical, heating, ventilation, and air-conditioning systems. A number of Occupational Safety and Health (OSH) issues, including the removal of asbestos and the provision of more direct egress, were also addressed. Much of the remaining work for the Vulcan building (Phase II) is similar in nature and will be undertaken and completed during 2005.

In October, staff from Public Works and Government Services Canada and DFO reviewed design proposals for the van Steenburgh Building renovations. The project will involve major work on three floors of the van Steenburgh (north and south), as well as the seven floors of the service tower. The project will address OSH issues, the building envelope, and electrical and mechanical deficiencies. When completed the building will permit barrier-free access, comply with current codes, and incorporate sustainable development strategies during the planning, design, and implementation stages. The van Steenburgh Building's significance as a heritage property will be taken into consideration during the design stage, which will begin during winter 2005. Construction will possibly be completed in 2008.

These projects collectively will result in renovation of the older buildings at the Institute.

The Vulcan Building's new diesel shop with diesel and outboard motor mechanics Lloyd Oickle (left) and Richard LaPierre

In Our Communities

Outreach at the Bedford Institute of Oceanography during 2004

FISHERIES AND OCEANS CANADA

Joni Henderson

The third annual "Team Nova Scotia Science Fair Showcase" was held at BIO in April. Dr. Richard Wassersug of Dalhousie University delivered the keynote address, *Biology in Zero-G: How Animals React to Weightlessness*, to an enthusiastic audience. Staff and special guests, including the Hon. Jamie Muir, Nova Scotia Minister of Education, toured the winning projects and discussed them with the young scientists. The general public also visited the displays and wished the students luck in the upcoming Canada-wide Science Fair in St. John's.

The annual World Oceans Day poster contest, *Discover the Ocean in Your Back Yard*, for junior and senior high schools around the province, attracted more than 100 entries. The top ten winners received a framed photograph of their entries and an Oceans Day windshirt (a shirt made of fabric resistant to wind penetration). As well, the top three winners were treated to a tour of BIO and lunch aboard a Canadian Coast Guard vessel.

DFO manages the tour program at the Institute; visitors during the May–August tour season numbered 4,078. While this represented an increase in "guided tours", the number of visitors to the Institute was down slightly from previous years. This was due to the cancellation of "self-guided" tours because of heightened security restrictions. In the

Leatherback turtle display

Team Nova Scotia 2004 at BIO before departing for the Canada-wide Science Fair

Atlantic whitefish exhibit

Ship's wheelhouse exhibit

past, small groups and families were welcome to come in for a self-guided visit rather than a booked tour. This allowed time for larger groups to have a tour with the guides. In 2004, much of the guides' time was spent sharing their knowledge with relatively small groups, taking time which could have been spent with larger groups.

The Fish Lab and Sea Pavilion continued to be popular; people want to see marine life. Improvements to the tour also were well-received. The Seabed Mapping display was enhanced and relocated adjacent to the Titanic exhibit to make room for an exhibit highlighting "Species at Risk". Some features of this new exhibit, which proved to be a popular success, include:

- a full-size model of a northern right whale tail
- a life-size replica of a leatherback turtle
- an interactive wheel which visitors spin to see if they would survive, against the odds, as an Atlantic whitefish
- a plexiglass case housing Atlantic salmon life cycles where young visitors can make the fish swim.

Interpretive panels complement these features with information about these Species at Risk and the work being done by DFO staff at BIO to help ensure their survival.

Another addition to the tour route was a simulated ship's wheelhouse. This exhibit, which invites visitors to steer the ship, reveals the operational side of BIO research vessels; video footage taken at sea by the crew of the research vessel CCGS *Hudson* was actually responsible for making some visitors seasick!

Individual employees continued to accommodate requests from schools, universities, and the general public for job shadowing and for guest speakers on a variety of scientific disciplines. Their efforts are testament to staff commitment to community education about oceanographic activities at BIO.

Two field trips were offered at the EdGEO workshop. The group travelled around the Halifax Regional Municipality observing and learning more about Meguma Group gold-bearing rocks, deposits of the last glaciation, and local geo-environmental issues. The next trip was a full day "on-bus-edu-tainment" tour introducing participants to Carboniferous and Triassic rocks and their fossils. Using the school bus as a mobile classroom allowed for ongoing presentations and discussions. Stops included Blue Beach, Rainy Cove (above), and Walton

For the first time, Nova Scotia teachers were joined by out-of-province educators: Bill MacIntyre, the Prince Edward Island Science Consultant, and David Serkoak, a school principal from Iqaluit, who is shown here participating in one of the hands-on activities of the offshore oil and gas session. David also performed the Inuit Drum Dance during the opening ceremony.

NATURAL RESOURCES CANADA

Jennifer Bates, Sonya Dehler, Rob Fensome, Nelly Koziel, Bill MacMillan, Phil Moir, Patrick Potter, John Shimeld, and Graham Williams

Each year sees increased participation by NRCan scientists in education outreach. Geological Survey of Canada (GSC) (Atlantic) staff volunteer to assist with the EdGEO program, contribute to EarthNet, and bring new ideas for advancing the understanding of geoscience in the community.

2004 marked the 10th anniversary of the EdGEO program. The theme for this year's workshop, held at BIO, was the geological history of Nova Scotia. (*See* ***Retrospective 2004: Workshops and Special Meetings***.) This narrative thread was woven through three days of interactive learning for Nova Scotia earth science teachers. Participants pronounced the thematic approach a success and all agreed it will be used for future workshops.

The EdGEO workshop was organized by a committee with representation from the province's geoscience and education communities. Financial support came from the National EdGEO Committee, while in-kind support was provided by the GSC Atlantic, the Nova Scotia Department of Natural Resources, the Nova Scotia Museum of Natural History, Dalhousie and St. Mary's universities, various schools and boards, and the Atlantic Science Links Association.

EarthNet (http://earthnet-geonet.ca)—the online resource for earth science information for Canadian educators and students of all grade levels—gained another foothold in 2004. Godfrey Nowlan of the GSC Calgary agreed to lead the National EarthNet Committee and has embarked on establishing local representation in all provinces and territories. Website development is led by the EarthNet Development Committee, itself led by GSC Atlantic and comprising members from the geoscience and education sectors. The GSC remains the primary supporter of this education outreach program.

In 2004, NRCan staff, as members of the Atlantic Geoscience Society (AGS) Education Committee, participated in the development of *Nova Scotia Rocks*, a pamphlet that highlights some of the most interesting geological sites in the province. As well, several staff members gave invited talks at schools, universities, and

The success of the EdGEO program depends upon the knowledge, experience, and enthusiasm of the geoscience and education communities. Committee members included NRCan's Rob Fensome (far left), and Terry Goodwin of the Nova Scotia Department of Natural Resources who is demonstrating the complex geological history of the rocks underlying Halifax.

libraries; judged science fairs; and contributed to community meetings. Notable among these is the evening talk series at the Nova Scotia Museum of Natural History which carried into its fourth season with ongoing high attendance. NRCan employees' work with the AGS continues on a number of projects: the Halifax Harbour video, a Halifax Geoscapes poster, and the education outreach program for the joint meeting in Halifax of the Geological Association of Canada, the Mineralogical Association of Canada, the Canadian Society of Petroleum Geologists, and the Canadian Society of Soil Sciences.

Collaboration with museums, science centres, societies and associations, and other government agencies is critical for the development of education products and activities to bring earth science into the classroom. Just as important are the contributions of the artistic community: design, paintings, sketches, and photography all enhance any education product. Through the AGS, NRCan staff are participating in a proposal, with the University of New Brunswick and St. Francis Xavier University, to the NSERC CRYSTAL (Centres for Research in Youth, Science Teaching and Learning) program, which will present opportunities to work across the sciences with others in the Atlantic region.

