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Cover photo: The CCGS Amundsen *passes through Lancaster Sound during the ship's inaugural voyage in August 2003, almost 100 years to the day after Roald Amundsen sailed the same waters during his historic voyage through the Northwest Passage on the* Gjoa *(1903-1906). © Martin Fortier, ArcticNet NCE*

Photo is courtesy of Dr. Martin Fortier, who was Chief Scientist on the voyage. Dr. Fortier, of Université Laval, is the Executive Director of ArcticNet, a Network of Centres of Excellence of Canada that brings together scientists and managers in the natural, human health, and social sciences with their partners in Inuit organizations, northern communities, government, and industry to help Canadians face the impacts and opportunities of climate change in the Arctic.

Back cover photo: CCGS Amundsen *engaged in mapping work in Canada's Arctic, August 2005 © Jonathan Beaudoin*

Photo is courtesy of Jonathan Beaudoin, a PhD student at the University of New Brunswick in Fredericton, whose main research interest is the application of oceanographic databases for multibean echosounding in the Canadian Arctic Archipelago. Jonathan, who holds bachelor degrees in Geomatics Engineering and Computer Science, is the Ocean Mapping Group's dedicated research assistant associated with the ArcticNet project.

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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 Bedford Basin. It has grown to become Canada's largest centre for ocean research. Scientists at BIO perform 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 four divisions within its Science Branch including the Canadian Hydrographic Service (CHS), three 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, and 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), 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, and contractors 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 ocean uses.

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FEATURE

Delineating Canada's Continental Shelf under the United Nations Convention on the Law of the Sea

Jacob Verhoef (NRCan) and Richard MacDougall (DFO)

INTRODUCTION

The United Nations Convention on the Law of the Sea (UNCLOS) establishes a comprehensive regime for the regulation of those marine areas that are outside the internal waters of "States". The development of the treaty was a long and complicated negotiating process. The third conference, convened in 1973 and lasting until 1982, involved representatives from over 160 sovereign States and culminated in what has often been called a "constitution for the oceans". UNCLOS required ratification by 60 countries before it came into force. This happened on November 16, 1994, one year after receiving its 60th ratification. At the end of 2005, a total of 157 countries had signed the treaty and 149 had ratified, making UNCLOS one of the most successful treaties in the history of the United Nations.

Canada has been a strong and consistent proponent of UNCLOS and Canadian diplomats were recognized for their activities during the negotiation of the treaty. Canada was among the signing countries in 1982 and ratified UNCLOS on November 6, 2003.

MAIN PROVISIONS OF UNCLOS

The Convention is a comprehensive attempt by the international community to regulate all activities in the world's oceans, including all aspects of the resources of the sea and all uses of the ocean. For this, UNCLOS divides the seafloor into zones of national and international jurisdiction, with each coastal State's authority diminishing seawards. It recognizes the right of a coastal State to the seabed and water column offshore to 200 nautical miles (nm)—the Exclusive Economic Zone (EEZ) —and the seabed beyond 200 nm under special circumstances. The part of the world's oceans outside national jurisdictions, the *High Seas* and the *AREA* (Figure 1), is defined as the "common heritage of mankind", and the International Seabed Authority was established to oversee its use.

In addition, the more than 300 articles of the Convention include provisions for marine research, the protection and preservation of the marine environment, and the settlement of disputes. A complete overview of UNCLOS is beyond the scope of this paper that will focus only on Article 76 which defines the circum-

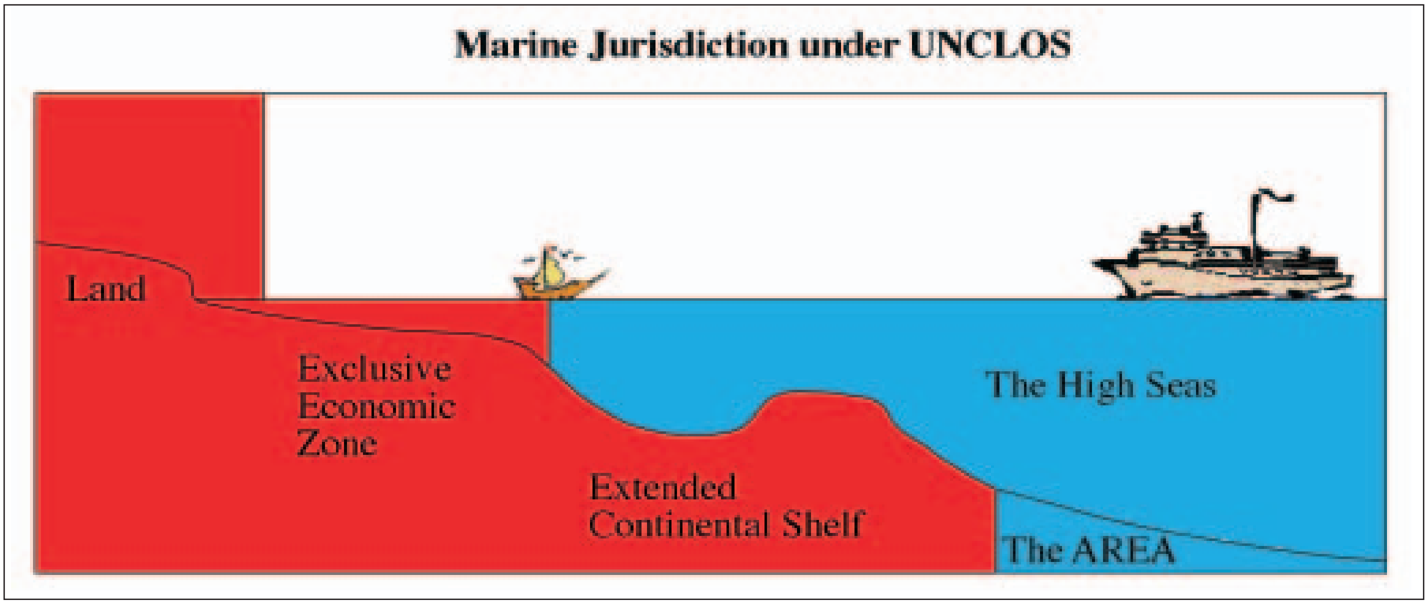


Figure 1. Territorial jurisdictions under UNCLOS: red areas are under the jurisdiction of the coastal State; blue areas are the High Seas and the AREA.

stances whereby a coastal State can extend its jurisdiction beyond the customary 200 nm. This is an important article for Canada, since, under the treaty, a coastal State has "the sovereign rights for the purpose of exploring and exploiting its natural resources" in that extended area. However, these rights are only with respect to resources on and below the seabed, including sedentary species. (This is in contrast to the EEZ where the coastal State also has exclusive rights to the biological resources in the water column.)

ARTICLE 76

Article 76 is relatively short, about one page of text. However, its interpretation is not straightforward and has already generated a large number of discussion papers. It is important to realize that Article 76 describes the definition of coordinates of a legal offshore limit that are based upon geological and geomorphological characteristics of the seafloor. Its implementation requires the analysis and interpretation of the shape of the seabed, depth of the seafloor, and thickness of the underlying sedimentary layer. These measurements result in a preliminary outer limit obtained by the application of distance formulas outlined in Article 76. Article 76 also defines a so-called constraining line, beyond which the offshore limit cannot extend. To construct the final outer limit, a coastal State chooses at each point the most landward line from the preliminary and constraining lines. The final outer limit is defined by straight line segments connecting the points, which cannot be farther apart than 60 nm.

Based upon an application of Article 76 to generalized global data sets, it is expected that 40-60 nations may have a possible claim for extending their outer limits beyond 200 nm. The jurisdiction in the extended area has to be actively claimed: a coastal State has to submit a claim, with substantiating information outlining its case, within ten years from the time that it ratified the Convention. By the end of 2005, four countries (Russia, Brazil, Australia, and Ireland) had submitted their entire or partial claims.

COMMISSION ON THE LIMITS OF THE CONTINENTAL SHELF (CLCS)

Under Article 76 of UNCLOS, coastal States can submit claims for an extended continental shelf to the Commission on the Limits of the Continental Shelf (CLCS). The 21 commission members, elected exclusively from states that have ratified the Convention, are experts in the field of geology, geophysics, or hydrography. They serve a five-year term and are eligible for re-election.

To assist coastal States in the preparation of their submissions, the CLCS has produced a set of technical guidelines outlining the information to be submitted, including supporting material. The

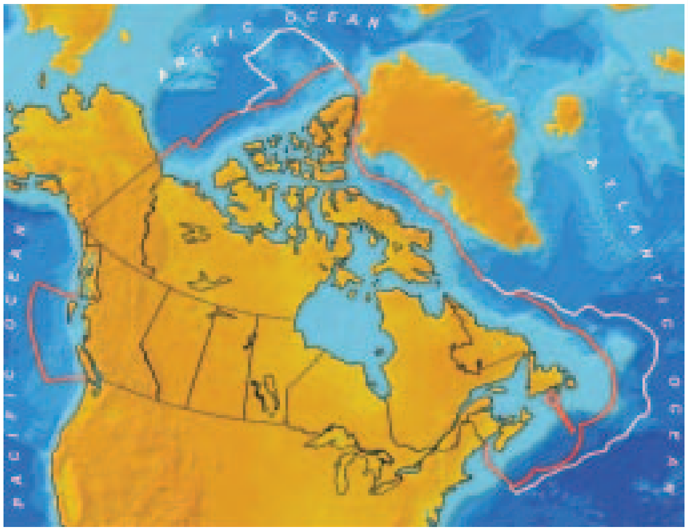


Figure 2. Map shows the Canadian case: current and prospective offshore jurisdiction. Red line represents the EEZ of ~ 4 million square kilometres. White lines indicate areas outside of EEZ: Atlantic Ocean ~ 1 million square kilometres; Arctic Ocean ¾ million kilometres; Pacific Ocean – not certain.

CLCS reviews the submission and makes appropriate recommendations to the coastal State. Only the coastal State can establish the final and binding limits of its continental shelf on the basis of those recommendations. The main role of the CLCS is to ensure that claims are within terms of Article 76 and the review process lends legitimacy to a State's claim. It is important to note that the CLCS cannot pronounce on disputed areas between neighbouring States. These disputes have to be resolved by the parties through negotiations or mutually agreed dispute settlement.

CANADA'S CASE

Canada is a coastal State bordering three oceans, and a significant part of its territory is submerged land in the 200 nm Exclusive Economic Zone (Figure 2). However, Canada is also a "broad-margin" State, i.e., a coastal State whose continental margin extends beyond 200 nm. Therefore, the provisions of Article 76 could allow Canada to formally extend its outer limits beyond 200 nm.

In 1994, the Geological Survey of Canada (GSC) and the Canadian Hydrographic Service (CHS) performed a desk-top study of Canada's offshore areas in the context of Article 76. For this study, all bathymetric and geological data were compiled and analyzed to establish the provisional outer limits of the continental shelf. The results (Fig. 2) demonstrated that Canada could possibly extend seabed jurisdiction over regions in both the Atlantic and Arctic oceans. (The narrow margin in the Pacific Ocean provided no clear prospects for extension.) The study found that the size of the area

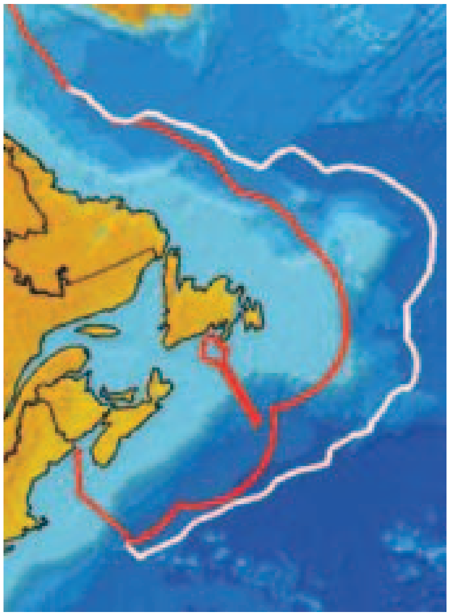


Figure 3. The Atlantic program

beyond 200 nm could be as large as 1.75 million square kilometres, or as is often quoted, "an area about equal the size of the three Prairie Provinces".

It should be noted that the amount and quality of the existing data used in this preliminary analysis was deemed insufficient to substantiate the claim to the CLCS. The majority of the data collected by the GSC and CHS lies within Canada's EEZ. The application of Article 76 requires data outside the 200 nm zone and this is where Canada is lacking the information required for a submission.

CANADA'S UNCLOS PROGRAM

The 2004 Federal Budget announced funding of $70 million over 10 years for the survey work that is required to conclusively establish the limits of Canada's entire continental shelf off its Atlantic and Arctic coasts. This would secure international recognition of Canadian jurisdiction over the resources on and under Canada's continental shelf beyond the customary EEZ in the Atlantic and Arctic oceans.

The delivery of the UNCLOS program is the joint responsibility of three federal departments: the GSC (NRCan) is responsible for seismic surveys; CHS (DFO) is responsible for bathymetric surveys; and Foreign Affairs Canada will provide legal advice on UNCLOS and the CLCS and will co-operate in the preparation and presentation of the submission.

The scientific component of the UNCLOS program will be directed by an inter-departmental Management Board consisting of one Director each from the GSC and CHS. A small program office has been established at the Bedford Institute of Oceanography to oversee and coordinate the mapping effort. Since both the GSC and CHS already have offices at BIO, this location allows an efficient delivery of the program. In addition, scientific staff from both organizations will work on the program to specify data collection, perform quality assurance, and analyze the information, resulting in the establishment of the coordinates of the outer limit. Based on the analysis of existing data, a survey program has been designed to collect the minimum amount of new data necessary to produce a scientifically sound and defensible claim, while maximizing Canada's claim. About 85% of the funding will be utilized for the acquisition of new data, and approximately two-thirds of the cost of the program will be in the Arctic, where limited data exists and conditions are more challenging.

THE ATLANTIC PROGRAM

The continental shelf in the Atlantic Ocean encompasses a broad shelf and therefore, the application of Article 76 could allow Canada to extend its limits beyond 200 nm. (Fig.2 shows the results of the desk-top study). Depending on the structure of the margin, the application of either the sediment formula (mainly along the Nova Scotia and Labrador margins) or the distance formula (along the Grand Banks margin) will provide Canada with the maximum extension beyond 200 nm. The outer limit shown in Figure 3 is the most advantageous combination of the application of these two formulae.

The Atlantic program will collect bathymetry information focused along the Grand Banks margin and seismic data (using standard industry type multi-channel seismic) focused along the Scotian and Labrador margins.

A significant amount of seismic data has already been collected along the Scotian margin, mainly by the oil and gas industry. That information has been reviewed to see if it could be used to substantiate Canada's claim. Unfortunately, most of the data is located along the shelf break, inside the 200 nm limits (red line in Fig. 3). In contrast, the information required for the application of the sediment formula requires information extending into the area outside 200 nm (the region between the red and white lines).

It is anticipated that the data collection in the Atlantic Ocean will take three to four field seasons, depending on weather conditions and availability of suitable vessels. Establishing Canada's outer limits in the Atlantic Ocean has some urgency, as petroleum exploration is already taking place near and outside the 200 nautical mile EEZ on the Grand Banks. For instance, the Hibernia field is located only about 30 nm inside the EEZ, and in a recent land-lease in Orphan Basin, the majority of the parcels are located outside our EEZ. Canada could be the first country to produce oil and gas beyond 200 nm, and establishing the outer limits under UNCLOS would provide certainty for industry.

THE ARCTIC PROGRAM

The Arctic program is not straightforward, as the Arctic Ocean has complicated seafloor geology and circumstances for data collection in that area are much more difficult. Moreover, there is the potential for overlapping claims from the neighbouring countries (for instance, the Russian submission in 2002 partially overlapped with the area Canada could claim; Canada was therefore among those countries who submitted a protest to the CLCS against the Russian claim).