The BIO Oceans Association: Highlights of 2004

Donald Peer, President

The Bedford Institute of Oceanography Oceans Association (BIO-OA) was formed by a group of retired public servants previously involved in Ocean Science and Hydrography who share an abiding interest in BIO. In addition to social activities, the OA is concerned with the history of the Institute and in enhancing public knowledge about the oceans. Membership is open to anyone who shares their goals. A current focus is the preservation of archival material.

LIBRARY ARCHIVES

The OA Library Archives Committee, chaired by Dr. Bosko Loncarevic with the assistance of BIO Archivist and Librarian Marilynn Rudi, has been instrumental in establishing a Memorandum of Understanding towards an effective Library Archives program at BIO. Signed by BIO management and the OA, the agreement ensures that material will not be discarded. The objective of the BIO Archives is the preservation of all BIO records with research value that are not acquired by the National Archives of Canada. This material includes cruise reports and contributions to national and international organizations and will complement the formal published material in scientific journals and technical reports.

EQUIPMENT ARCHIVES

During the last part of the 20th century, development of oceanographic equipment was so rapid that early prototypes sometimes so quickly became obsolete that their existence and functional characteristics are today unremembered. The significance of historical data depends on an understanding of the equipment used to collect it. The Equipment Archives Committee, chaired by Dr. Charles Schafer, includes members who have either used this technology or have been involved in its development. These pieces of equipment are valuable also for public education as they demonstrate the history of the achievements of BIO staff. The committee proposed that an Ocean Education Centre be established at the Institute where artefacts can be stored and displayed. The proposal was accepted by BIO Directors and a space will be incorporated in future renovations.

This photo from the BIO Archives shows the bow of the British oil tanker, *Kurdistan*, being sunk by the Canadian navy in deep water off the Nova Scotia coast. A 7,000-ton oil spill resulted when this ship broke up in a storm in Cabot Strait off the Nova Scotia coast, March 16-17, 1979. The bow section had no oil and was sunk whereas the stern section was towed ashore where oil remaining in its holds was recovered. At the time, BIO mobilized a group of scientists with experience in oil-pollution incidents to assist the Canadian Coast Guard in dealing with the *Kurdistan* spill. Institute scientists conducted scientific research on the aftermath of the spill, organized and hosted a two-day workshop on all aspects of the incident, and published the proceedings of the workshop.
Photo by Department of National Defence

PHOTO ARCHIVES

The Photo Archives Committee, chaired by Michael Latrémouille, is identifying and cataloguing a large number of slides and negatives taken prior to 1980. One need is for former BIO staff to identify the photo content and prepare captions. Of particular curiosity is a collection of photos from the former DFO Halifax Laboratory.

2004 BELUGA AWARD

The Beluga Award is an important honour bestowed on valued colleagues. At the Annual General Meeting of the BIO-OA on 19 May, Dr. David McKeown received the award in recognition of his 35-year career at BIO. ***(See Retrospective: Awards and Honours.)***

MEMBERSHIP ACTIVITIES

The BIO-OA Seminar Series continued in February with a talk by Alan Ruffman on the 1929 earthquake and tsunami on the Burin Peninsula of Newfoundland. The fall seminar was by David Walker of the Museum of the Atlantic who spoke on the history and present condition of the CSS *Acadia*. OA members enjoyed get-togethers at a summer barbeque and potluck on Springfield Lake and at the BIO Christmas party. The OA newsletter keeps members informed of association activities and those of its members. A new Editorial Working Group has formed to produce the newsletter. The OA invites all those interested to join their group, meet old friends, contribute to the programs, and enjoy social activities. For more in-depth information, see the website at (www.bedfordbasin.ca).

Community Assistance in 2004

BIO staff continued their long tradition of contributing to their community. In 2004, $65,624.92 was raised for the Government of Canada Workplace Charitable Campaign (GCWCC) through individual contributions and events. The GCWCC provided opportunities for staff to get together for fun, like the “Beat the Winter Blues Party” and the Christmas Hockey Game/Family Skate/Dance, as well as lively competitions such as NRCan’s “Chili and Curry Challenge”. Proceeds from these events go to the campaign, which was managed by Account Executives Maureen MacDonald (NRCan) and Rhonda Coll (DFO).

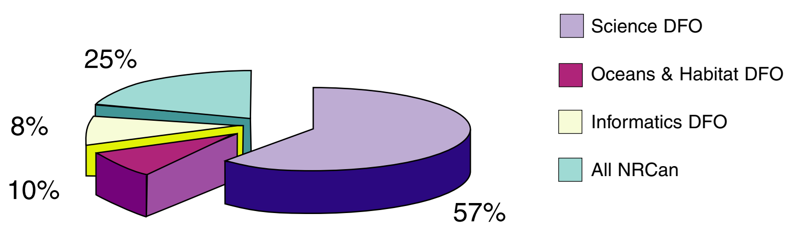
Other charitable activities were organized by different groups throughout BIO. As well as managing the annual book sale, this year the Library staff organized a Christmas Angel Tree which brought in gifts for 100 needy children. The DFO Marine Environmental Sciences Division raised funds through raffles and three festive coffee parties to provide Christmas gifts and food for seventeen individuals, while, as in previous years, BIO volunteers, as their “Christmas Gift of Giving”, assembled and delivered boxed Christmas dinners for the Parker Street Food Bank. The Food Bank was supported also through an Institute-wide food and winter clothing drive. The Cancer Society’s Daffodil Campaign was again well subscribed, and the SPCA was helped with funds and supplies.

Best jack-o’-lanterns – NRCan’s pumpkin carving contest

Financial and Human Resources

Where the Institute obtains funding and how it is spent

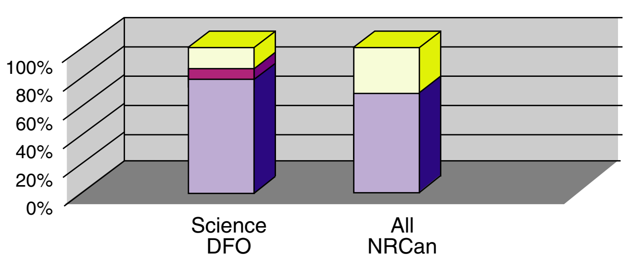
Annual appropriation from government by parliamentary vote



DEPARTMENT	SECTOR	AMOUNT ($000)
DFO	Science	22,672
DFO	Oceans & Habitat	3,786
DFO	Informatics	3,200
NRCan	All	9,682

Environment Canada and DND have staff working at BIO. The resources used by those staff members are not captured in this report.