Data acquisition in the Arctic region will be technologically challenging, mainly due to the harsh environment. The complicated seafloor geology focuses on the two submarine ridges that extend north of Ellesmere Island (the Lomonosov and Alpha-Mendeleev ridges). The first requirement is to establish whether or not those ridges are a natural prolongation of the Canadian landmass. If this is the case, the possible extension of Canada beyond 200 nm is outlined by the white area in Figure 5. Therefore, the first phase of the Arctic program addresses the prolongation question by measuring crustal seismic velocities on the Lomonosov Ridge and comparing them to those on the adjacent continent. Because of technical challenges of data collection in the remote ice-covered areas of the Arctic Ocean, the GSC (in consultation with Foreign Affairs Canada) has negotiated with the Geological Survey of Denmark and Greenland (GEUS) to collaborate on surveys in the area north of

Figure 6. Canada and Denmark collaborating in Arctic data collection – photo courtesy of Trine Dahl-Jensen, Geological Survey of Denmark and Greenland

Ellesmere Island and the Labrador Sea. This will not only reduce the cost for both countries, but also lead to a joint interpretation of the collected information, thereby reducing the possibility of overlapping claims and disputes. An agreement has been developed for a joint Arctic field program on the ice, starting in March 2006.

The second phase of the Arctic program will require the collection of seismic and bathymetric information to establish the outer limits of the shelf according to the distance and/or sediment formulae. Collection of seismic information would require an icebreaker as the survey platform and probably another icebreaker as escort. A similar arrangement is being considered for the bathymetric data collection; however, possible alternative options are being considered. The unpredictable ice and weather conditions might make it difficult to collect information during some of the short “seasonal windows” over the next several years. Therefore, the Arctic data collection will take advantage of data collection opportunities whenever they arise.

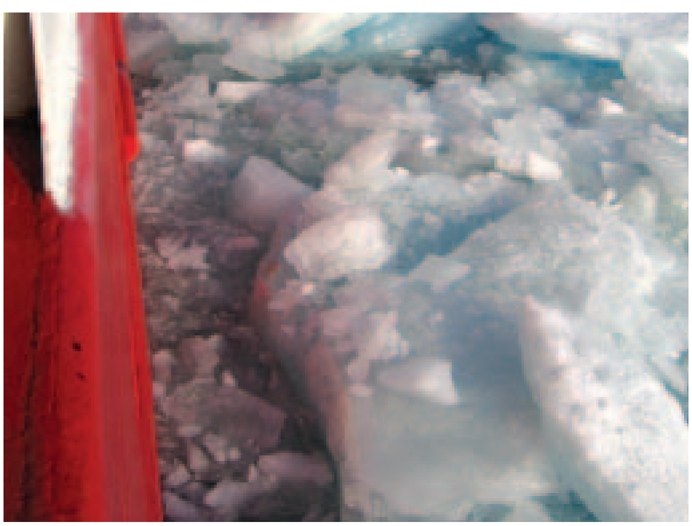


Figure 4. Arctic mapping work was carried out from the CCGS Amundsen *in August – photo courtesy of Jonathan Beaudoin.*

Figure 5. Canada’s Arctic UNCLOS Program: red section indicates Canada’s EEZ, white section is where Canada hopes to obtain jurisdiction. Flags indicate other nations which may have competing claims.

CONCLUSIONS

The ratification of UNCLOS in 2003 by Canada has started the ten-year period in which Canada must submit a claim for its extended continental shelf. Doing so could potentially give Canada the jurisdiction over resources on and below the seafloor in an additional area in the Atlantic and Arctic oceans that might be as large as the three Canadian Prairie Provinces. Through the collaborative CHS-GSC program at BIO, the application of UNCLOS provides a unique opportunity for geoscientific and geomorphological data of the seafloor to be used to define the legal outer limit of the Canadian territory.

ACKOWLEDGEMENTS

The authors thank Richard Haworth, David Monahan, and Ron Macnab, who played a key role in the early development of the program.

Science Activities

Time Series Studies of Carbon and Transient Tracers in the Labrador Sea for Understanding Global Climate Change

Kumiko Azetsu-Scott, Peter Jones, Robert Gershey, and Frank Zemlyak

The oceans play a key role in the earth's climate system. They exchange heat, water, and chemicals, including greenhouse gases such as carbon dioxide, with the atmosphere and/or land. They also transport heat, water, and carbon dioxide globally, thereby contributing to the stability of regional climates. Understanding how oceans interact with the climate is crucial in assessing future climate change and its influence on our daily lives.

Changes in climate and associated marine ecosystems occur on various time scales. Time series studies are essential to distinguish trends from natural variability and to predict future climate and marine ecosystem responses. A time series study consists of measurements taken at regular intervals (e.g., every day, every week, every month, or every year). One of the best known examples in climate science is time series measurements of atmospheric CO_2 in Hawaii by C. Keeling of the Scripps Institution of Oceanography, which made us aware of the human influence on the earth's climate.

The Ocean Circulation Group at BIO has conducted time series studies of transient tracers and carbon systems in the Labrador Sea since the early 1990s. Transient tracers have a known atmospheric history, which can be used to estimate the time scale of ocean processes such as ventilation of the intermediate and deep water. The studies are part of an ongoing multidisciplinary program encompassing physical, chemical, and biological oceanography in DFO's Ocean Sciences and marine Ecosystem Research divisions. They constitute the longest time series studies across a section conducted anywhere in the North Atlantic.

THE LABRADOR SEA – THE CRITICAL SITE IN GLOBAL CLIMATE CHANGE STUDIES

The largest scale water flow in the ocean is represented schematically by the Global Ocean Conveyor Belt (Figure 1). Surface saline water is warmed in the low latitudes of the Atlantic and flows northward to the Labrador and Nordic seas, where it loses heat to the atmosphere, becoming cooler and denser. This dense water sinks (deepwater formation) and starts flowing southward towards Antarctica. After about 1000 years, this cold, deep water upwells to the surface mainly in the Pacific and Indian oceans and returns as surface flow to the North Atlantic, where the cycle starts again. Deepwater formations in the Labrador and Nordic seas have been suggested as major engines driving the conveyor belt. In the winter, strong northwesterly winds cool the surface of the Labrador Sea (Figure 2) and mix the water column (deep convection). The depth of convection varies from year to year. In some years it reaches only to 500 m, while in extreme winters, it has reached to over 2000 m. This convection produces the relatively fresh and cold Labrador Sea Water (LSW). During the formation of LSW, atmospheric gases are incorporated into the deepening mixed layer. The LSW subsequently spreads and transfers atmospheric signals to the intermediate depths of the North Atlantic Ocean. Deep water produced in the Nordic Seas—North East Atlantic Deep Water (NEADW) and Denmark Strait Overflow Water (DSOW)—also flows to the North Atlantic through the deep Labrador Sea. Thus, the Labrador Sea provides an ideal gateway to study variability of physical, chemical, and biological characteristics of the major water masses that contribute to the lower limb of the great conveyor belt and the role of the ocean in global climate change.

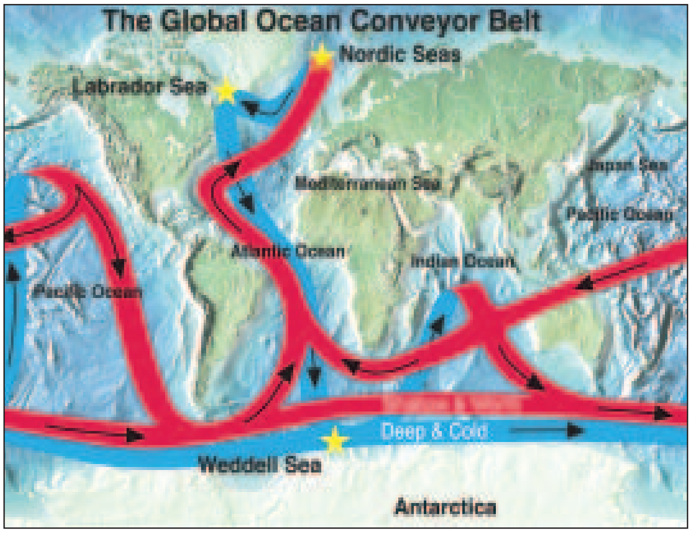


Figure 1. The Global Ocean Conveyor Belt is represented by red and blue lines. Yellow stars indicate the deep convection sites, which contribute to the global ocean conveyor belt. (modified from Broecker, 1987)

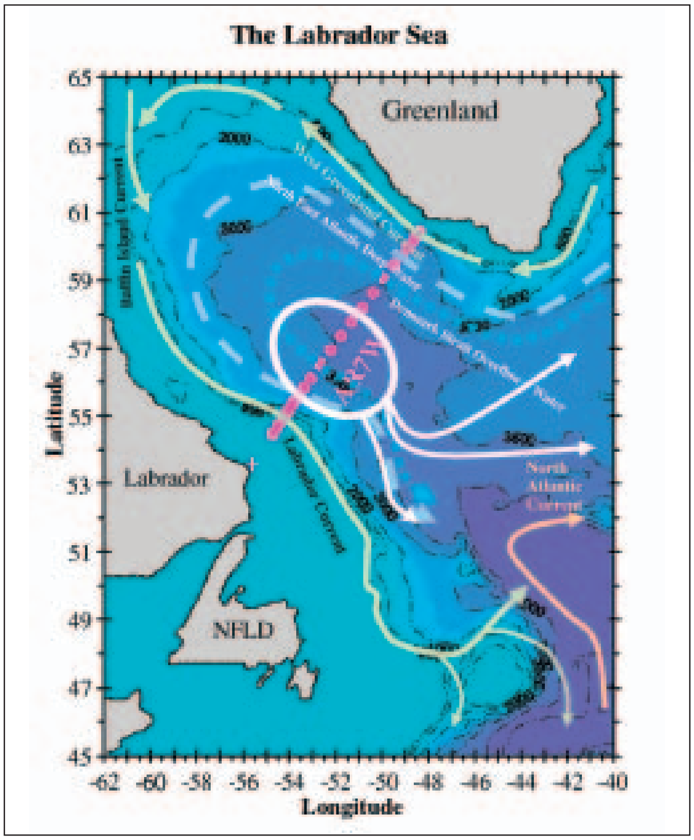


Figure 2. On this map of the Labrador Sea, solid green lines represent surface currents and broken blue lines represent deep currents. The white circle is where Labrador Sea Water is formed and the white lines show spreading LSW. The red line indicates the time series line.

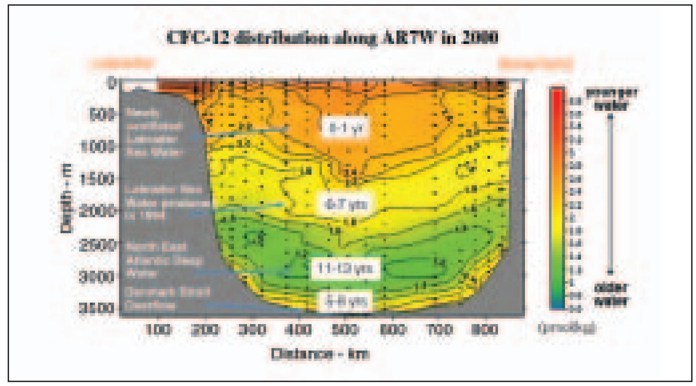


Figure 3. Distribution of CFC-12: numbers in the white squares are age estimates.

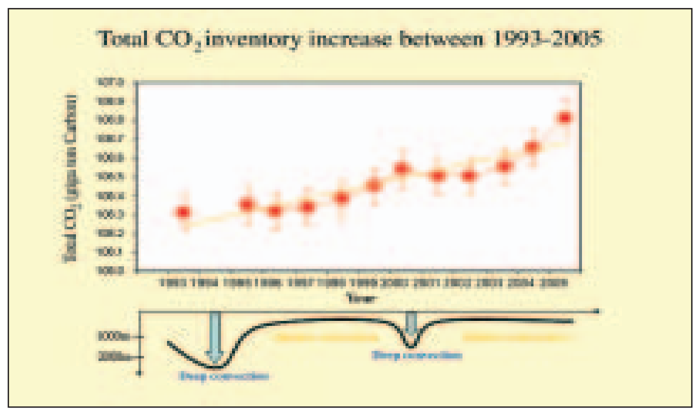


Figure 4. The inventory of total CO_2 in the Labrador Sea has been increasing steadily, with possible enhanced CO_2 uptake during the deeper convection period.

WHAT CAN TRANSIENT TRACERS DO?

Chlorofluorocarbons (CFCs), or "freons", are anthropogenic compounds that have been used as refrigerants and in other industrial applications since the early 1930s. CFCs have been found to destroy the ozone layer, and their production was banned in 1988 (Montreal Protocol). Despite this, atmospheric concentrations of CFCs have been increasing throughout the 1990s because of their slow release to the environment from, for example, old refrigerators and air conditioners. We can estimate the age of water masses by measuring their CFC concentrations. The surface water CFC concentrations reflect those in the atmosphere, which have been increasing over much of the last century. Therefore, water that sinks to the depths carries CFC concentrations corresponding to when it was at the surface. Comparing the concentrations of CFCs in the water and those of atmospheric history thus gives an estimate of the time or "age" of the water mass since it left the surface.

The distribution of the compound CFC-12 along a section across the Labrador Sea between Labrador and Greenland is shown in Figure 3. Using CFC distribution, we identify three major water masses in the Labrador Sea from top to bottom: LSW, NEADW, and DSOW. Convection depths became shallower in the latter half of the 1990s and covered LSW that formed in 1994 at depths between 1500-2200 m. In 2000, convection reached 1600 m and a new distinctive LSW was formed. The ages of NEADW and DSOW are about 12 and 6 years, respectively. NEADW is older than DSOW because the path that this water mass follows to the Labrador Sea is longer than the DSOW path.

Understanding the uptake processes and subsequent spreading of these tracers from the formation site provides a foundation for the interpretation of observations downstream. CFC measurements in the Labrador Sea have been used to estimate LSW production and the spreading rate of the lower limb of the conveyor belt. They have also been applied to the essential task of calibrating ocean circulation models.

CARBON UPTAKE AND STORAGE IN THE LABRADOR SEA

The ocean is a huge reservoir of carbon, storing more than 95% of the total carbon in the atmosphere-ocean system. Thus, small changes in the oceanic carbon cycle can have a major impact on atmospheric carbon concentrations. During the formation of the LSW, atmospheric gases are incorporated into the deepening mixed layer providing an efficient conduit of CO_2 to long-term storage in the deep ocean. Over the period of our study, each year the total inorganic carbon inventory has increased at the average rate of 0.03 Gigaton of Carbon (Figure 4). The oceans, and especially the Labrador Sea, can be highly variable in physical, chemical, and biological properties. Time series observations provide crucial information on the temporal variability of carbon sequestration associated with the deep convection processes in the North Atlantic Ocean. This information contributes to the understanding of changes in carbon cycle in the ocean caused by human activity, apart from the large natural variability. Further, we can identify the role of the ocean for controlling the atmospheric CO_2 level and global warming.

In the laboratory, from left: Frank Zemlyak, Kumiko Azetsu-Scott, Bob Gershey, and Peter Jones

Modelling Environmental Effects on the Early Life Stages of Fishes and Invertebrates in the Southern Gulf of St. Lawrence

Joël Chassé

The ocean's physical environment can affect the drift, growth, and survival of the early life stages of fishes and invertebrates. Over the last decade, effort was made to better link environmental conditions to fish stock recruitment. In most cases, however, the information is used in a qualitative way and it has been recognized that a more quantitative approach is needed to better understand environmental effects on stock recruitment. Unfortunately, the scarcity of past oceanic observations often precludes the development of data-based environmental indices. When forced with realistic data, hydrodynamic numerical models could be good alternative tools to provide information on the states of the ocean. A numerical model is an amalgam of mathematical equations representing physical laws and solved using computers.