Other sources of funding

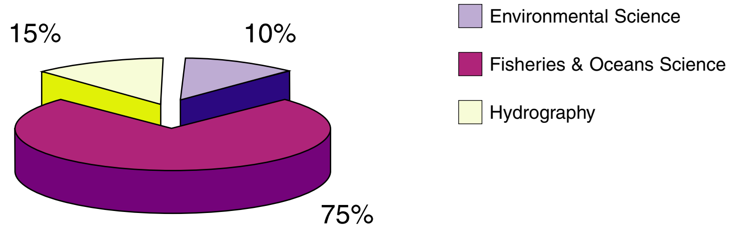


DEPARTMENT	SECTOR	GOVERNMENT ($000)	INSTITUTIONS ($000)	INDUSTRY ($000)
DFO	Science	8,516	771	2,388
NRCan	All	2,487		1,245

Industry Institutions Government

Program spending

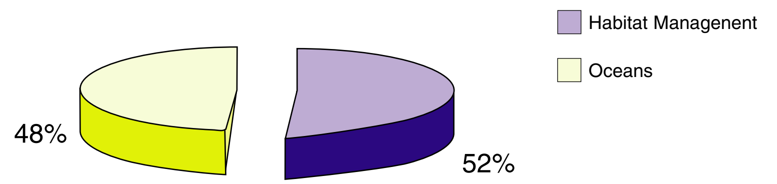
DFO Science



SECTOR	AMOUNT ($000)
Environmental Science	3,362
Fisheries & Oceans Science	25,780
Hydrography	5,204

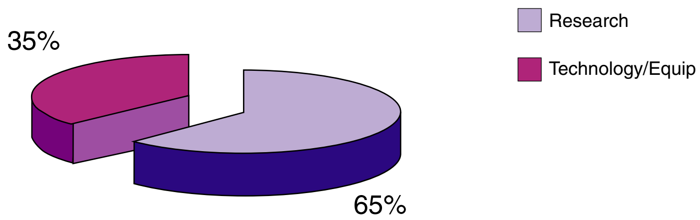
Program spending cont.

DFO Oceans and Habitat



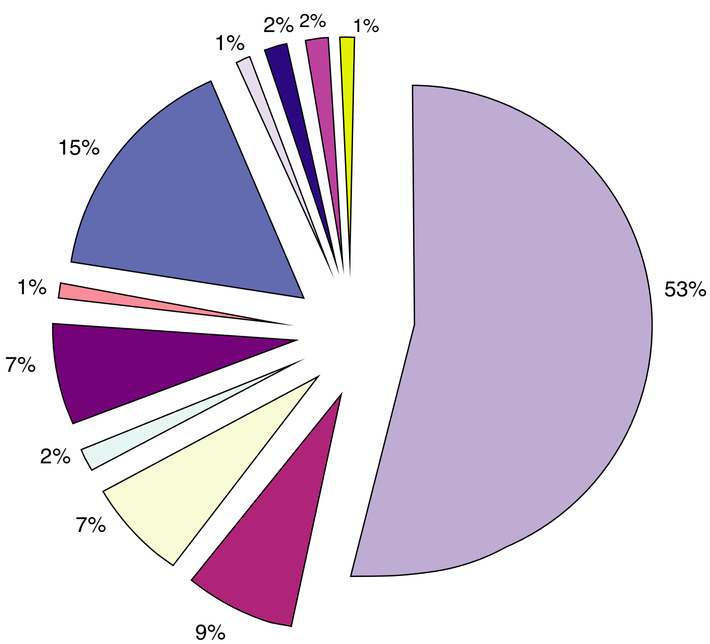
SECTOR	AMOUNT ($000)
Habitat Management	2,030
Oceans	1,882

NRCan



	AMOUNT ($000)
Research	8,719
Technology/Equipment	4,695

BIO staff by department/division



DFO - Science	354
DFO - Oceans & Habitat	59
DFO - Informatics	47
DFO - Other	10
DFO - Coast Guard Tech Services	46
DFO - Aquaculture Coordination	5
NRCan - GSC Atlantic	105
EC - Operational Laboratories	4
DND - Survey Office	13
PWGSC - Site Operations	10
Research Coordination Units	9
Total	662

People at BIO in 2004

DEPARTMENT OF NATIONAL DEFENCE

LCdr Jim Bradford
LCdr Robert Smith
LT (N) Scott Moody
CP02 Ghislain Charest
CP02 Ian Ross*
P01 Wendy Martin
P02 Leslie Guyomard
P02 Ron Clark
P02 Jeff Sooley
MS Tina LaCroix
LS Ronnie Meltzer
LS Sean Truswell
LS Karen Warren

ENVIRONMENT CANADA

Margot Boudreau, Student
Christopher Craig
David MacArthur
Robby MacLeod, Student
Laura O'Connor, Student
Diane Tremblay
Jamie Young

FISHERIES AND OCEANS CANADA

Canadian Coast Guard - Technical Services

Marine Electronics
Jim Wilson, Supervisor
Gerry Dease
Mylene DiPenta
Don Eisener*
Jason Green
David Levy
Robert MacGregor
Richard Malin
Morley Wright
Mike O'Rourke
Mark Robbins

Vessel Support
Andrew Muise, Supervisor
Tom Hann (secondment)
Richard LaPierre
Lawrence Morash (secondment)
Steve Myers
Lloyd Oickle
Harvey Ross
David Usher

Marine Aids and Maintenance
Phil Nelson, A/Coordinator
Martin LaFitte
Leonard Mombourquette
Richard Myers
Raymond Smith

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

Canadian Coast Guard - Operational Services

Michelle Brackett

Science Branch

Regional Director's Office
Michael Sinclair, Director
Marie Charlebois-Serdynska
Richard Eisner
Dianne Geddes*
Sharon Morgan
Ann Nicholson
Sherry Niven, Hypatia Project
Bettyann Power
Tara Rumley

Program Planning and Co-ordination:
Science Informatics Section
John O'Neill, Head
Jim Gale, SABS
Lenore Bajona
Anthony Joyce
Kohuila Thana

Canadian Hydrographic Service (Atlantic)
Richard MacDougall, Director
Bruce Anderson
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
Steve Forbes
Doug Frizzle*
Jon Griffin
Judy Hammond
Jolette Hannon
James Hanway
Heather Joyce
Glen King
Mike Lamplugh

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2004.
*Retired in 2004.

Christopher LeBlanc
Bruce MacGowan
Carrie MacIsaac
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
Bob Pietrzak
Vicki Randhawa
Doug Regular
Gary Rockwell
Glenn Rodger
Dave Roop
Tom Rowsell
Chris Rozon
Mike Ruxton
Cathy Schipilow
June Senay
Alan Smith
Andrew Smith
Nick Stuifbergen
Michel Therrien
Herman Varma
Wendy Woodford
Craig Wright
Craig Zeller

Diadromous Fish Division
Larry Marshall, Manager
Peter Amiro
Rod Bradford
Henry Caracristi
Alan Cook
Daniela Denti
Jamie Gibson
Carolyn Harvie
Phil Hubley
Eric Jefferson
Dave Longard
Shane O'Neil
Patrick O'Reilly
Karen Rutherford
Debbie Stewart
Daisy Williams

DFD Offsite:
Leroy Anderson
Mary Allen
Doug Aitken
Judy Anderson
Krissy Atwin
Denzil Bernard
Bev Davison
Claude Fitzherbert
Jason Flanagan
David Francis
Dawn Goff
Trevor Goff
Michael Goguen
Randy Guitar
Ross Jones
Craig Keddy
Beth Lenentine
Danielle MacDonald
William MacDonald
John Mallery
Andrew Paul
Robert Pelkey
Greg Perley
Rod Price
Christie Robinson, Student
Francis Solomon
Louise Solomon
Brian Sweeney
Michael Thorburne
Malcolm Webb
Ricky Whynot
William Whynot
John Whitelaw
Gary Whitlock

DFD- Gulf Fisheries Center:
Paul LeBlanc

Invertebrate Fisheries Division
René Lavoie, Manager
Jerry Black
Clare Carver, Volunteer
Manon Cassista
Amy Chisholm
Jae Choi
Ross Claytor
Andrew Cogswell
Nellie Cormier, Volunteer
Michele Covey
Ron Duggan
Cheryl Frail
Raj Gouda, Volunteer
Lorraine Hamilton
Stephanie Howes, Volunteer
Lea-Anne Henry
Trevor Kenchington, Volunteer
Peter Koeller
Mark Lundy
Barry MacDonald
Bob Miller
Stephen Nolan
Doug Pezzack
Alan Reeves
Shawn Roach
Ginette Robert
Dale Roddick
Kevin Strychar, Volunteer
Bob Semple
Glyn Sharp
Angelica Silva
Stephen Smith
Koren Spence
Amy Thompson, Student
Daniel Thompson
John Tremblay
Benedikte Vercaemer
Cathy Wentzell
Linda Worth-Bezanson
Ben Zisserson

Centre for Marine Biodiversity:
Ellen Kenchington, Director
Victoria Clayton

Marine Fish Division
Wayne Stobo, Manager
Shelley Bond
Don Bowen
Bob Branton
Alida Bundy
Steve Campana
Rachel Cassoff
Christie Dyer
Peter Comeau
Wanda Farrell
Mark Fowler
Melanie Hurlburt
Peter Hurley
Warren Joyce
Bill MacEachern
Linda Marks
Tara McIntyre
Jim McMillan
Jeff McRuer
Bob Mohn
Rachelle Noel
Patrick O'Laughlin
Jim Reid
Mark Showell

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2004.
*Retired in 2004.

Jim Simon
Nancy Stobo
Clarissa Theriault
Kurtis Trzinski
Scott Wilson
Gerry Young
Kees Zwanenburg

MFD Offsite:
Susan D'Entremont
Gilbert Donaldson
Jim Fennell

Ocean Sciences Division
Peter Smith, Manager
Gabriela Gruber
Meg Burhoe

Biological Oceanography:
Glen Harrison, Head
Jeffrey Anning
Florence Berreville, Student
Bilal Bjeirmi
Heather Bouman, Student
Jay Bugden
Benoit Casault
Carla Caverhill
Emmanuel Devred, PDF
Paul Dickie*
Marie-Hélène Forget, Student
Cesar Fuentes-Yaco, Research Associate
Leslie Harris
Erica Head
Edward Horne
Mary Kennedy
Paul Kepkay
Marilyn Landry
William Li
Alan Longhurst, Visiting Scientist
Heidi Maass
Anitha Nair, Student
Markus Pahlow, Research Associate
Kevin Pauley
Linda Payzant
Trevor Platt
Catherine Porter
Douglas Sameoto
Jeffrey Spry
Shino Takahashi
Alain Vézina
George White

Coastal Ocean Science:
Simon Prinsenberg, Head
Catherine Barrault
Dave Brickman
Gary Bugden
Sandy Burtch
Jason Chaffey
Joël Chassé
Brendan DeTracey
Ewa Dunlap
Frederic Dupont, PDF
Ken Frank
Dave Greenberg
Charles Hannah
Helen Hayden
Bob Lively*
Ingrid Peterson
Brian Petrie
Liam Petrie
Roger Pettipas
Charles Tang
Chou Wang

Ocean Circulation:
John Loder, Head
Robert Anderson
Karen Atkinson
Kumiko Azetsu-Scott
Berit Babe, Visiting Scientist
Allyn Clarke
Sharon Gillam-Locke
Blair Greenan
Doug Gregory
Yijun He, Visiting Scientist
Ross Hendry
Jeff Jackson
Peter Jones
David Kellow
Zhenxia Long, Post Doctoral Fellow
Youyu Lu
Neil Oakey*
Roberto Padilla-Hernandez, Visiting Scientist
William Perrie
Xuejuan Ren, Visiting Fellow
Marion Smith
Brenda Topliss
Bash Toulany
Dan Wright
Igor Yashayaev
Frank Zemlyak
Weibiao Zhang, Visiting Scientist
Qingping Zou, Visiting Scientist

Ocean Physics:
Michel Mitchell, Head
Brian Beanlands
Larry Bellefontaine
Don Belliveau
Rick Boyce
Derek Brittain
Norman Cochrane
John Conrod
Helen Dussault
George Fowler*
Jim Hamilton
Bert Hartling
Alex Herman
Randy King
Bruce Nickerson*
Ted Phillips*
Merle Pittman
Bob Ryan
Murray Scotney
George States
Scott Young*

Systems Engineering:
George Steeves, Supervisor
Garon Awalt
Kelly Bentham
Bob Ellis
Bruce Julien
Mike LaPierre
Daniel Moffatt
Glen Morton
Neil MacKinnon
Val Pattenden
Todd Peters
Nelson Rice
Greg Siddall
Leo Sutherby

Marine Environmental Sciences Division
Paul Keizer, Manager
Jim Abriel
Byron Amirault
Debbie Anderson
Carol Anstey
Marie Archambault
Shelley Armsworthy
Robert Benjamin
Cynthia Bourbonnais
Chiu Chou
Pierre Clement
Matthew Coady, Student
Susan Cobanli
Stephanie Cooper
Peter Cranford

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2004.
*Retired in 2004.

John Dalziel
Jennifer Dixon
Grazyna Folwarczna
Don Gordon
Gareth Harding
Barry Hargrave
Jocelyn Hellou
Rosalie Allen Jarvis
Ali Khelifa
Thomas King
Brent Law
Ken Lee
Jim Leonard
Kevin MacIsaac
Paul MacPherson
Ole Mikkelsen
Tim Milligan
John Moffatt
Rick Nelson
Lisa Paon
Georgina Phillips*
Brian Robinson
Sheila Shellnut
Judy Simms
John Smith
Sean Steller
Peter Strain
Peter Thamer, Student
Laurie Tremblay, Student
Herb Vandermeulen
Peter Vass*
Gary Wohlgeschaffen
Philip Yeats

Maritimes Provinces Regional Advisory Process (RAP)/ Outreach
Bob O'Boyle, Coordinator
Guillian Doell, Student
Steven Fancy, Student
Keli Fisher, Student
Joni Henderson
Valerie Myra
Tana Worcester

Species at Risk Coordination Office:
Diane Beanlands
Lynn Cullen
Arran McPherson
Kirsten Querbach
Kimberly Robichaud-LeBlanc

Oceans and Habitat Branch

Regional Director's Office
Faith Scattolon, Regional Director
Carol Ann Rose, A/Regional Director
Trudy Wilson, Assistant Director
Jane Avery
Shawna Bourque
Bev Grant
Jaime Wombolt

Habitat Management Division
Paul Boudreau, Manager
Victoria Burdett-Coutts
Stacey Burke
Joe Crocker
Karen Curlett
Rick Devine
Joy Dubé
Joanne Gough
Anita Hamilton
Tony Henderson
Darren Hiltz
Stacey Hynes
Carol Jacobi
Brian Jollymore
Darria Langill
Jim Leadbetter
Melanie MacLean
Charlene Mathieu
Shayne McQuaid
Amanda Park
Marci Penney-Ferguson
Ted Potter
Peter Rodger
Tammy Rose
Carol Sampson
Heidi Schaefer
Phil Seeto
Carol Simmons
Reg Sweeney*
Phil Zamora

Offsite (Gulf Fisheries Centre):
Ted Currie
Dale Hood

Oceans and Coastal Management Division
Joe Arbour, Manager
Shauna Barrington, Student
Heather Breeze
Debi Campbell
Lesley Carter
Scott Coffen-Smout
Penny Doherty
Dave Duggan
Derek Fenton
Jennifer Hackett
Tim Hall
Glen Herbert
Tracy Horsman
Stanley Johnston
Paul Macnab
Denise McCullough
Melissa McDonald
David Millar
Jason Naug
Celeine Renaud
Bob St-Laurent
Maxine Westhead

Aquaculture Coordination Office

Mark Cusack, Director
Valerie Bradshaw
Darrell Harris
Cindy Webster
Sharon Young

Real Property Safety and Security Branch

Brian Thompson, Senior Site Leader
Judy Lutley

Finance & Administration

Contract Services
Joan Hebert-Sellars

Material Services (Stores)
Larry MacDonald
Bob Page
Ray Rosse

Communications Branch

Art Cosgrove
Francis Kelly
Carl Myers

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*Retired in 2004.