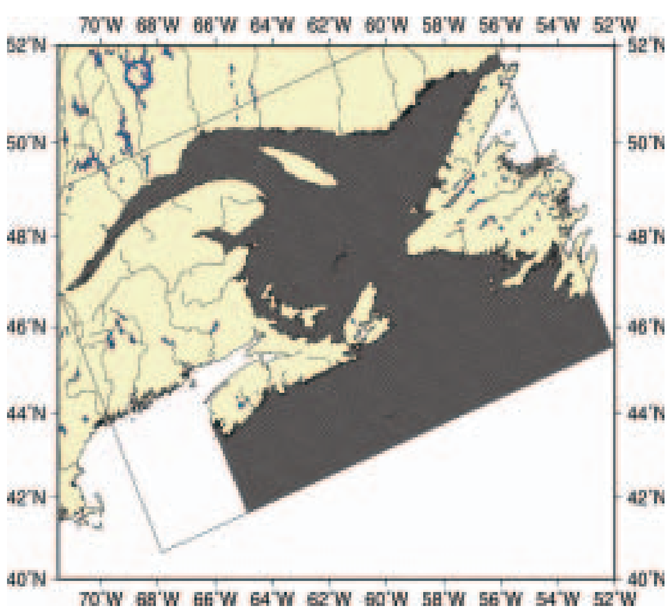


Figure 1. Domain covered by the grid of the model: the resolution is approximately 4 km at 48°N

This article presents a three-dimensional biophysical modelling system used to hindcast oceanic conditions as well as the drift, growth, and survival of the early life stages of selected fishes and invertebrates in the Southern Gulf of St. Lawrence (SGL). The objectives are to produce information from 1950 to the present to better understand the effect of the physical environment on the survival of the early life stages, and to use the modelling system in forecast mode by integrating information from climate scenarios. Model-based indices are provided through output of physical properties of the ocean and/or through modelling of some biological properties themselves.

A generic bio-physical modelling system has been implemented for the Gulf of St. Lawrence and northeastern Scotian Shelf (Figure 1). Individual-Based Models (IBM) of the early life stages of fishes and invertebrates are incorporated into a full hydrodynamic model of the ocean. The main biological inputs to the model are the parameters representing the distribution and abundance of the early stages of the life cycle (i.e., eggs and larvae), as well as growth and mortality rates. The physical component is a high-resolution predictive model capable of long-term advection-diffusion of the temperature and salinity fields. In the model, the water column is divided in layers, with a finer resolution closer to the surface, in order to resolve the mixed layer. Special equations are also included for the calculation of the mixing between the dif-

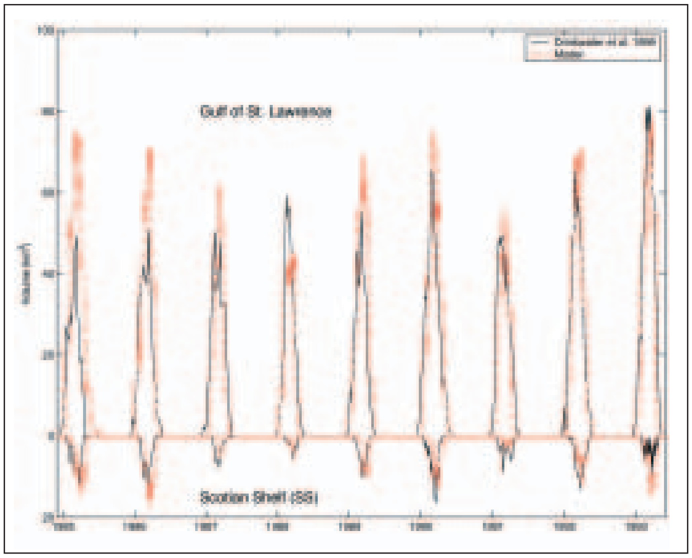


Figure 2. Observed (black lines) and simulated (red) ice volume in the Gulf of St. Lawrence (upper) and Scotian Shelf (lower)

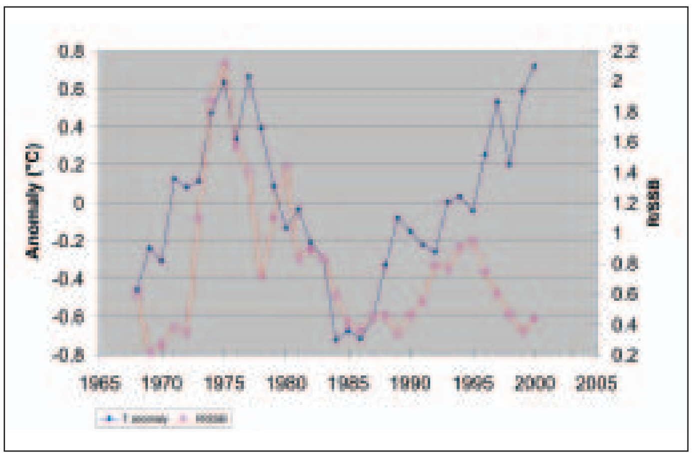


Figure 3. Simulated temperature anomaly for month of June over the SGL and comparison with Cod Recruitment Rate (R/SSB) (Data courtesy of G. Chouinard and D. Swain, GFC)

ferent water masses. It is driven with the NCEP reanalysis data provided by the NOAA-CIRES Climate Diagnostics Center (Boulder, Colorado) and includes the wind, air temperature, cloud cover, atmospheric pressure, and relative humidity from which the heat fluxes are calculated. It includes the tides and runoff from the main rivers of the system and is initialized with temperature and salinity fields. The modelling system also includes an ice model coupled to the ocean and atmosphere which allows for modelling processes for any time of the year and provides quantitative information that could be used to better understand bio-physical processes.

Water levels and currents are reproduced by the model. Comparison of the model surface temperature with Sea Surface Temperature (SST) from satellite observations (1982-2000) shows a good performance of the model. Ice properties are also reasonably well reproduced with the modelling system, as shown by a 10-year simulation (1985-1994) that demonstrates the model capabilities in terms of ice modelling (Figure 2). Fine tuning of the coupled models is ongoing and even better results are expected.

Several fish and invertebrate recruitment questions need to be answered in the SGL. As an example, Figure 3 shows the observed recruitment rate of cod compared to a modelled temperature anomaly time series of the surface water in the SGL. R/SSB represents the cod recruitment rate. An increase in R/SSB happened at the beginning of the 1970s following an increase of temperature in the surface layer. (Higher temperatures typically mean greater recruitment.) R/SSB dropped in the mid-1970s and increased again at the end of the 1980s, after a temperature rise, but finally dropped in the late 1990s while the temperature was still going up. The reason for higher R/SSB in the mid-1970s is still unknown. It is not obvious that the two time series are directly related, but there clearly are physical factors other than temperature such as the drift of larvae, that could affect cod recruitment in the SGL. That conclusion underlines the importance of having Individual Bases Models (IBMs) of the early life stages to investigate this kind of issue.

The models include fictive particles, representing clusters of eggs and/or larvae, released in the model at the beginning of a simulation and followed by a numerical tracking method. Each cluster has properties like the number of eggs or larvae, the current egg or larval stage, and the growth rate. The clusters are then sent to a growth module, where each entity generally grows as a function of the ambient temperature. The number of eggs and larvae in the cluster are adjusted with a mortality rate in another module. The mortality rate depends on the species but a typical value is around 20% per day. After the mortality module, the clusters are sent back to the tracking module. When the larvae reach their maturity, they are sent to a settlement module where they contribute to the next phase of recruitment. At any time during the simulation, the concentration fields of eggs and larvae can be calculated for each stage and output for analysis or display purposes. The individual life history of each cluster is also an output and this allows for the calculation of lifetime based temperature indices. The biological data input includes, but is not limited to, the concentration of snow crab mature females measured during an annual trawl survey conducted in the SGL by DFO's Gulf region (courtesy of Mikio Moriyasu, Gulf Fisheries Centre [GFC]), cod eggs concentration (courtesy of Martin Castonguay, Institut Maurice Lamontagne),

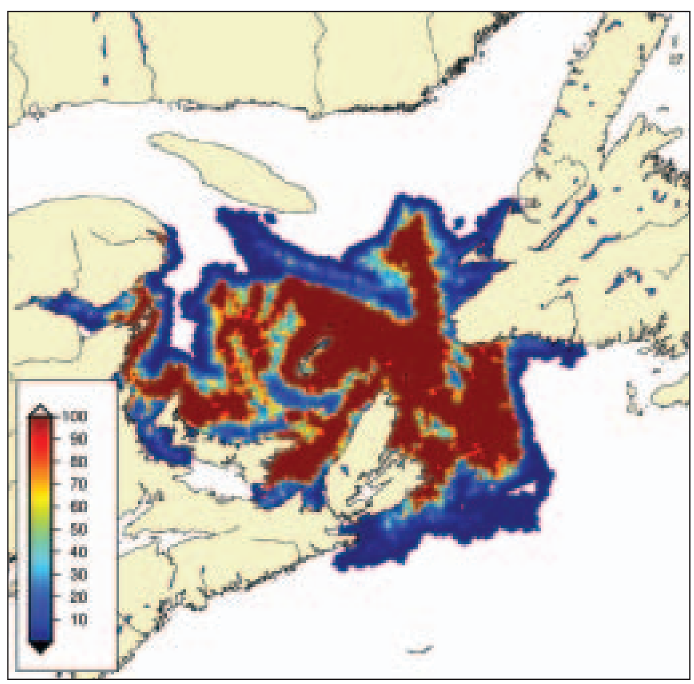


Figure 4. Settlement concentration for the snow crab larvae in 1989

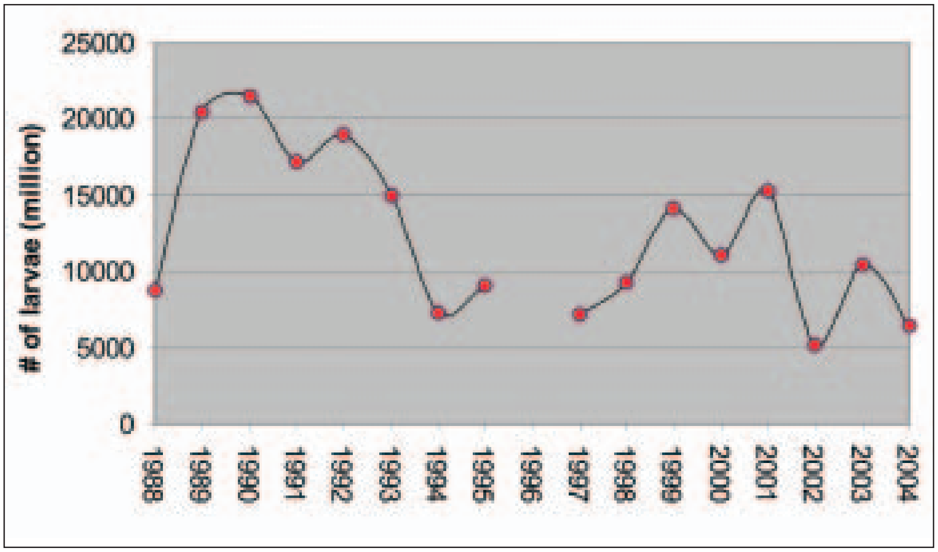


Figure 5. Time series of snow crab larvae settlement in the Southern Gulf of St. Lawrence

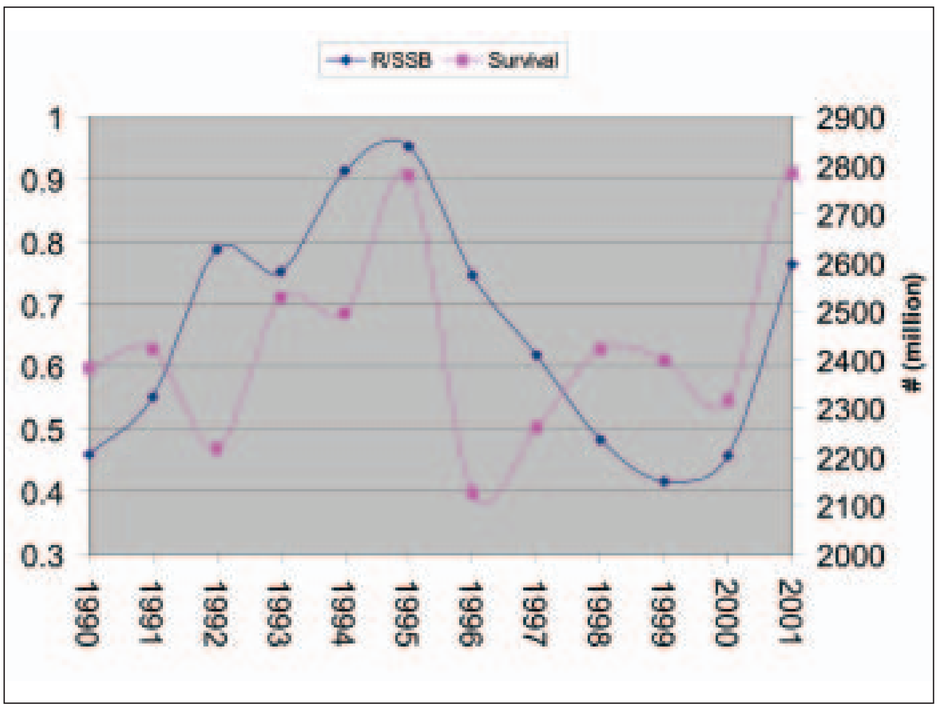


Figure 6. Time series shows cod survival in comparison to cod modelling.

and berried-female lobster concentration (courtesy of Robert Miller, BIO and Michel Comeau, GFC).

Figure 4 shows the snow crab larvae settlement for 1989 as an output example. The main settlement concentrations are located on the east side of the Southern Gulf mostly due to westerly winds that transport the surface water, where the larvae are located. The snow crab larvae reaching the deep Laurentian Channel and warmer water (> 6°C) are not likely to survive as the conditions are known to be unfavorable; this constraint remains to be implemented in the model. The main settlement area for cod larvae is located in the SGL, north of Prince Edward Island, with some concentrations also along the coast of New Brunswick and east of Cape Breton Island. The differences in the settlement patterns for snow crab and cod larvae occur because the snow crab larvae are found in the upper surface layer which is more affected by wind patterns. As well, the snow crab larvae are in a pelagic phase for a longer time period than the cod larvae. This allows for more dispersion in the environment.

The survival of snow crab larvae in the SGL for 1988-2004 is shown in Figure 5 while the survival for cod larvae (1999-2002), compared to the cod modelling, is shown in Figure 6. The time series for snow crab peaks in 1990 and shows lower survival at the end of the 1990s. For cod, the modelled time series peaks in 1995, with a minimum in 1996. An improvement could be seen when comparing with Figure 3 where only temperature was used as a physical index. The whole time series from 1971 to 2005 for cod will be modelled soon. A detailed analysis of the results shows that the survival of the larvae is a highly non-linear function of temperature, drift, and mortality. In general, by shortening the larval stage lengths, warmer temperatures are more favorable for survival while drift and mortality rate could be impediments.

The next step is to further link environmental conditions to adult concentrations through population dynamics models. These models will simulate the change in adult population by solving equations combining adult concentration, habitat index, mortality, and recruitment. Then, it is conceptually feasible to model the concentration and movement of the crabs in the environment. These models can also be used to simulate the effect of different fishing scenarios on the distribution of the species. Such a model is under development for snow crab and the habitat index is based on an analysis of the crab distribution as a function of temperature. There is a calibration phase that consists mainly of defining the diffusion and attraction coefficients with a time series of data from 1988 to the present. The model will then be used to forecast conditions, using bottom temperature information calculated with the hydrodynamic model driven with the new forcing from Intergovernmental Panel on Climate Change climate scenarios. The main challenge of this part of the project is to determine the balance between the mortality and the recruitment. Estimates are provided through larval drift (9 years earlier, since this is the time snow crab needs to enter the fishery) and fishing scenarios. For each simulated (future) year, the new distribution of mature snow crab will then be used to feed the larval drift model to estimate the changes in recruitment. A complete modelling system will then be available to allow for a better comprehension of the environmental effects on the whole life cycle of the species.

Biodiversity Facilities – Innovation in Support of the Conservation of Fishes

Patrick O'Reilly and Shane O'Neil

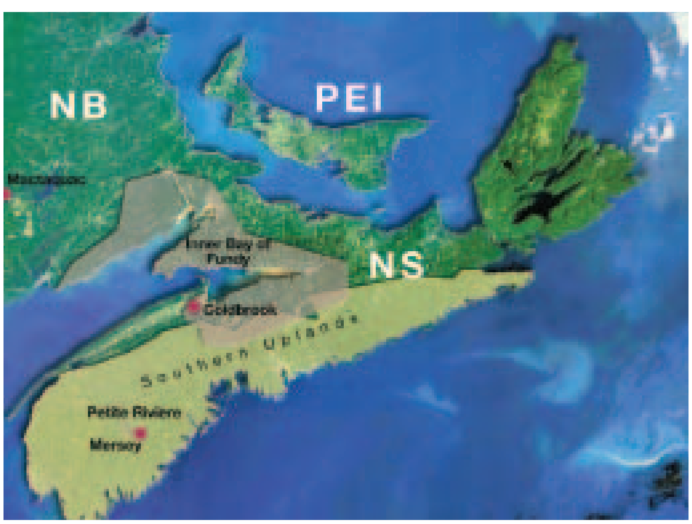
Environmental factors such as climate change, acid rain, and loss of habitat have contributed to a decline in the abundance of many freshwater-dependent species in the Maritime Provinces. Atlantic salmon are a well known example of a locally occurring species in trouble, with most populations along the Atlantic coast of mainland Nova Scotia being either extirpated or at high risk of becoming so within the next two decades. Salmon of the inner Bay of Fundy (iBoF) are at even greater peril, and have recently been assessed as endangered by COSEWIC (Committee On the Status of Endangered Wildlife In Canada). Atlantic whitefish, globally endemic to the Petite Riviere watershed in Lunenburg County, Nova Scotia (NS), are also imperiled. To reduce the chances of losing these populations in the near future, DFO Maritimes has undertaken several Live Gene Bank (LGB) programs at Mersey, Coldbrook, and Mactaquac biodiversity facilities.

LGB programs at these three locations vary but are directed at population conservation and include elements of captive breeding or captive rearing, sperm cryopreservation, and research directed at improving the success of the programs. In the case of the iBoF Atlantic salmon, where marine mortality is especially high, juveniles are captured from the wild and reared in captivity until adults, thereby bypassing the marine phase of the life cycle. Mature salmon are spawned according to a pedigree-based breeding program designed to minimize inbreeding, loss of genetic variation, and the among-family component of selection for captive conditions. A few juveniles from each family are reared in captivity, but most are released into river habitat, where they are exposed to natural selection during a large part of their life cycle. Where possible, they are later captured in natural river habitat as late stage parr or out-migrating smolt, and returned to the LGB, where the process begins again.

The biodiversity facilities' role in helping to conserve salmon from the Atlantic coast of mainland NS (a region of distinct geology also referred to as Southern Uplands [SU]) is quite different. Here, juveniles are captured from the river, reared through to maturity at the Coldbrook Biodiversity Facility, and then released into native habitat to spawn on their own. Offspring of successfully spawning salmon can benefit from mate choice and breeding competition among their parents, and also from early exposure to natural conditions as eggs, fry, and parr.

The use of captive breeding and rearing in the maintenance and recovery of declining fish populations is not an exact science. Research is an important component of iBoF and SU salmon conservation efforts, both to enable recovery programs to be adaptively managed and to contribute to our understanding of the effects of captive breeding and rearing on wild salmon in general, so that future programs can be more effective.

Much of the Atlantic salmon research being carried out at the biodiversity facilities can be grouped into one of four categories: 1)



Map shows location of biodiversity facilities and areas of threatened Atlantic salmon stocks.

Liquid nitrogen (-196°) is being poured from a dewar in preparation for a cryopreservation trial.

"Cryostraws" containing milt from endangered iBoF salmon are being readied for cooling in liquid nitrogen vapour, by Patrick O'Reilly (left) and Shane O'Neil.

monitoring the recovery of family lineages and maintenance of genetic variation over time; 2) analysis of the relative impacts of inbreeding and outbreeding on survival and growth of salmon; 3) investigations into specific aspects of captive breeding and rearing on the survival, growth, and behaviour of salmon in captivity and in the wild; and (4) studies of the effects of introgression of aquaculture salmon into wild iBoF populations.

The LGB program is primarily composed of two separately managed populations of Atlantic salmon, one derived from hundreds of juveniles collected from the Big Salmon River located in New Brunswick, and the other from a similar number of juveniles collected from the Stewiacke River in Nova Scotia. Small numbers of juveniles have also been obtained from several other remnant populations within the iBoF.

Beginning in 2005, research into the effects of specific aspects of captive rearing on the survival, growth, and behaviour of iBoF salmon in captivity and in the wild was initiated. We will also be investigating the effects of captive rearing at different life cycle stages on spawning success in semi-natural and natural conditions. Finally, comparisons of survival and rates of growth of the progeny of first and second generation LGB salmon in captivity and in the wild will be made to assess the cumulative (primarily genetic) effects of captive rearing on the fitness of wild salmon.

Further, earlier research conducted at BIO identified highly genetically divergent and highly domesticated European aquaculture salmon in the Bay of Fundy area. To assess the potential effects of aquaculture escapees of European origin on wild iBoF salmon, first generation European-North American hybrid salmon captured in an iBoF river are being backcrossed to North American salmon, and survival and growth under varying conditions monitored in captivity.

Cryopreservation research at our facilities is directed at establishing a reliable technique to freeze viable milt (sperm) which is necessary to preserve the genetics of the population, because regardless of the intent or successes of the LGB program, important and rare genes will be lost. Preserving genes through cryopreservation also prevents gene alteration through captive rearing practices. Cryopreservation involves the freezing of sperm in a protectant solution in liquid nitrogen (at -196°C). Cryopreserved sperm can be stored frozen indefinitely or specimens thawed out as required to contribute genes to the LGB mating program. Although the technique has been reported successful with some salmonid species, the process and effectiveness can be quite variable, particularly for Atlantic salmon. Trials were conducted at Coldbrook in 2003 and 2004 and at Mactaquac in 2005. The approach has been well documented and includes several steps: 1) collecting the milt, 2) examining the milt for motility and discarding specimens with low motility unless their genes are particularly rare and valuable, 3) mixing the milt with the appropriate extender (solution used to protect the cells during freezing), 4) selecting the method for freezing the milt and associated storage containers, 5) freezing by the desired method, and 6) storing the frozen sperm in liquid nitrogen.

In the 2003 and 2004 trials, success rates with the cryopreservation procedure varied, so a third set of trials was scheduled for Mactaquac in 2005, when several treatment groups were again set up to improve our understanding of the process and our success rate. The results of those fertilization trials will be available in the spring of 2006. At the same time, the cryopreservation gene bank was initiated with the sperm from 22 Big Salmon River males collected and preserved in a dewar (liquid nitrogen container) at Mactaquac. Although the storage unit will require ongoing maintenance and a periodic top-up of liquid nitrogen, the preservation of the endangered genes is well worth the effort. The knowledge and experience gained will permit broader cryopreservation of sperm from our endangered Atlantic salmon and Atlantic whitefish stocks in the coming years. Collectively, these efforts are working towards conservation of fish populations as risk.

Chemical Evidence to Support Environmental Conclusions

Jocelyne Hellou

Environmental science is a multi-disciplinary field where numerous specialties interact to answer questions relating to environmental health. Chemistry is an essential discipline within this science, and DFO's Organic Chemistry Group (OCG) of the Ecosystem Research Division at BIO is a leader in environmental research. One significant area of OCG research is the identification of contaminants found in sediments and marine life, along with behavioural effects on organisms.

To identify deviations from a normal population, an ecotoxicologist will rely on a geographical comparison of matched subjects to determine the significance of an anomaly. Although matching the life history of an aquatic species with the environmental history of an area is not easy, chemistry provides powerful tools to extract, separate, isolate, and quantify specific molecules of interest. They can generally easily differentiate the biologically derived from the man-made chemicals. After that, the assignment of the source of chemicals, although problematic or not unique in some cases, will enable a link to be made with the presence or persistence of a chemical in the environment.

The OCG has expertise in analysing a variety of chemicals, including many molecules identified by government as "priority pollutants" because of their known potential toxicity, along with "emerging" chemicals that need more attention. In our lab, chemical analyses are performed with quality assurance/quality control, thus ensuring good data. Because of this high quality, chemical results from the OGC lab play a major role in explaining biological effects that can be associated with many confounding variables.

Aquatic organisms are exposed to contaminants through various mechanisms: ingestion of food, respiration in water or air, and simple dermal contact. How much is taken up over time will vary with both the chemical and the animal species under consideration. Ultimately, the bioaccumulation of contaminants within an organism represents the balance between the proportions taken in, and those eliminated by the gills (respiration) and through egestion of body fluids. Additionally, the sex, age, reproductive cycle, enzyme activity, and amount of lipid in tissues can influence the fate and effects of contaminants on animals. The amount and length of exposure are also critical variables. Depending on the species being studied, the investigation of fate can relate to identifying the presence of the original molecule(s) discharged into the

Ecosystem Research Division staff and students collect amphipods along with sediments.

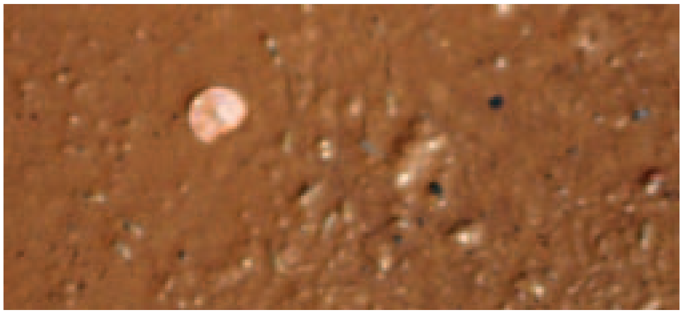


Photo of inter-tidal sediments under seawater shows tiny amphipods in relation to a slightly submerged penny. The white spots represent the various amphipods moving around.

Amphipods measure about 1 cm when extended and weigh less than 10 mg (wet weight). They can look transparent in the right light conditions. Photo by Roger Smith, Department of Biology, University of New Brunswick, Fredericton

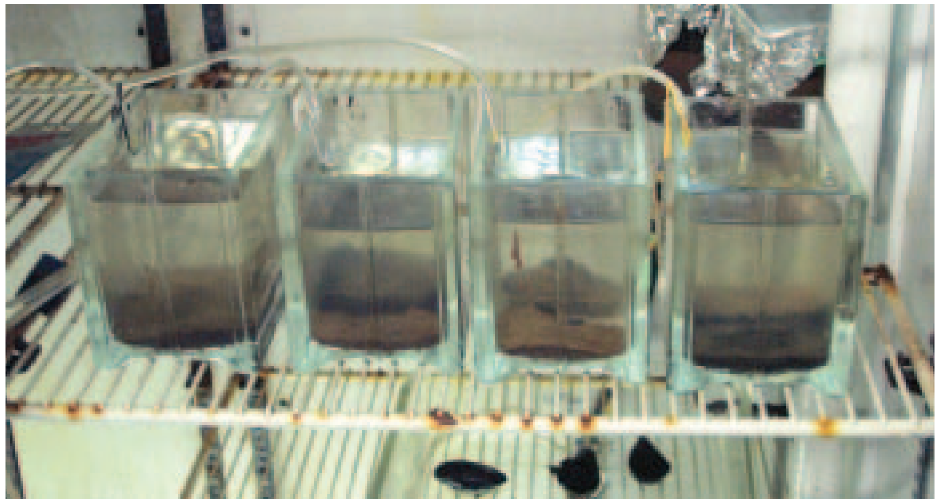
environment, or of new products formed in the environment or within the body tissues of animals. Perhaps the uptake route most easily understood by humans is the one played by food, as diet is a common entry point of biologically derived and anthropogenic chemicals into all organisms. For example, the common belief that "you are what you eat," is partly responsible for the growing popularity of organic food.

The OCG has been conducting controlled experimental research under a variety of conditions to help answer bioavailability and risk questions for understanding cause-effect relationships of contaminants on organisms. In our laboratory, as in many others around the world, inter-tidal mussels are studied to investigate the concentration of contaminants associated with *the water column*. In our case, biological effects in local mussels are examined also to determine the impact of exposure to contaminants. However, there is no commonly used field animal to examine the availability or impact of contaminants present in *sediments*. Applying the selection criteria that led to the use of mussels, namely, geographically widespread, abundant, easily collected, and tolerant of a range of temperature and salinity, the lowly amphipod, *Corophium volutator*, was chosen as our study subject. Low in the benthic food chain, these small crustaceans feed on detritus, diatoms, and bacteria and are prey for invertebrates, birds, fish, and even grey whales. Amphipods have been commonly used for toxicity tests examining narcosis (LC50 [lethal concentration for 50% of a population]) and burrowing behaviour.

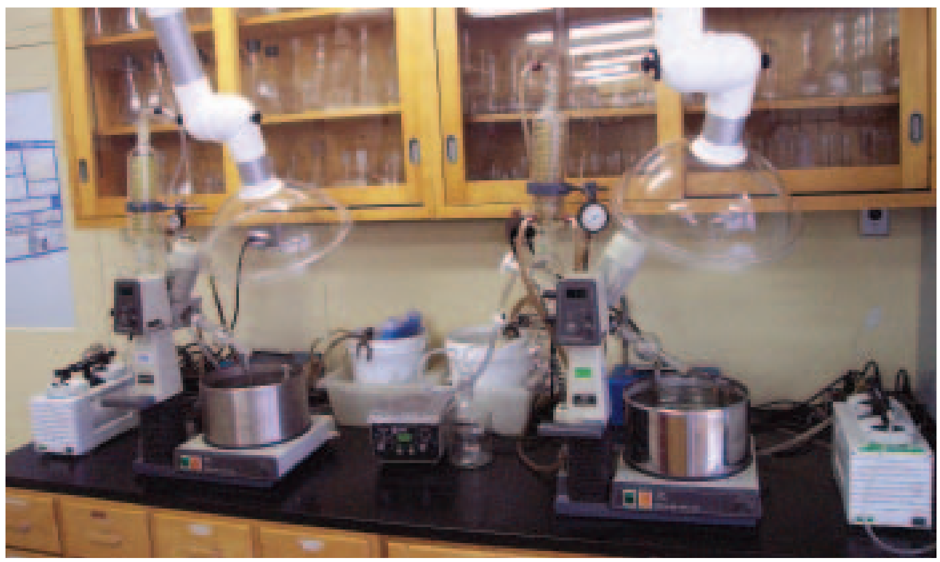
Students hold the Eckman Grab (a bottom sediment grab sampler) and bucket while Jim Leonard from the OCG scoops sediments collected in Halifax Harbour from the grab and into a jar inside the bucket.

To determine the quality of harbour sediments, a chemical-biological approach was developed with *Corophium volutator*. This involved determining the bioavailability of contaminants to the amphipods by measuring their bioaccumulation in these animals and the resulting behaviour of the organisms. Our interest was to determine if amphipods would relocate according to the type of sediments they encounter in their habitat. The test aimed to discover if amphipods avoid contaminated sediments.

In toxicology, avoidance behaviour is regarded as a cumulative indicator of effects on an organism. This simple-to-explain-and-understand laboratory-derived effect would ultimately reflect population level effects in the field. Therefore, negative response or avoidance displayed in a behavioural test would represent an early warning signal of these potential effects in the field.



Experiment tanks containing sediments and seawater, with partitions slightly visible, facing the camera. Tubing introduces air through a needle.



Glassware and tools including two rotary evaporators used in OCG chemistry laboratory

Experiments were conducted using reference and contaminated sediments. The reference sediments were taken from where the animals were collected; the contaminated were reference sediments with the addition of physical and chemical materials that could be found on a beach due to human or natural disturbances. Amphipods were placed in tanks that were divided at the bottom to allow separation of the sediments. The sediments were added to each side to a height of 1-2 cm: one side contained reference sediments and the other more contaminated sediments. These were then covered with sea water, which would allow the amphipods to swim between the two sides of the tank. At the termination of the experiment, the survival and location of the amphipods, which swim easily but prefer to reside in sediments, were recorded. The location of animals was also compared relative to the presence of reference sediments on both sides of the tank, and in >90% of the tests, 40-60% of the amphipods were found on each side of the tank.