Informatics

Technology Services
Gary Somerton, Chief
Chris Archibald
Julia Armstrong
Keith Bennett
Paulette Bertrand
Patrice Boivin
Doug Brine
Bruce Fillmore
Judy Fredericks
Lori Gauthier
Marc Hemphill
Charles Mason
Jim Middleton
Sue Paterson
Tim Rodgers
Andrea Segovia
Mike Stepanczak
Paul Thom
Michael VanWageningen
Charlene Williams
Paddy Wong

Client Services
Sandra Gallagher, A/Chief
Mike Clarke
Bonnie Fillmore
Pamela Gardner
Ron Girard
Jeff Hatt
Carol Levac
Dave MacDonald
Roeland Migchelsen
Juanita Pooley
Kevin Ritter
Krista Wry
Bobbi Zahra

Program Services Division
Tobias Spears, Head
Florence Hum
Adrian Inness

Library
Anna Fiander, Chief
Rhonda Coll
Lori Collins
Lois Loewen
Maureen Martin
Marilynn Rudi
Diane Stewart

Records
Jim Martell, Supervisor
Myrtle Barkhouse
Carla Sears

NATURAL RESOURCES CANADA

Geological Survey Of Canada (Atlantic)

Director's Office
Jacob Verhoef, Director
Jennifer Bates
Pat Dennis
Carmelita Fisher
Don McAlpine
Judith Ryan

Administration
George McCormack, Manager
Cheryl Boyd
Christine Doyle
Terry Hayes
Cecilia Middleton
Julie Mills
Barb Vetese

Marine Resources Geoscience
Mike Avery
Ross Boutilier
Bob Courtney
Bernie Crilley
Claudia Currie
Sonya Dehler
Rob Fensome
Peter Giles
Paul Girouard
Gary Grant
Ken Hale
Evelyn Inglis
Arthur Jackson*
Ruth Jackson
Chris Jauer
Nelly Koziel
Paul Lake
Bill MacMillan
Anne Mazerall
Phil Moir
Gordon Oakey
Phil O'Regan
Russell Parrott
Stephen Perry
Patrick Potter
Wayne Prime
Matt Salisbury
John Shimeld
Phil Spencer
Barbe Szlavko
Frank Thomas
Hans Wielens
Graham Williams
Marie-Claude Williamson
Mark Williamson

Marine Environmental Geoscience
Ken Asprey
Anthony Atkinson
David Atkinson
Marie Baker
Darrell Beaver
Robbie Bennett
Steve Blasco
Austin Boyce
Owen Brown
Calvin Campbell
Borden Chapman
Gordon Fader*
Robert Fitzgerald
Donald Forbes
Paul Fraser
David Frobel
Michael Furlong
Iris Hardy
Robert Harmes
Scott Hayward
David Heffler
Sheila Hynes
Kate Jarrett
Kimberley Jenner
Fred Jodrey
Heiner Josenhans
Edward King
Vladimir Kostylev
Bill LeBlanc
Michael Li
Robin Lucas
Maureen MacDonald
Kevin MacKillop
Bill MacKinnon
Gavin Manson
Susan Merchant
Bob Miller
David Mosher
Bob Murphy
Alan Orpin
Kathyrn Parlee
Michael Parsons
Eric Patten
Dick Pickrell
David Piper

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2004.
*Retired in 2004.

Walta Rainey
Angus Robertson
John Shaw
Andy Sherin
Steve Solomon
Gary Sonnichsen
Bob Taylor
Brian Todd
Ethymios Tripsanas
Kevin Webb
Dustin Whalen
Bruce Wile

PUBLIC WORKS AND GOVERNMENT SERVICES

Leo Lohnes, Property Manager
Diane Andrews
Bob Cameron
Geoff Gritten
Brian Fanning
Paul Fraser
Jim Frost
Garry MacNeill
Phil Williams
Bill Wood

COMMISSIONAIRES

William Bewsher
Paul Bergeron
Dave Cyr
John Dunlop
Donnie Hotte
Rex Lane
Leonard MonMinie
Francis Noonan
Don Smith
Lester Tracey

CAFETERIA STAFF

Kelly Bezanson
Lynn Doubleday
Laurie LePage
Mark Vickers

OTHERS ON THE BIO CAMPUS

International Ocean-Colour Coordinating Group (IOCCG)

Venetia Stuart, Executive Scientist

Partnership for the Observation of the Global Oceans (POGO)

Shubha Sathyendranath, Executive Director
Tony Payzant

Fishermen and Scientists Research Society (FSRS)

Jeff Graves
Carl MacDonald
Shannon Scott-Tibbetts

Geoforce Consultants Ltd.

Mike Belliveau
Graham Standen
Martin Uyesugi

Contractors

Michael Borek, Biological Oceanography
Derek Broughton, Marine Fish
Catherine Budgell, Library
Barbara Corbin, Records
Tania Davignon-Burton, Marine Fish
Kevin Desroches, CHS
Adam Drozdowski, Coastal Ocean Science
Bob Gershey, Ocean Circulation
Yuri Geshelin, Ocean Circulation
Adam Hanway, CHS
Matt Hawley, CHS
Yongcun Hu, Ocean Circulation
Raouf Kilada, IFD
Edward Kimball, Ocean Circulation
Weibiao Li, Ocean Circulation
Alexander MacLean, Informatics: Special Projects Division
Louise Malloch, Biological Oceanography
Kathryn Mombourquette, IFD
Jill Moore, Marine Fish
Peter Payzant, Biological Oceanography
Tim Perry, Biological Oceanography
Merle Pittman, Ocean Physics
Jeff Potvin, Informatics
Edith Rochon, Library
Ron Selinger, Records
Victor Soukhovtsev, Coastal Ocean Science
Jacquelyn Spry, Biological Oceanography
Tineke van der Baaren, Coastal Ocean Science
Tammy Waetcher, CHS
Alicia Williams, Marine Fish
Inna Yashayaeva, Ocean Circulation
Baoshu Yin, Ocean Circulation

Scientist Emeritus

Piero Ascoli
Dale Buckley
Ray Cranston
Fred Dobson
Subba Rao Durvasula
Jim Elliott
George Fowler
Ken Freeman
Alan Grant
Peter Hacquebard
Ralph Halliday
Lubomir Jansa
Brian Jessop
Charlotte Keen
Tim Lambert
Don Lawrence
John Lazier
Mike Lewis
Doug Loring
David McKeown
Brian MacLean
Ron Macnab
Ken Mann
Clive Mason
Peta Mudie
Charlie Quon
Charlie Ross
Hal Sandstrom
Charles Schafer
Shiri Srivastava
James Stewart
John Wade

Recognition

BIO staff wish to recognize the contribution and support provided by the Captains and crews of Canadian Coast Guard vessels tasked to assist scientific research at BIO.

Phil Hubley, right, with (from left) DFO engineers Hans Jansen and Vern Conrad at Baker Lake in northern New Brunswick, where they were engaged in fish-passage related work.