The experimental design also called for examining behaviour relative to a gradual increase in added material to the contaminated side of a tank. Trials were performed with sediments containing a range of levels of added sand, ground seaweed, burned wood, coal, fresh diesel and crankcase oils, as well as harbour sediments containing contaminants. Increased proportions of seaweed and the above two oils were added to the contaminated side of a tank, leading to higher death rates among the amphipods rather than to an avoidance behaviour towards these sediments. However, in many cases, when harbour sediments were added to reference sediments in increasing amounts, there was an increased avoidance of the contaminated sediments in favour of the reference sediments.

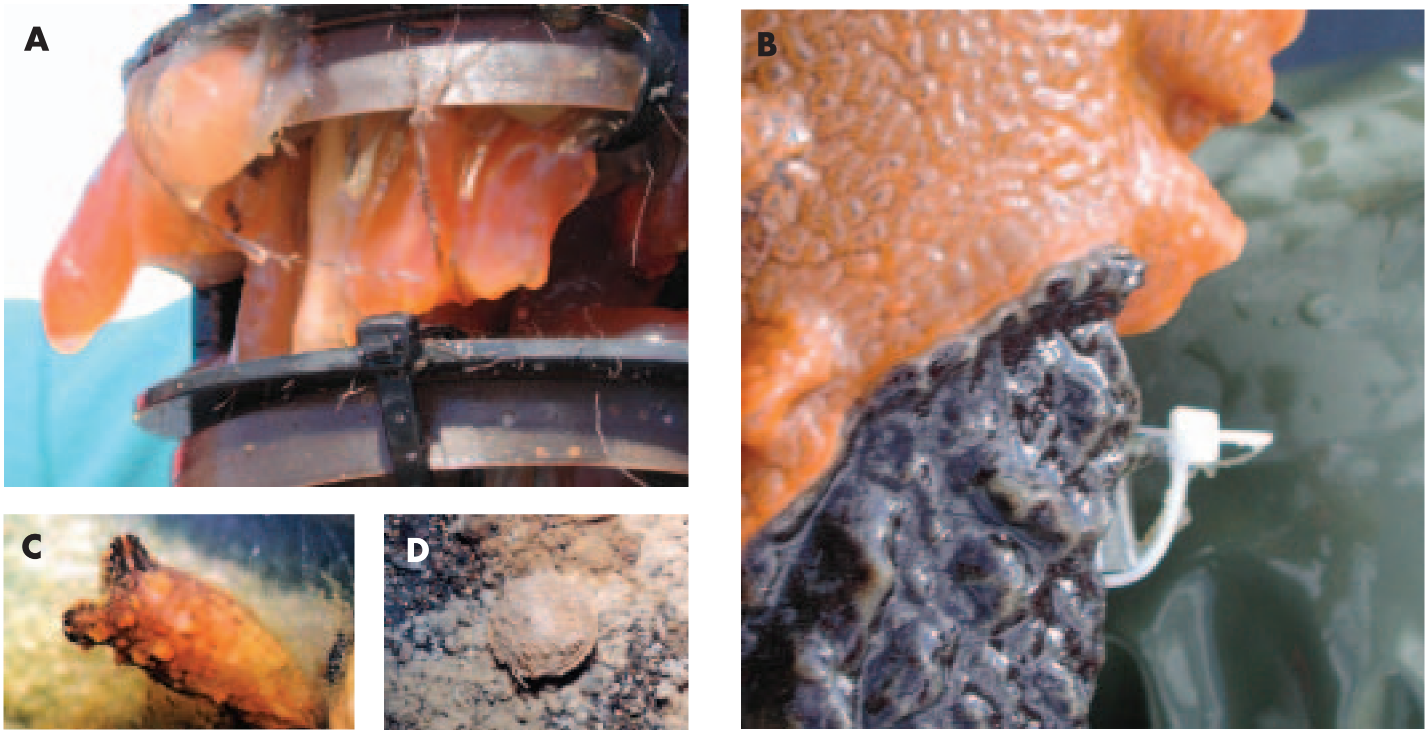
The most abundant group of organic contaminants in harbour sediments is the polycyclic aromatic hydrocarbons (PAH). Our experimental results led to further work to examine the PAH content in the animals' bodies. Therefore, amphipods were exposed to the lowest harbour sediment mixture that elicited the avoidance response. Animals were then analysed for PAH bioaccumulation. PAH were detected in amphipods at a concentration 1,000 times lower than levels associated with narcosis or the commonly used LC50 toxicity test. Using the latter results as the endpoint, none of the harbour sediments was deemed associated with toxicity.

Behavioural toxicology is proving to be a useful tool to explain ecosystem interactions, and research is continuing to untangle variables playing a synergistic or antagonistic role. The attraction/avoidance of sediments represents a balance between the presence and type of available food and of more and less potent contaminants. To strengthen our ability to interpret ecosystem interactions, we need to better understand the chemical-biological link between the fate of chemicals and the behavioural response in diverse animals. This requires that we continue our investigations. As Lord Macaulay, the 19th Century British intellectual, stated, "Knowledge advances by steps, not by leaps."

(The above investigations benefited from the help of many co-op students, for which the OCG is most grateful.)

Maritimes Most Wanted: Have You Seen These Tunicates?

Bénédickte Vercaemer



*A. Vase tunicate (*Ciona intestinalis*) B. Top: Violet tunicate (*Botrylloides violaceus*); bottom: Golden Star tunicate (*Botryllus schlosseri*) C. Club tunicate (*Styela clava*) (photo: US Geological Survey (USGS), Woods Hole)* D. Didemnum sp. *on a scallop (photo: USGS)*

Tunicates, also known as ascidians or "sea squirts", are a type of Aquatic Invasive Species (AIS) which pose a serious threat to the marine ecosystem in Atlantic Canada as well as to the shellfish harvesting and aquaculture industries. Once established in a new habitat, tunicates are very difficult and expensive to control, especially in a bay with aquaculture and boating operations. There, fishing and recreation can increase their numbers by providing attachment structures in the water column and spreading their distribution through inadvertent transportation. The solitary "Vase tunicate", *Ciona intestinalis*, present in Nova Scotia but of unknown origin, is now a prominent fouling species that has caused significant problems for the mussel aquaculture industry since 1997 by overgrowing mussels, reducing yields, and increasing costs of harvesting and processing. On Nova Scotia's Isle Madame and South Shore, increasing numbers of Vase tunicate have been fouling several mussel farms. Recently, the tunicate has been found also in Prince Edward Island—in the Montague and Brudenell rivers, and St. Mary's Bay—where it compounds the problem that the mussel industry is already experiencing with other tunicate species, the Club tunicate (*Styela clava*), the Violet tunicate (*Botrylloides violaceus*), and the Golden Star tunicate (*Botryllus schlosseri*). These last two tunicates form colonies and thus are considered a greater challenge for the shellfish industry. They are found also in Nova Scotia. Another colonial tunicate, *Didemnum sp.*, recently found on Georges Bank, but also present in coastal waters on the east coast of the United States (US) and on the west coast of both the US and Canada, has drawn attention since it spreads rapidly and fouls marine habitats and man-made structures. By overgrowing benthic organisms, including scallops, mussels and oysters, it threatens aquaculture, fishing, and other coastal and offshore activities.

In September 2004, the Canadian Council of Fisheries and Aquaculture Ministers approved the *Canadian Action Plan to Address the Threat of Aquatic Invasive Species*, and funding for an AIS Program became available in July 2005. The program goal is to conduct targeted research and provide strategic science advice to help reduce the introduction and spread of AIS through prevention, early detection, and rapid response mechanisms. One of the two AIS projects conducted by the Ecosystem Research Division at BIO is part of the *Case Study of Tunicates in Maritime Canada* (http://www.dfo-mpo.gc.ca/media/backgrou/2005/hq-ac83b_e.htm).

Information provided through a mussel grower questionnaire survey by the Nova Scotia Department of Agriculture and Fisheries gives imprecise information on the distribution of the vase tunicate in Nova Scotia. Local population explosions have been reported around Lunenburg/Mahone Bay in southern Nova Scotia, and on southern Cape Breton Island. These hot spots are separated by hundreds of kilometres, and several mussel farms located between these hot spots have reported no tunicates.

To understand why there is such a patchy distribution of tunicates, a survey was undertaken in September 2005 to document the population explosion of the vase tunicate on the South Shore between Chester and LaHave and to assess the level of genetic differentiation and gene flow (exchange of larvae) among various bays in this area. At present, we do not have information on the population diversity and structure within this hot spot nor do we know if the range of this hot spot is expanding and, if so, how fast. This project makes heavy use of field collectors and molecular tools, such as the DNA microsatellite markers being developed.

This study monitors the vase tunicate's settlement pattern on a medium spatial scale and samples them at various locations within this hot spot to establish if this ascidian's distribution includes various differentiated (independent) populations isolated by distance and independent founding events, sustained by a rapid expansion of the local population. If adequate genetic differentiation is revealed, it may be possible for us to assign the recent vase tunicate explosion in PEI to a specific origin. This, in turn, may provide knowledge on the possible route of introduction to the area and help design a strategy to contain the range expansion of this tunicate. Conversely, this study may reveal that the distribution of the vase tunicate is more or less continuous along Nova Scotia's South Shore, with gene flow sufficiently strong to homogenize the various populations at a regional scale. Under this scenario, the local hot spots may simply be areas where the tunicate finds particularly suitable ecological conditions for a rapid population increase rather than areas where it was inadvertently introduced. This knowledge is necessary to develop strategies to help tunicate-free mussel and shellfish farms stay this way.

The study builds on existing expertise at Dalhousie University in Halifax and the Gulf Fisheries Centre in Moncton, with development and application of molecular tools to aquaculture issues and invasive species, respectively. It also expands on the work carried out during two successful years of collaborative research on tunicates by BIO, Dalhousie University (Dr. Christophe Herbinger, Masters Student Stephanie Howes, and Honours Student Rémi Daigle), and Indian Point Mussel Farms (Peter Darnell).

IF YOU SPOT A TUNICATE, PLEASE CONTACT:

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Collector retrieved from the field (Lunenburg) showing the vase tunicate and the colonial tunicates: violet tunicate and golden star tunicates

Vase tunicate and colonial tunicates fouling oyster spat and net

New Initiatives Fund Search and Rescue Project Labrador

S. Forbes, J. Griffin, and R. Palmer

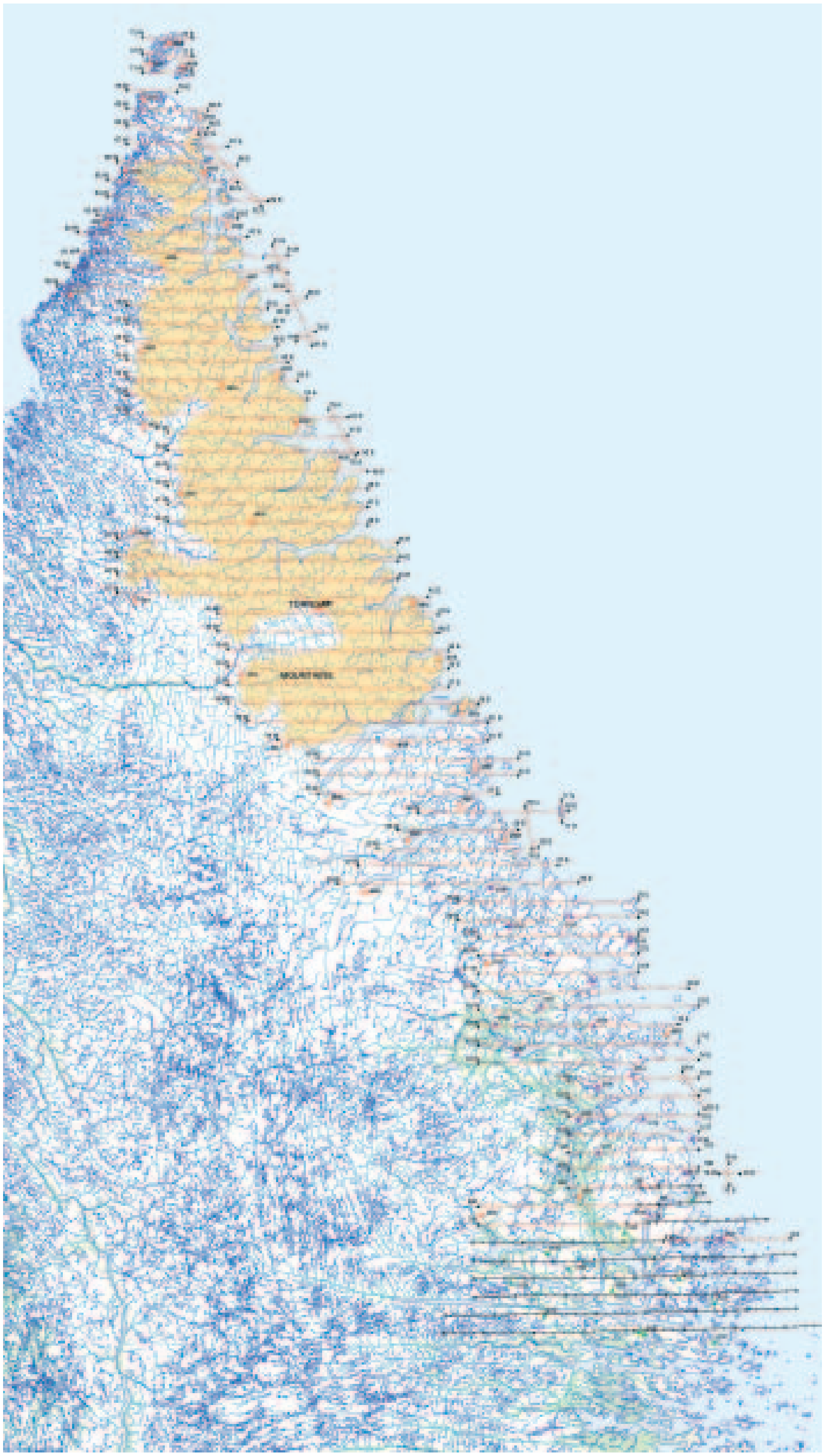


Figure 1. The area to be surveyed and the proposed flight lines for aerial photography

The Canadian Hydrographic Service (CHS) is aware of a lack of modern coastal information on Canadian charts along the Labrador Coast, particularly from Nain to the Button Islands. There are instances of rocks and islands that are not identified, or properly positioned, and some coastal features, such as fjords, that do not have good shoreline identification as currently published on CHS products. This situation is hazardous to mariners and those involved in Search and Rescue (SAR) missions. However, the current priorities, funding, and resources have seriously curtailed the effort necessary to address charting this region to modern standards.

CHS Atlantic Region submitted a multi-year project proposal to the New Initiatives Fund (NIF) SAR in 2002 to address the SAR component by using Global Positioning System (GPS)-controlled high resolution aerial photography to map the coastline from Nain to the Button Islands. The proposed project objectives would provide modern shoreline information produced from the aerial photography, published on provisional charts. The NIF is a jointly funded, interdepartmental program that supports projects that could not be funded entirely by the proponent department(s). The fund consists of two components: the financial contribution from NIF and the financial or in-kind support from the proponent (CHS Atlantic). These projects typically run from one to a maximum of three years and the Labrador project received approval in the summer of 2003. Figure 1 shows the Labrador coastline and the proposed flight lines to collect the aerial photography used to generate the digital shoreline information.

CHS Atlantic, as part of the project proposal, developed a Memorandum of Understanding (MOU) with the Survey and Mapping Division (SMD) of Newfoundland and Labrador, and the NIF. CHS Atlantic had successfully contracted the SMD office in past years to deliver shoreline information for Newfoundland and Labrador derived from aerial photography. Their specific role in this project under the terms of the MOU was to provide the technical support, the survey, and survey equipment necessary to establish the ground control and targets for the aerial photography. In addition they would contract the equipment (aircraft, camera, etc.) needed to fly the photography and digitally process the photographs taken to derive and deliver the shoreline information to CHS Atlantic for incorporation to the provisional charts.

AERIAL PHOTOGRAPHY DATA COLLECTION

The data collection consisted of obtaining the aerial photography and collecting water level information at four locations between Nain and Cape Chidley, Labrador (Figure 1). The project proposed collecting all the data in 2003 and 2004 and delivering the provisional charts by March 2006.

The required ground control and aerial targets were established in Labrador during July and early August 2003. There is a short flying window for the collection of aerial photography in this region. The operation must take place after the snow has melted in late July or early August to allow the aerial targets to be seen on photography. New snow arrives mid-September to early October. In addition, the data collection requires clear weather in an area where the weather can be very inclement even in the summer months.

The summers of 2003 and 2004 were not amenable to aerial photography, with poor weather and unexpected equipment failure. At the end of September 2004, only 50% of the coastline photography had been captured. It was very apparent that the project could not be completed within the original proposed timeframe, even if the data collection was completed in the summer of 2005. A project amendment was submitted in fall 2004 proposing that the data collection would be completed in the summer of 2005 and that the project be extended one year to allow the delivery of the provisional charts by March 2007. This amendment was accepted by NIF and, fortunately, the weather in northern Labrador was cooperative in the summer of 2005. The aerial photography was completed and 100% of the coastline between Nain and the Button Islands was captured.

WATER LEVEL DATA COLLECTION 2004 AND 2005

Also problematic was the gathering of the water level information to establish vertical datum for hydrographic data collection and to determine the high water mark for the interpretation of the aerial photography and the elevation datum for the hydrographic charts. This data collection was not inhibited by weather but by the polar bear population in the remote areas selected for the water level gauges and their associated equipment. The bears were very interested in our survey equipment (GPS receivers, batteries, water level gauges, etc.) and unfortunately were not very gentle when handling the gear. Numerous batteries were destroyed, a GPS receiver disappeared, and other equipment was seriously damaged. Even with steel cages for the gauge equipment and other precautions taken during the 2005 water level data collection, the bears caused equipment problems and failure.

In spite of the bear's picnic, chart datum was established at Cape Chidley and Hebron Fjord. Benchmarks were established at Brownell Point, Eclipse Channel, and Williams Harbour sites and the preliminary results indicate that the data collected is adequate for establishing the vertical datum.

BATHYMETRIC DATA COLLECTION 2005

The CHS planned to acquire data on the Labrador Coast in 2005 using the hydrographic vessel CCGS *Matthew* to collect multibeam data between Nain and Cape Chidley and to establish a 100% bottom coverage corridor. This information would augment the bathymetric data already present on existing charts in the area and would be incorporated on the provisional charts for the NIF project.

The corridor surveys were sounded with a combination of single beam and multibeam echo sounders (MBES) - Simrad 710. Although this was a standard deployment, it was the inaugural use of the newest MBES in Canada, and the second deployment of this instrument in the world. This cruise served as a true shakedown after the spring refit. The challenge of working in these northern waters was to safely survey poorly charted waters. With the multibeam launch *Plover* running ahead of the *Matthew*, a safe path was

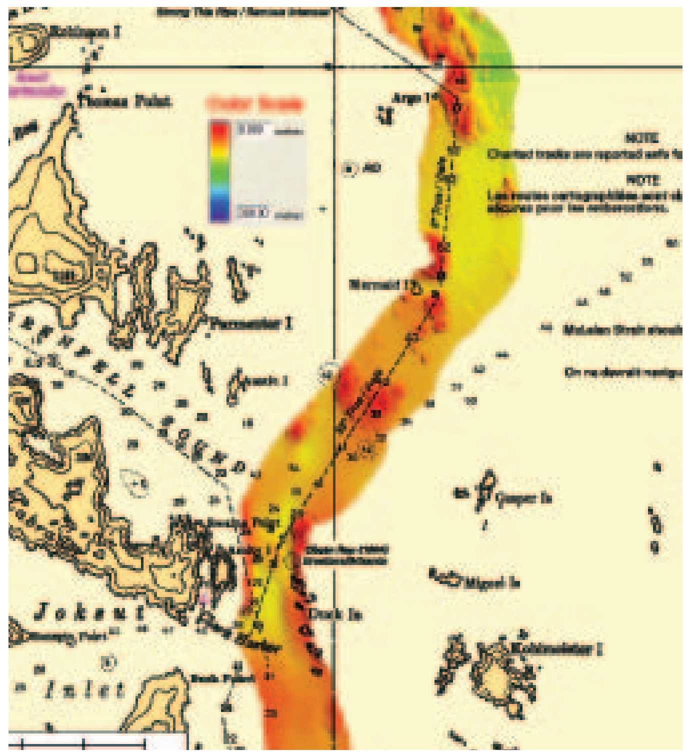


Figure 2. A portion of the corridor surveyed in 2005 depicted on Chart 4773

assured. As this first pass was being acquired, the *Matthew* was able to peer into the un-surveyed area 200 metres off-nadir (centre beam), which provided a necessary safety buffer. On the next survey pass, the ship would travel directly over the area just previously surveyed. This newly acquired multibeam data (sometimes only minutes old) was then processed and merged with existing published (albeit, much older) chart information; this updated information was then sent to the displays used to guide the bridge in their navigation.

This "just-in-time" hydrography permitted a greater area to be surveyed in the given time as the bridge team could draw greater confidence from the chart from which they were navigating. This technique almost doubled the coverage because without this merging of data, the ship would have advanced its swath by only half the previous swath width, an indication as to the increased density of soundings is evident in Figure 2. This image shows the

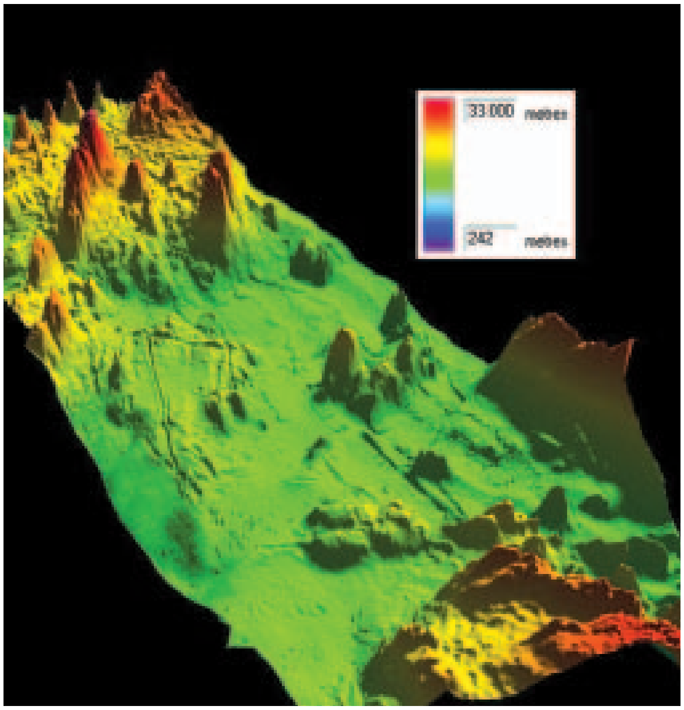


Figure 3. Multibeam imagery near Eclipse Harbour, Labrador (approximately a 2.6-kilometre swath width)

differing densities in data acquired this summer (in color), and the background data on the chart data acquired prior to 1943. This figure is from CHS Chart 4773, and the depths shown are in fathoms and feet.

During summer 2005, to establish the corridor, over 1.2 billion soundings were obtained over a combined distance of 9200 km. Figure 3 is a three-dimensional portrayal of the bottom using the multibeam data collected.

PROJECT STATUS 2005

Scanning of the aerial photography is expected to be completed by December 2006. The next step is to analyze the photography and, in conjunction with the GPS ground control, digitally process the data to produce the high resolution accurate shoreline information.

CHS Atlantic has completed the approved chart scheme and format for the provisional charts. The remaining digital shoreline information is expected to be delivered by early March 2006. All the digital shoreline for the project will be analyzed and reviewed with the scanned photography, topography, and information from all other available sources to incorporate the new shoreline on the provisional charts. CHS Atlantic has captured the bathymetry from the older charts that currently cover this area. This bathymetry, in addition to the multibeam data, will be compiled and registered for the provisional charts. The actual production of these six charts will take place during 2006 with delivery of the digital products by March 31, 2007.

CONCLUSIONS

The Labrador coast is poorly charted in many areas, leading to serious safety concerns for all mariners traversing these waterways. The delivery of provisional charts with modern and historical bathymetric data incorporated on a chart base and with accurate shoreline information will greatly enhance the safe navigation in the Nain to Button Islands region. The charts will provide the Canadian Coast Guard and associated agencies with high resolution shoreline for SAR operations.

The success of this project has been the direct result of a cooperative initiative among the Fisheries and Oceans New Initiative Fund sponsor, the Canadian Coast Guard, the Canadian Hydrographic Service, Atlantic Region, and the Survey and Mapping Division of the Newfoundland and Labrador Department of Environment and Conservation.

Who are Those People in Uniform?

Lt(N) Scott Moody

A small group of Canadian Forces Navy personnel is located in the Polaris Building at BIO. Comprising both Regular and Reserve Force members, these uniformed personnel operate the Trinity Route Survey Office (RSO), which is responsible to the Navy for seafloor mapping on the east coast of Canada. The RSO is co-located with the Canadian Hydrographic Service (CHS) in order to take advantage of the expertise and data available there. When the office moved to BIO in 1995, the Navy owned some sidescan sonars, but lacked the experience and knowledge to operate them effectively. Their new location gave them access to the multibeam sonar data being developed at BIO. This data provides increased information about the seafloor, making it safer to tow side scan sonar from ships.

Since coming to BIO, the group in the Trinity Operations Room has grown from 3 to at least 10 people (the number fluctuates). The original plan was to prepare Mission Plans to support the Maritime Coastal Defence Vessels, thus allowing the ships to go to sea with an advanced side scan sonar system, collect data, and provide it to the RSO after the mission. However, the Maritime Coastal Defence Unit side scan sonar program encountered some delays, so in 2002, the RSO purchased a Klein 5500 side scan sonar system, which would allow the collection and processing of data from vessels of opportunity. Easy to use and set up, the equipment is a commercial, off-the-shelf item capable of collecting high-resolution data at speeds up to 10 knots. To date, data has been collected from boats as small as 7.6 metres and as large as 55.3 metres.

With this new equipment, in 2005 the RSO assisted with a NATO exercise in the Kattegat between Denmark and Sweden, conducting Rapid Environmental Assessment of the area, followed by mine hunting. Subsequently, the equipment was used to survey east coast harbours and approaches, and part of the Great Lakes between Hamilton and Sarnia, Ontario. In December, the side scan sonar was successfully deployed to locate a downed Canadian Coast Guard helicopter on the seafloor off Newfoundland.

Route Survey Office personnel, from left: back: PO2 Leslie Guyomard, PO2 J. Sooley, PO2 E. Roussy, MS M. Comrie, LS B. Brown, CPO2 Langille, CPO2 J. Charest, MS K. Warren; front: Capt(N) O. Thamer, Lt(N) S. Moody, Adm. McNeil, LCdr J. Bradford, Cdr. J. Barber

Following survey work, the RSO is kept busy processing data and building a contact database. After each survey, the new data is compared to existing data, and new contacts are added to the database. To support the every-increasing amount of data, the RSO has recently acquired a new 10 TbRAID with server. This very large data storage device will safeguard data in case of loss of a hard drive and will allow the office to maintain the data online.

As long as there is need for the Navy to survey the seafloor and to have access to the expertise at BIO, the Route Survey Office will remain at the Institute.

New Energy Options for Northerners: Baffin Bay and the Labrador Shelf

Chris Jauer

Figure 1. Rock sample dredged from Scott Inlet, Baffin Island, covered with oil from an underwater seep

The New Energy Options for Northerners (NEON) project at the Geological Survey of Canada (GSC) (Atlantic) has yielded insights to the petroleum potential offshore Nunavut and northern Labrador. Work along this offshore margin in the 1970s by GSC staff noted numerous marine oil seeps and even recovered oil-encrusted rock samples from the sea floor near Scott Bay, Baffin Island. In 1979, petroleum industry exploration made a significant gas discovery at the Hekja O-71 well just outside Frobisher Bay. A nearby test well drilled in 1982 was dry. A later test midway between Canada and Greenland, the Gjoa well, was also dry as was the most recent test done in 2001 at Qulleq, offshore Greenland. At the time of drilling the Hekja well, a gas discovery of any kind offshore would have been a commercial failure due to the staggering costs of pipelines and related infrastructure versus the low price of natural gas. Because of this history, the region has been mostly

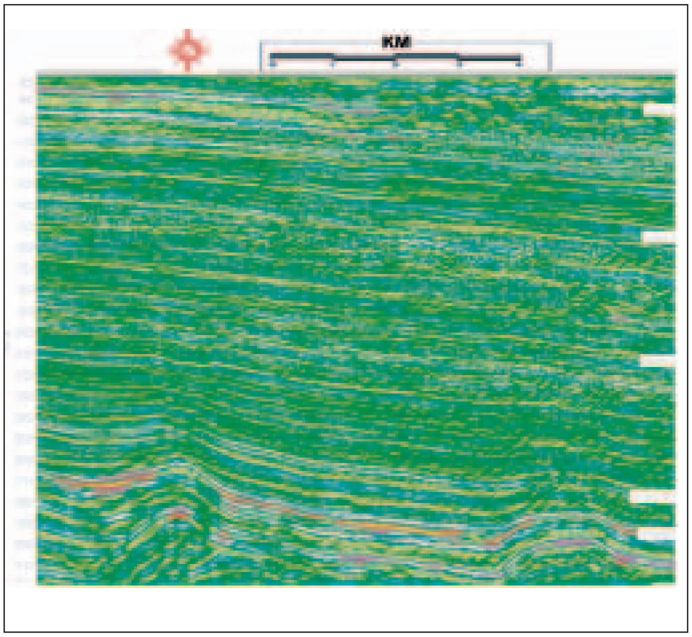


Figure 2. Enhanced seismic reflection image of the gas discovery at Hekja

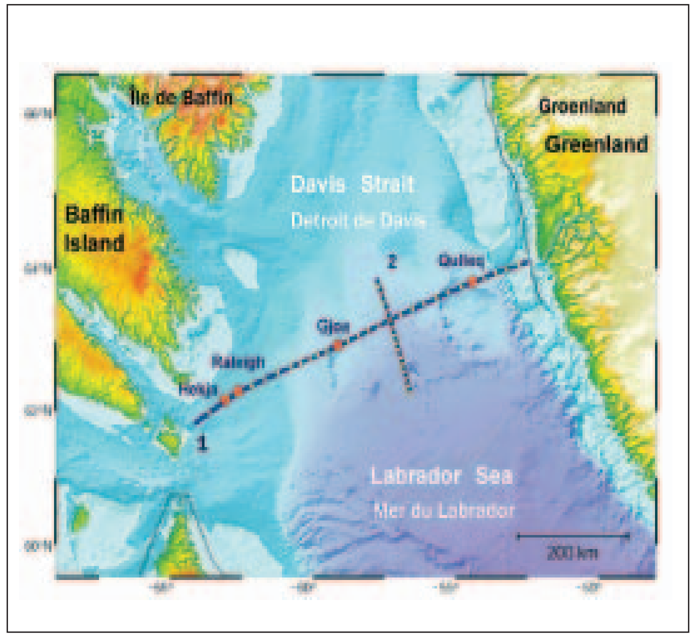


Figure 3. Area of seismic refraction survey in the Davis Strait

dormant in terms of petroleum exploration activity until the recent global shifts in petroleum pricing and forecasts of future supplies for consumers. With this renewed incentive for finding hydrocarbons, the main task of the NEON project is to re-examine the how, why, and where of petroleum in this region.

To conduct petroleum exploration, an area has to be studied with such geophysical tools as seismic surveys, gravity and magnetic field surveys, sampling of the geology from surface exposures, and drill cores. The geological centre for petroleum is a basin, a depression in the deeper bedrock that has been filled with sedimentary rocks. Such basins are typically easily recognizable from geophysical surveys, even when under water. Organic material from plants and animals, deposited with the sediments in a geological basin, is required as the source material for petroleum. Additionally, this source material has to be preserved. The main threat to our petroleum source material is oxygen; therefore, all this organic material has to be fairly quickly buried and sealed. Next, the sealed source matter needs heat to transform it into petroleum. Geological heating is essential for any petroleum occurrence: not enough and the source matter will not have matured to form any hydrocarbons; too much and only a graphite residue will be left behind; the proper range of temperatures eventually "cooks up" petroleum over many thousands of years.