IN MEMORIAM

Philip Douglas Hubley

Philip Douglas Hubley, a renowned fish culture and fish passage engineer with the Diadromous Fish Division, Science Branch, DFO, passed away on July 12, 2004, from complications due to a motor vehicle accident in Prince Edward Island. Phil joined the Freshwater and Anadromous Division of the Resource Development Branch of the then Fisheries and Marine Service, Environment Canada in March, 1975, after graduating from Dalhousie University (B.Sc.) and the Technical University of Nova Scotia (B.Eng.). At the time of his death, he was just beginning to contemplate a well earned retirement. Throughout his career, Phil exhibited a professionalism that garnered respect from his colleagues and peers in government and the private sector, both in Canada and internationally. He was a dedicated conservationist who devoted himself to guiding the physical management of federal fish culture (biodiversity) facilities throughout the Maritime Provinces and to fish passage engineering. This latter expertise entailed the design and supervision of the construction of major fishways/fish ladders to allow fish passage around barriers. He was one of three or four public servants in Canada involved in this practice. Many fishways will stand testament to Phil's engineering prowess; one such structure completed in the mid-1970s is in the Liscomb River, where, with esthetic appeal and virtually no maintenance, it functions today with the same efficiency as when it was built.

One responsibility close to Phil's heart was the engineering associated with DFO fish culture facilities. He designed and oversaw the construction of a major expansion of the Mactaquac, the Mersey, and the Cardigan facilities. In 1991, he received a Deputy Minister's Award for work related to the visitor centre at Mactaquac. Most recently, he provided comprehensive engineering services (including maintenance, modification, and expansion of existing facilities) to the Division's biodiversity and assessment facilities. In 2002-04, he managed Treasury Board-approved biodiversity facility improvements valued at $3.5M. One of the last projects he completed was a large arch structured building at the Coldbrook Biodiversity Facility, which now houses the endangered inner Bay of Fundy Atlantic salmon. Phil's work in helping to prevent the extirpation and facilitate the potential recovery of endangered Atlantic salmon and Atlantic whitefish stocks in the Maritimes are his legacy.

Since the late 1990s, Phil also ensured compliance to statutory requirements of Sections 20-22 of the Fisheries Act regarding upstream/downstream fish passage, fish stops or diverters, fish screens, and maintenance flows. He negotiated with water-use developers on design details and water requirements for fish passage, for example, with NS Power on re-licensing, modifications, or reconstruction of over 450 existing fish passage facilities.

The energy and capabilities Phil exhibited at work were mirrored daily in his personal life. He was active, with his sons Brad and Richard, in the Dartmouth United Soccer Club and with curling, volleyball, and bridge clubs. His generosity with his time, energy, and talents earned him the Governor General's Jubilee Award in 2002. He and his wife, Denise, hosted the Division's annual Christmas party in their home for nearly 20 years. With recent downsizing, retirees have out-numbered current staff at these parties, a large part of what has contributed to the closeness of the Diadromous group.

Phil's optimism, expertise, sense of humour, knowledge, advice, stories, and warmth will be missed.

INDIVIDUALS WHO RETIRED IN 2004

Paul Dickie retired from DFO in October, after 31 years as a biologist in the Biological Oceanography Section. A native of Stewiacke, Nova Scotia, Paul was trained in microbiology at the University of Guelph and joined the Marine Ecology Laboratory in 1973. He has been a team member studying the plankton ecology of different environments extending across 86 degrees of latitude. In 1991, Paul collected the first sample in the Bedford Basin Plankton Monitoring Program. For 13 years, he spent almost every Wednesday morning on a boat in the middle of Bedford Basin. His final sampling was conducted three days before retirement, marking 650 missions. Paul helped create a long-term water-body dataset of scientific, socio-economic, and cultural significance. He was also an exemplar of community outreach: by accepting "job shadows" on his sampling expeditions, Paul has mentored more than 110 students from elementary and secondary schools, and universities. In retirement, he has become a happy farmer.

Don Eisener began his electronics career at BIO in May 1969, working in the Metrology Division. After three years there, he joined the Marine Electronics group, Computer/Microwave section, where he remained for the balance of his time at BIO. Throughout Don's employment with DFO he worked on numerous projects in support of Science and Hydrography including technical support at sea on CSS *Baffin*, CSS *Maxwell*, CCGS *Hudson*, and CCGS *Matthew*. He retired in November after 35 years of service. His colleagues wish him well in his retirement, when Don is sure to spend time restoring his 1953 Mercury Monarch and his farm tractor in Tatamagouche.

Gordon Fader retired from the Geological Survey of Canada (Atlantic) in November, after a 35-year career. He began work at BIO with the Lew King team, mapping the surficial and bedrock geology of the Scotian Shelf and Grand Banks of Newfoundland. During his career he published almost 300 publications and, as a popular speaker in Atlantic Canada, gave over 700 presentations on marine geological topics. He also played the piano at most BIO parties, retirements, and special events over the years. Best known for his research and mapping of Halifax Harbour, he remains a Scientist Emeritus with NRCan.

George Fowler retired from DFO's Ocean Physics Section in March after 36 years at BIO. His career was devoted to the design and development of innovative technology to address DFO Science needs. George was involved in most aspects of ocean measurement and sampling including drilling for rock samples from the deep ocean floor, profiling and sampling the water column, and measuring various properties of sea ice. His elegant designs are typically ingenious applications of basic principles of physics. George conceived and built many original models and displays at BIO, such as the iceberg outside the auditorium. He will continue contributing to BIO as a Scientist Emeritus, while pursuing his keen interest in ancient history, now the subject of his university studies focusing on ancient languages.

Doug Frizzle joined the Canadian Hydrographic Service (CHS), Atlantic Region, on October 25, 1975 as a field hydrographer. In the 1980s, he moved into the CHS Cartographic unit at BIO. Doug took part in the National Ocean Science (NOS) and the CHS Cartographic Exchange Program, spending three months at the NOS offices in the United States in 1989. He also participated in an exchange program with the Geological Survey of Canada at BIO in 1991. Doug became Supervisor, Data Transformation Section in 1997. This evolved into the Electronic Navigation Chart (ENC) Production and Maintenance unit. Doug was Supervisor of ENC in the Nautical Publications Division until his retirement in June. CHS colleagues have always respected Doug for his caring and sensitive approach to the people he supervised, his calm demeanour when faced with difficult problems, and his interpersonal skills, innovation, and positive approach to his work. In 1996, DFO honoured him with a Merit Award for his implementation and support of the CHS national and regional ENC production procedures. In 2004, he was co-recipient of both an ADM Commendation/Merit Award and the DM`s Prix d'Excellence. These awards are indicative of the respect that his co-workers and managers have for his work ethic and abilities.

Dianne Geddes retired in April after more than 31 years in the federal Public Service. She began her career in 1972 with the Department of Indian Affairs and Northern Development in Yellowknife, working for the Northwest Territories Water Board and the Arctic Waters Oil and Gas Advisory Committee. Dianne returned to Nova Scotia in 1978 and began working with DFO at BIO as part of the Canadian Atlantic Fisheries Scientific Advisory Committee secretariat. When the committee was disbanded in 1992, Dianne worked for the Regional Advisory Process. Most recently she was editor of the BIO annual review and manager of the BIO history project.

Arthur Jackson joined the Geological Survey of Canada on June 12, 1972 and retired in July after 32 years. Throughout his career at BIO, Arthur provided critical computer support and eventually became a software administrator for geophysical workstations. His well-deserved reputation as a problem solver and for getting the job done led to many demands on his time which he always met with a professional, but easy-going, attitude.