The petroleum explorer must next determine if reservoir rock for hydrocarbons is actually present and whether these problematic hydrocarbons actually traveled from their source beds into this reservoir. The petroleum explorer has to deduce whether or not the potential reservoir was ever filled with hydrocarbons, or if so, whether it has remained intact or has been breached, losing its contents through tectonic activity such as earthquakes caused by faulting or other events. Traditionally, petroleum explorers have used seismic reflection data to find structural bumps in the subsurface that could be petroleum traps.

Figure 2 is an enhanced seismic reflection image of the gas discovery at Hekja, seen as the hill-like feature near the bottom. To the right is a second feature that likely holds hydrocarbons as well. Although this seismic snapshot is invaluable, to assess the region's potential for petroleum a wider perspective is needed. In 2002, a seismic refraction survey that transects the four wells drilled in the region was acquired as a joint effort between NRCan and several academic institutions in Canada and Denmark.

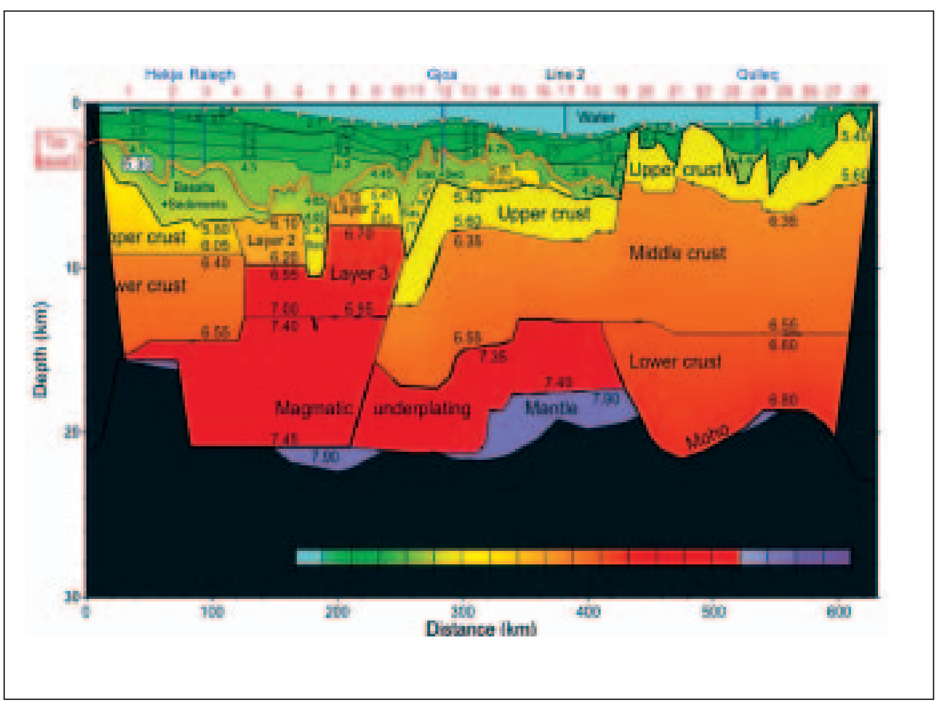


Figure 4. Seismic velocity scale in km/sec: continental crusts are noticeably slower than oceanic crust.

This type of survey results in a calculated seismic velocity model, rather than a conventional seismic image. Specific types of rock can be identified by how quickly they transmit seismic waves; this survey yields a seismic velocity "fingerprint" of the regional geology. Sources of heat to cook hydrocarbons are the deep continental and oceanic crust rocks identified on the profile (Figure 4). This is a very important consideration as the heat produced from oceanic crust is generally higher than from continental crust; a variety of petroleum generating areas appears to be possible in the region.

Confirmation of the heat being generated beneath the sea was obtained in the summer of 2005. A scientific cruise along the transect path took direct heat measurements with a heat flow probe that was lowered into the sea floor in many locations. Another important feature of the oceanic crust identified on the profile is how this zone fits the understanding of the underlying tectonic plates configuration. During the geological evolution of this region there has been rifting of the crust and extensive movement of the plates. This movement of the underlying basement, while quite slow over a human lifetime, has moved the plates hundreds of kilometres from each other over tens of millions of years. The resulting deformation of the overlying basin rocks that ride these plates has both made and unmade possible petroleum traps as these rocks were squeezed and stretched.

The rifting of the plates which occurred along the dotted lines of the map (Figure 5) was also accompanied by volcanic activity, as seen in the vast basaltic flows that were encountered during the drilling of the Canadian wells. The enormous amount of basalt that has flowed here in the geologic past represents another heat factor to be considered in evaluating this region's petroleum potential.

Using the inventory of historical seismic data in the region enabled the creation of a map showing the distribution of the hydrocarbon-producing sandstone, the Gudrid sand unit from the Hekja well (Figure 6). This well location on the map is marked as the more western red pentagon. From an exploration standpoint, the numerous small closed contours such as the one around the discovery, hint at a multitude of possible hydrocarbon accumulations. The reality of drilling, however, was borne out by the second well drilled to the east in 1982, which was barren of hydrocarbons. This emphasizes the high degree of risk that any petroleum explorer must deal with: a geological feature that merely looks similar to another hydrocarbon deposit is never a guaranteed success. The success rate for "frontier" basins, i.e., basins with very little drilling and a low amount of geological data, is usually 5%, or one in twenty attempts.

The final product of the NEON project will be the integration of all known data into a four-dimensional computer simulation of the region. This simulation runs through geological time (the 4th "D") and will enable investigators to look at various scenarios that address when hydrocarbons were formed, when they moved through the geological environment, and where they may ultimately reside. All these compiled data, along with the simulation study, will be made available as a petroleum energy prospectus for interested parties who may be considering resuming hydrocarbon exploration in the area.

Additionally, newer technologies such as Compressed Natural Gas and gas-to-liquid conversion methods are making such "stranded gas" accumulations like Hekja more viable from a commercial perspective. Since the transport of liquid hydrocarbons by tanker is much cheaper than compressing natural gas and then pipelining it to market, these technologies remove the need for massive infrastructure and ultimately resolve the paradox of isolated gas reserves in a world needing new energy sources.

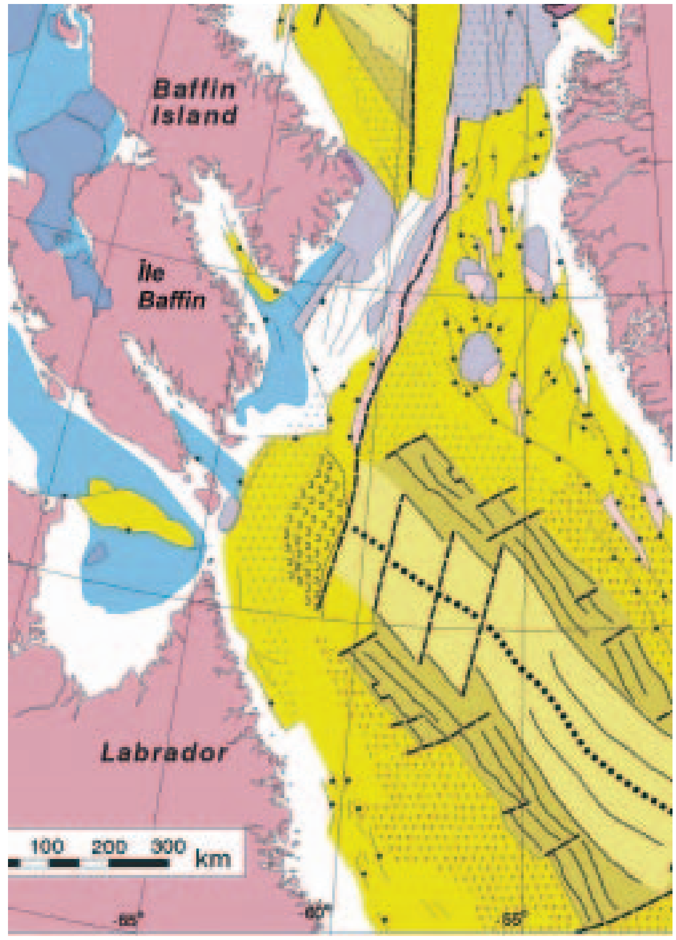


Figure 5.

It is indisputable that there is significant gas here. Viewing the entire region as a petroleum system comprising many factors that can be studied in a methodical manner, will go far toward predicting the location and amount of a resource available to northern residents and eventually to all Canadians.

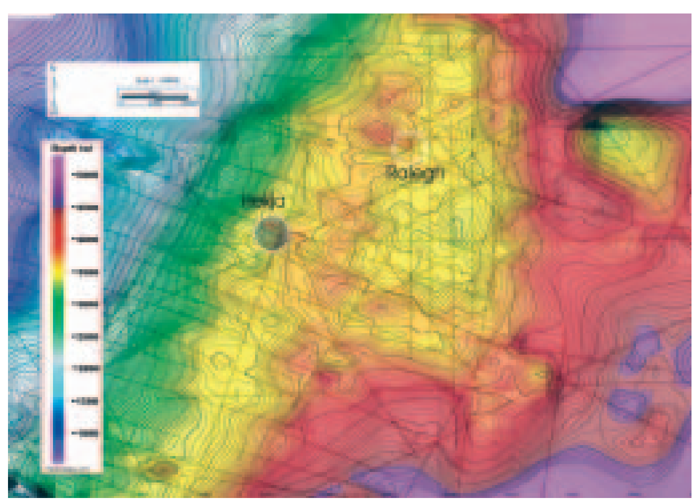


Figure 6. This map made from seismic reflection data shows the geography of the buried sandstone layer where petroleum was discovered at the Hekja well.

The New Marine Map Series: Underpinning Ocean Management in Canada

John Shaw and Brian J. Todd

INTRODUCTION

In the 1970s and 1980s the Geological Survey of Canada (GSC) and the Canadian Hydrographic Service (CHS) jointly published a benchmark series of surficial geology maps of the continental shelves of Atlantic Canada under the banner of the Marine Sciences Directorate of the then-named Department of the Environment. These maps remain in use several decades later. By the late 1980s, map production had ceased but the need for marine geological information continued to grow. Now, the coincidence of two factors has fostered the development of a new map series. First, collaboration between GSC and CHS in the application of multibeam sonar mapping technologies has provided exciting new imagery of the sea floor, and has led to insights into marine geological processes. Second, GSC's Geoscience for Oceans Management Program calls for the production of new marine geological maps, not only for Atlantic Canada, but also for the Pacific and Arctic regions.

THE APPROACH TO MAP MAKING

In 2003, GSC scientists wrote a draft document outlining a standard series of maps and mapping techniques, and a marine cartographic summit was held at the Institute of Ocean Sciences in Sidney, British Columbia to discuss the draft and to obtain consensus on the way forward. It was proposed that the standard map series for any particular area would comprise up to four sheets: 1) sun-illuminated sea floor topography; 2) backscatter strength; 3) surficial geology; and 4) benthic habitat. It was agreed that standard scales such as 1:50,000 and 1:250,000 would be ideal, but departures from this convention would be necessary in certain mapped areas. Also, since the entire offshore was not going to be mapped, the use of a contiguous grid of sheets, similar to NRCan's National Topographic Map Series, was avoided. We decided that land should be portrayed as a grey-shaded digital elevation model with contours superimposed, and that unmapped marine areas should have isobaths (contour lines on maps connecting points of equal depth in a body of water), preferably from the 1:250,000 CHS Natural Resource Map series. A considerable effort was made to expand on an existing series of symbols for marine maps.

MAP 1: SUN-ILLUMINATED SEAFLOOR TOPOGRAPHY

A rainbow colour scheme (shading from violet to red) was considered best for the sea floor topographic maps, with the maximum colour change applied to the zone of the most frequently occurring

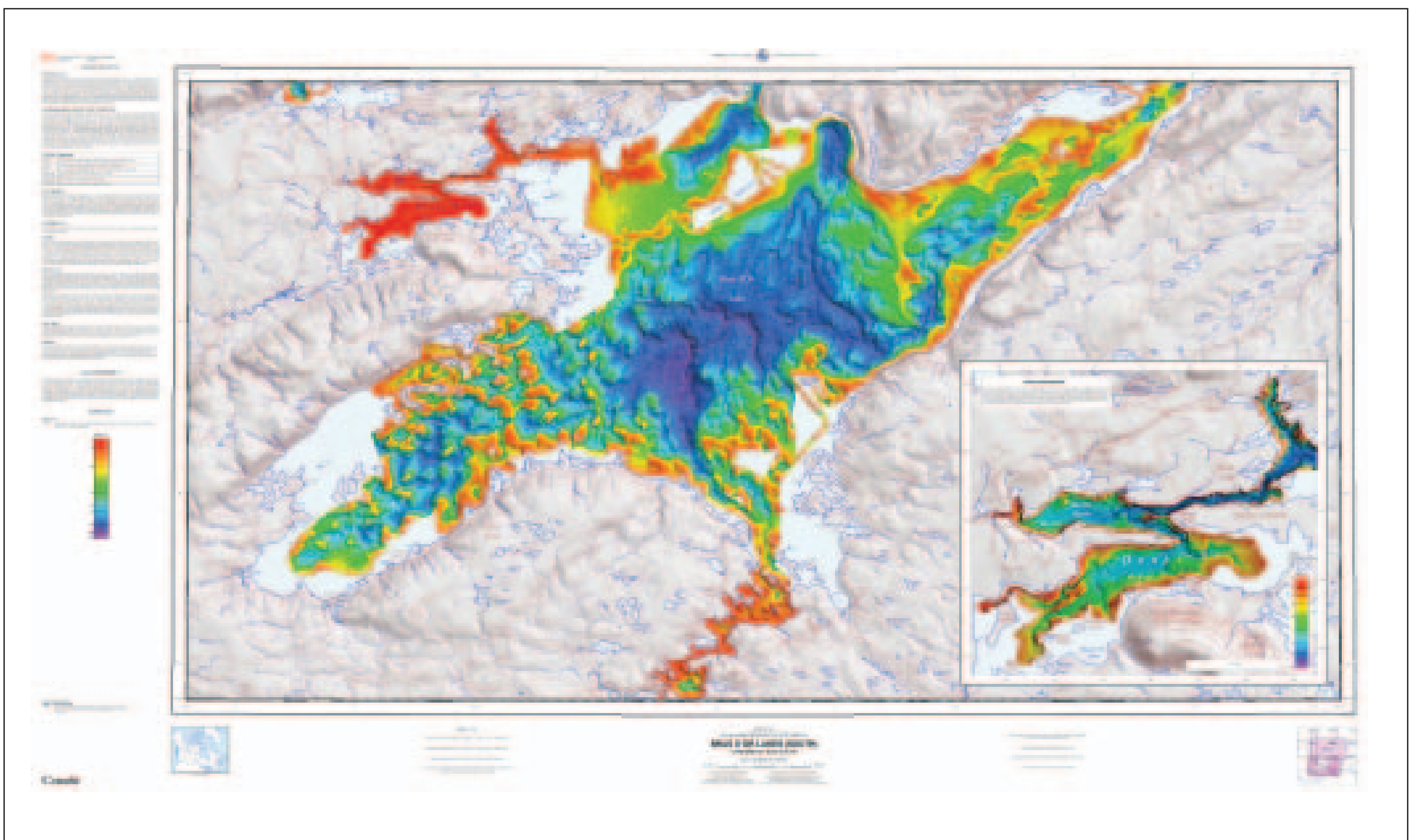


Figure 1. Sun-illuminated sea-floor topography, southern Bras d'Or Lakes, one of a three sheet series for this area