Robert Lively retired from the Coastal Ocean Science Section in July 2004, after 39 years with DFO. Bob began his career in the Computing/Data section, where, in the late 1960s, he began supervising the staff who downloaded meter and temperature recorder data. In those days, this came as film strips that were read manually and hand-written to standard forms. Bob worked as a field technician and analyst during the mid-1970s in coastal inlets from the Saguenay River to the Scotian Shelf; his favourite assignment was a three-summer stint in the Bras d'Or Lakes working out of Telegraph House in Baddeck. Over two decades he was a regular presence on Scotian Shelf, Gulf Stream, Grand Banks, and Arctic expeditions. Despite the usual bad weather, he most enjoyed the ice forecast cruises in the Gulf of St. Lawrence, on which he was often Chief Scientist. Bob constantly improved his skills and capabilities through courses at Dalhousie University and the Technical University of Nova Scotia. In the 1980s, he took charge of maintaining ship software related to data acquisition and eventually began building and servicing computers for the Ocean Sciences Section. Bob's contributions to oceanography at BIO were broad and valued. He is fondly remembered by his colleagues, especially by the junior scientists who benefited from his experience and advice.

Bruce Nickerson retired in July after 38 years at BIO. He started his DFO career on April 16, 1966 as a member of a tidal survey shore party. When that finished for the season, Bruce joined the crew of the CSS *Hudson*, but came ashore in January, 1967 to work in Shipping and Receiving. Bruce joined the Metrology Section (now Ocean Physics) in 1978, bringing his seagoing experience and rigging skills. He worked with the group on many development projects such as the Rock Core Drill and Batfish. In 1994, he moved to the Technical Operations Section as a member of the mooring group. Here he looked after the Rigging Shop, fabricating wire and rope moorings as well as deploying and recovering these moorings at sea. Bruce was a key ingredient to the success of the Ocean Sciences Division mooring programs over the past several years. We wish him much happiness in his retirement, particularly at his camp in Butcher Hill.

Dr. Neil S. Oakey retired in October. He began his career in 1962 as a Scientific

Officer in the Metrology Division of DFO. In 1964, he left to pursue a Ph.D. in nuclear physics but returned to oceanographic research at BIO in 1970 as a Research Scientist. Over the period 1970-2004, Dr. Oakey became an international scientific leader in the field of small-scale turbulent mixing in the ocean, making seminal contributions to ocean microstructure instrumentation and the measurement of ocean mixing rates. He was the first to develop tethered microstructure profilers that fall freely and are hydrodynamically quiet enough to routinely and accurately measure oceanic turbulent energy dissipation. He was Chief Scientist on many major expeditions contributing significantly to DFO, the World Ocean Circulation Experiment, the Global Ocean Ecosystem Dynamics program, the U.S. Coastal Mixing and Optics experiment, and other international programs. In recognition of his impact on Canadian oceanography, Dr. Oakey was awarded the 1998 J.P. Tully Medal by the Canadian Meteorological and Oceanographic Society.

Georgina Phillips retired in October after 32 years as a habitat biologist in the Marine Environmental Sciences Division, DFO. She began her career in 1972 in the newly formed Marine Environmental Quality Section, Marine Pollution Unit of the Marine Ecology Laboratory. Her work over three decades reflected changing priorities for environmental science within DFO. Projects included studies of effects of oil dispersants on benthic animals, ecosystem studies in the Upper Bay of Fundy to investigate the ecological consequences of tidal power development, and the distribution of persistent organic contaminants in St. Georges Bay, the Gulf of St. Lawrence, and Resolute Bay. Her research on environmental effects of salmon and mussel aquaculture in Prince Edward Island and southwestern New Brunswick reflected the growth of these new industries in the last decade. A general theme throughout her career was the increasing importance of teamwork, and she will be fondly remembered for her helpful and generous nature on many projects. She was Divisional representative for the United Way Appeal for many years and a long-standing member of the BIO laboratory safety committee. Georgina and Ted are looking forward to travel, holidays in their trailer, and sunny gardening days at their St. Margaret's Bay home.

Ted Phillips retired from DFO's Ocean Physics Section in July after 35 years at BIO. During his career, Ted applied his expert knowledge of electronics to the design of novel electronic systems for new ocean instrumentation. He was involved in most of the systems developed in the Section and his designs are integral to a variety of highly successful devices, many of which have been commercialized by private industry. He participated in regular field expeditions where his great talent in troubleshooting non-functioning equipment and prototypes made him an invaluable team member. His colleagues will remember Ted for his helpfulness and for his keen conversational ability. His wife, Georgina, also retired in 2004 and it appears that travelling will be high on their agenda.

Chief Petty Officer Ian Ross retired after serving more than 35 years in the Canadian Navy, Department of National Defence. He spent his last two years in the Route Survey Office at BIO.

Reginald Sweeney retired in July from a career that began in 1971 with DFO's Freshwater and Anadromous group. Dedicated to fish habitat research and management issues, in 1986 he was one of ten from the group to form the regional core of the new Habitat Management Division (HMD). Through his dedication, vast knowledge of the fish habitat realm, and keen grasp of Canadian environmental laws, Reg became a pillar of the HMD where he was intricately involved, and excelled in regulatory reviews and environmental assessments of major industrial projects. Latterly, he was DFO's main representative on mega projects like Offshore Oil and Gas Exploration and associated pipeline construction. He was at the leading edge of fish habitat protection when habitat impact avoidance or mitigation was needed. In retirement, he will continue his involvement in the Enfield Volunteer Fire Department and the Nova Scotia Hockey Association. The Habitat Management group will miss, as well as his skills, his strength, commitment, and loyalty.

Peter Vass retired in October after 35 years with DFO. Following graduation from the University of New Brunswick in 1970, he started working at BIO as a biologist in the new Environmental Quality Division of the Fisheries Research Board. Peter has worked with many scientists on a wide range of topics including organochlorine and hydrocarbon contaminant measurement in seawater, plankton, and fish; contaminant uptake in the laboratory; vertical movements of plankton in the sea; larval lobster production and survival in near- and offshore populations; larval lobster feeding experiments; PCB budgets for the southern Gulf of St. Lawrence; influx of organochlorine contaminants to the Arctic; field experiments on the effect of bottom trawling on the benthic community of offshore banks; deep-water corals; utilization of benthic habitat by demersal fish; and methylmercury budget and food-chain bioaccumulation in the Gulf of Maine. Equally at home in the lab and the field, Peter will be most remembered as an ingenious inventor and fabricator of gear to answer specific questions. Although he suffered from seasickness, never was there a sea trip too rough for him to work—as long as the gear could operate. Within the BIO community, Peter was the person who always made time to help. In true form, he saw the possibility of applying equipment developed at BIO to help the Transport Safety Board in the Swiss Air Disaster salvage operation where he volunteered his expertise and time. DFO has awarded Peter both a Regional Merit Award (1999) and the national Prix d'Excellence. Most cherished was the tribute by his colleagues: the BIO Oceans Association 2002 Beluga Award for exceptional service. In retirement, Peter will be finishing the Waverley home he is building single-handedly, and in later years, with his wife Debbie, expects to relocate to his native PEI where he will undoubtedly be a community leader.

Scott Young retired from the Ocean Physics Section in September after 37 years with DFO. He came to BIO as a graduate of the Nova Scotia Institute of Technology. Throughout his career, he contributed to the mechanical design and development of such new technology as towed systems, gliders, winches, and the ocean bottom rover. Scott's attention to minute detail and his high quality standards contributed to the success of so many projects. He truly enjoyed field work where he could see his devices perform, and his work has taken him from above the Arctic Circle to below the equator. His skills and resourcefulness made him a great asset to any team. Scott will be remembered for his good humour in both the lab and the field.

Publications and Products

Publications 2004

FISHERIES AND OCEANS CANADA
Maritimes Region - Bedford Institute of Oceanography

Science Branch:

1) Biological Sciences:

Recognized Scientific Journals:

Arkhipkin, A.I., S.E. Campana, J. FitzGerald, and S.R. Thorrold. 2004. Spatial and temporal variation in elemental signatures of statoliths from the Patagonian longfin squid (*Loligo gahi*). Can. J. Fish. Aquat. Sci. 61: 1212-1224.

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Gibson, G.D., and A.J.F. Gibson. 2004. Heterochrony and the evolution of poecilogony: Generating larval diversity. Evolution 58: 2704-2717.

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Henry, L.-A., and E. Kenchington. 2004. Ecological and genetic evidence for impaired sexual reproduction and induced clonality in the hydroid Sertularia cupressina (Cnidaria: Hydrozoa) on commercial scallop grounds in Atlantic Canada. Mar. Biol. 145: 1107-1118.

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Smith, S.J., and B. Sainte-Marie. 2004. Biological reference points for invertebrate fisheries: Introduction. Can. J. Fish. Aquat. Sci. 61: 1303–1306.

Smith, S.J., and P. Rago. 2004. Biological reference points for sea scallops (*Placopecten magellanicus*): The benefits and costs of being nearly sessile. Can. J. Fish. Aquat. Sci. 61: 1338–1354.

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Bradford, R.G., and C.M.B. Mahaney. 2004. Distributions of lake whitefish (*Coregonus clupeaformis*) fry from the lower Great Lakes federal hatcheries to elsewhere in Canada and beyond (Years 1878-1914). Can. Data Rep. Fish. Aquat. Sci. 1149: iii + 19 p.

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Campana, S., L. Marks, W. Joyce, and N. Kohler. 2004. Influence of recreational and commercial fishing on the blue shark (*Prionace glauca*) population in Atlantic Canadian Waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2004/069. 67 p.

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DFO. 2004. Eastern Cape Breton lobster (LFAs 27-30). DFO Sci., Stock Status Rep. 2004/032. 9 p.

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DFO. 2004. Potential impacts of seismic energy on snow crab. DFO Sci., Habitat Status Rep. 2004/003. 6 p.

DFO. 2004. Scallop Production Areas (SPAs) in the Bay of Fundy. DFO Sci., Stock Status Rep. 2004/051. 21 p.

DFO. 2004. Southern Gulf of St. Lawrence herring (4T). DFO Sci., Stock Status Rep. 2004/023. 8 p.

DFO. 2004. Southern Gulf of St. Lawrence snow crab (Areas 12, E and F). DFO Sci., Stock Status Rep. 2004/026. 16 p.

DFO. 2004. Southern shore Nova Scotia lobster (LFA 33). DFO Sci., Stock Status Rep. 2004/038. 11 p.

DFO. 2004. Western Cape Breton snow crab (Area 19). DFO Sci., Stock Status Rep. 2004/027. 12 p.

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Lavoie, R. (Chair). 2004. Proceedings of the Maritimes Regional Advisory Process of the Eastern Scotian Shelf Snow Crab; 22-24 March, 2004. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2004/023. iv + 32 p.

Miller, R., and V. Boudreau. 2004. Lobster stock monitoring by the Guysborough County Inshore Fishermen's Association. DFO Can. Sci. Advis. Sec. Res. Doc. 2004/037. 12 p.

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* Citation year is 2003; however, publication occurred only after publication of "Bedford Institute of Oceanography 2003 in Review.

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Hamoutene, D., J.F. Payne, A. Rahimtula, and K. Lee. 2004. Effect of water soluble fractions of diesel and an oil dispersant (Corexit 9527) on immune responses in mussels. Bull. Environ. Contam. Toxicol. 72: 1260-1267.

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Sailing Directions:

ATL 120, Labrador, Camp Islands to Hamilton Inlet (including Lake Melville)

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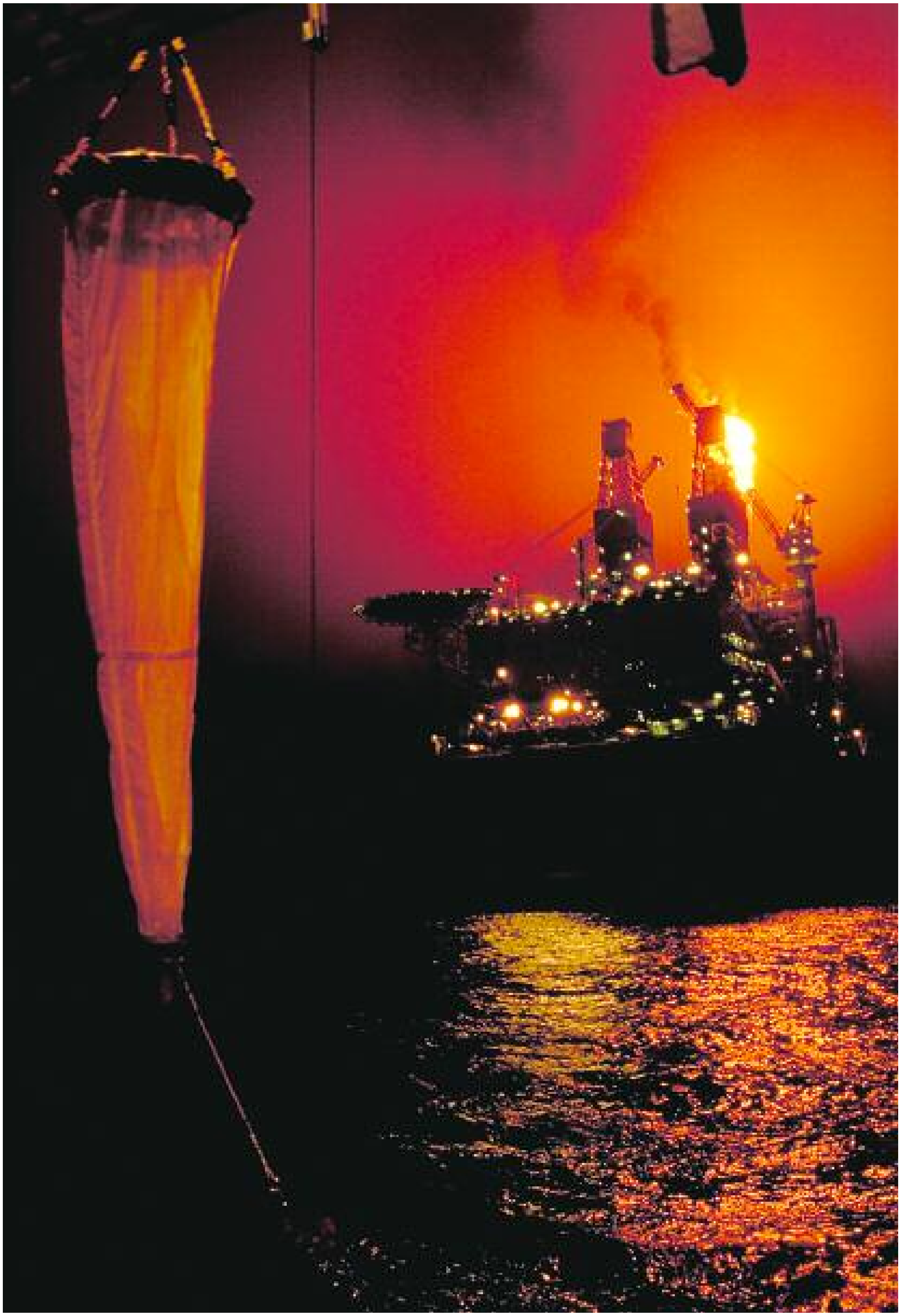
[1]Available from Nautical Data International Inc. (http://www.digitalocean.ca).



Sampling plankton next to the Hibernia *platform*

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