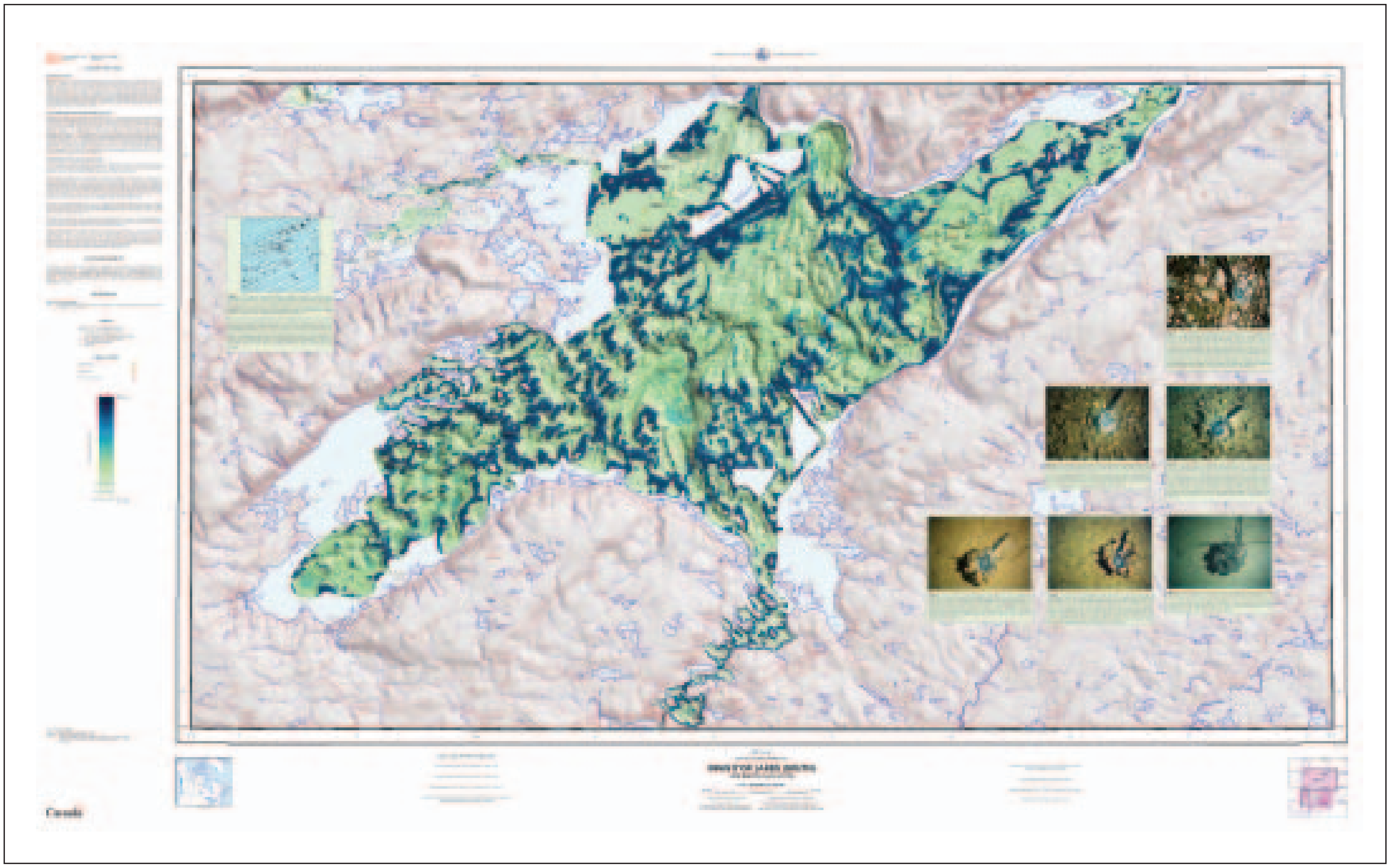


Figure 2: Backscatter strength, Bras d'Or Lakes

depths. Inset maps were used to enhance topographic variations in particular areas. Figure 1 shows the sun-illuminated topography map for the southern Bras d'Or Lakes, part of a series comprising three maps sheets each for the northern and southern lakes. The inset map of Denys Basin imparts topographic information not apparent at the scale of the main map sheet.

MAP 2: BACKSCATTER STRENGTH

Backscatter is the percentage of the transmitted signal that returns to the sonar transducer, expressed in decibels. Backscatter strength is a proxy for the sea-floor hardness and hence for the geological materials on the bottom. Past practice used a black-and-white toned scale, but for the new maps we adopted the "ocean" colour scale (shading from indigo to light green). We draped the backscatter strength over a grey sun-illuminated digital elevation model in order that the maps might convey any relationship between backscatter strength and topography. Figure 2 shows the backscatter strength map sheet for the southern Bras d'Or Lakes, corresponding to the area of Figure 1. The sea-floor photographs depict some of the bottom sediment textures responsible for backscatter strength variations.

MAP 3: SURFICIAL GEOLOGY

The third map in the series was the most difficult to realize. It involved careful consideration of the meaning of "surficial geology". Map three should not merely depict sea floor textures, because they were largely identified by their backscatter strength signals in map two. In addition, surficial geology has a three-dimensional aspect since it encompasses the thickness and lithology of sedimentary units, and the behavior of these sediments in modern wave and current regimes. However, we departed from the historical surficial geology map series in one significant respect, namely, the application of formation names. The authors of the historical map series had taken a formational approach to mapping. On the Scotian Shelf they recognized the Scotian Shelf Drift Formation (till), the Emerald Silt Formation (glaciomarine mud), and the Sable Island Sand and Gravel Formation (a transgressive deposit), among others; comparable formations pertained to the Newfoundland and Labrador shelves. The generic approach was adopted for mapping sediments on a glaciated continental shelf. In this approach, the Scotian Shelf Drift is denoted as ice-contact sediment and the La Have Clay as postglacial mud. Because the formation names are so commonly used, and retain their applicability in many areas, they are denoted in the map legends where possible.

Figure 3 shows the surficial geology map of Browns Bank. Descriptive text describes the data and the geological history. Cross-sections display the three-dimensional nature of the surficial geological units and large-scale topographic insets on the right highlight glacial geomorphological landforms characteristic of Browns Bank

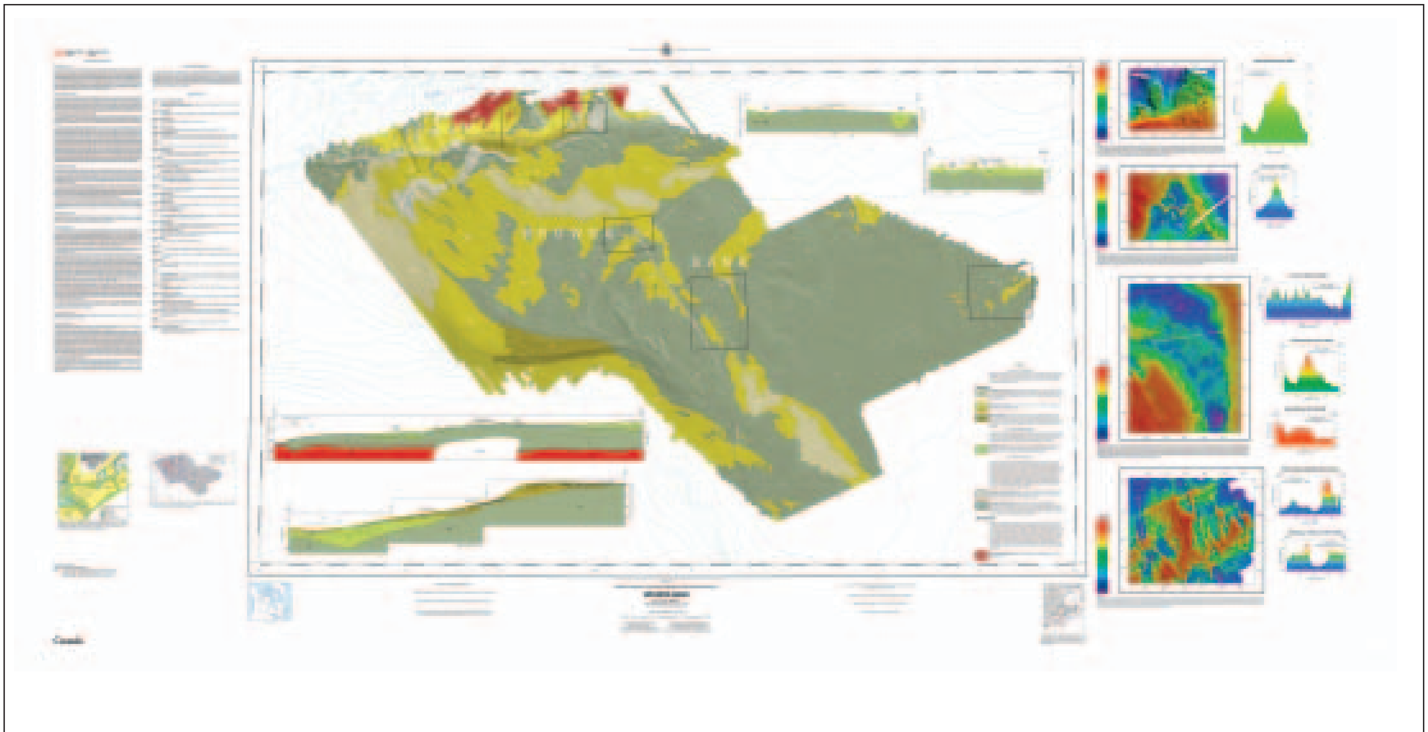


Figure 3. Surficial geology, Browns Bank

MAP 4: HABITAT

Habitat is defined as spatially recognizable areas where the physical, chemical, and biological environments are distinctly different from surrounding environments. Although modern sea floor imagery is a solid foundation for the study of habitats, the classification of habitats requires additional information in the form of video and photographic imagery and geological and biological samples of the seabed. Habitat characterization produces descrip-

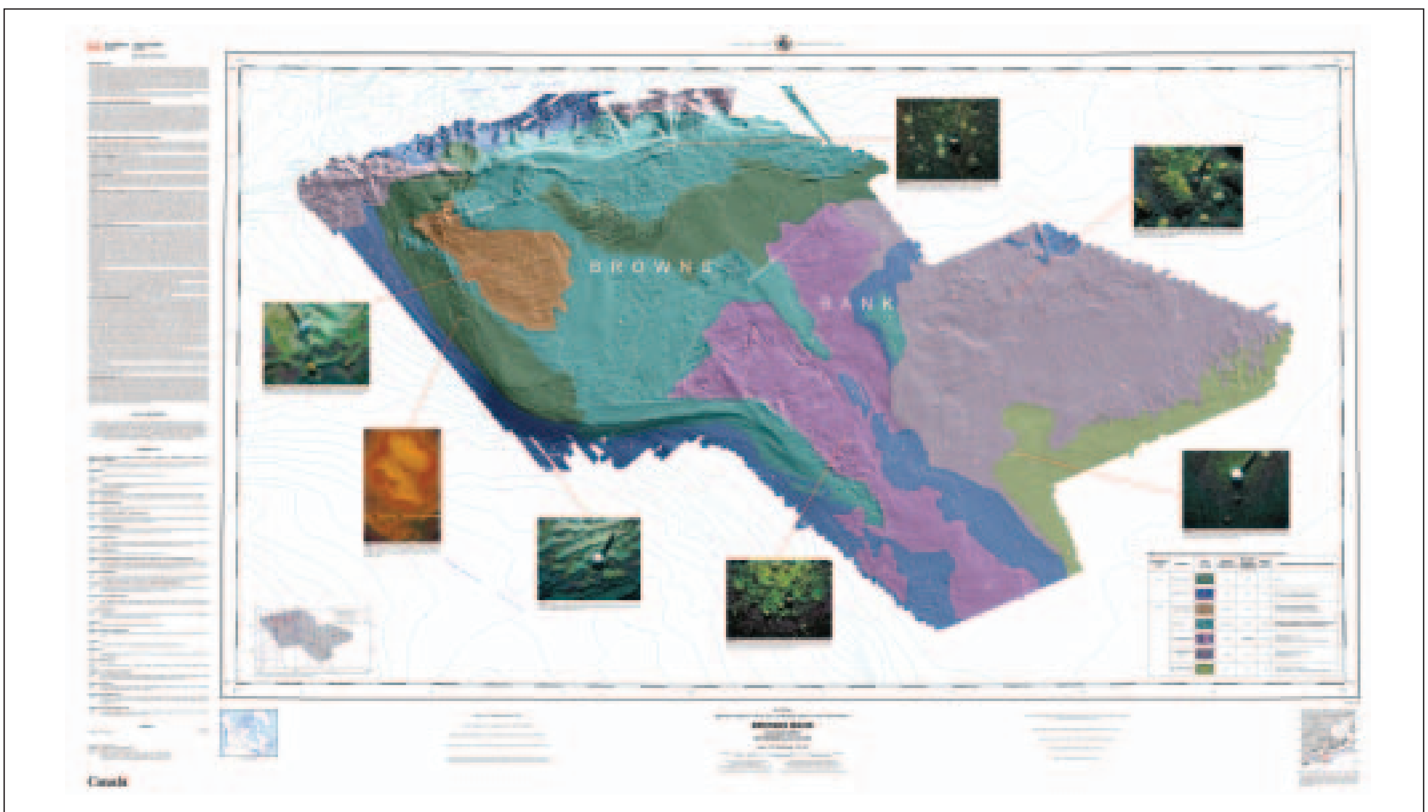


Figure 4. Benthic habitat, Browns Bank

tions of habitats based on geological, biological, chemical, and oceanographic observations. Habitat classification produces a set of habitat types based on a suite of standard descriptors of topographical, geological, biological, natural, and anthropogenic features and processes. Habitat mapping is the spatial representation of described and classified habitats. The habitat map for Browns Bank (Figure 4) delineates seven distinct habitat types with accompanying sea floor photographs.

THE FUTURE

New maps spanning the Atlantic, Pacific, and Arctic oceans will be output from the GSC's Geoscience for Oceans Management Program, and these products are at varying stages of production (Figure 5). Detailed maps will be based on multibeam sonar data (red and yellow designation on Fig. 5) while regional compilation maps will be created where no multibeam sonar data have been collected (green designation on Fig. 5).

These maps will be used in the private sector in the fishing, mining, and offshore hydrocarbon industries, as well as for emerging technologies such as tidal and wind power generation. Government regulators will also depend on these maps to support well-informed decision making concerning future human use of ocean resources. In particular, the maps will be the essential underpinning for new ocean management plans under Canada's Oceans Strategy.

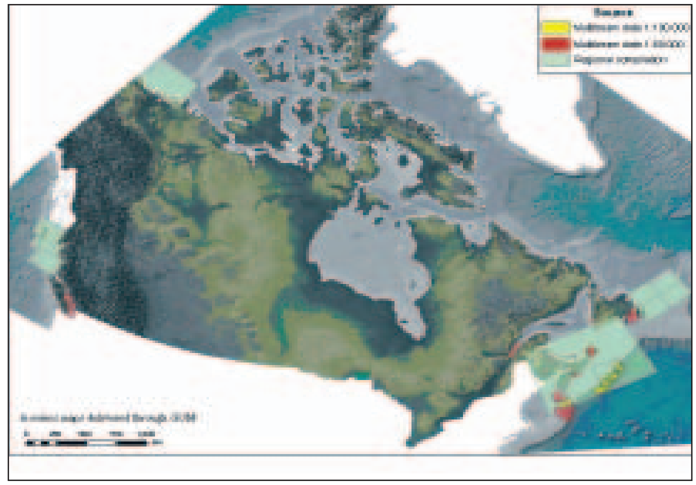


Figure 5: Offshore maps in production for Canada's three oceans

BIO Science in Partnership

Partnerships: Building on a Research Community

Ross Boutilier

Canada needs excellent science to support evidence-based decision making, for policy development, and for regulation. To this end, several federal departments and agencies are actively involved in scientific research and application. However, experience has taught us that in today's world, solving scientific problems is becoming increasingly complex and dependent on multidisciplinary approaches. A single laboratory, institution, department, or even government seldom has the capacity to address these problems alone. Only through effective partnerships can we address the increasingly complex scientific issues of our time.

Government departments and agencies seek to be more responsive to changes in how science is conducted to support decision-making, especially in how our work links directly to our partners in all areas of the economy. Key reports on Canadian Federal S&T that support this approach can be found on the website of the Council of Science and Technology Advisors (CSTA) at *http://www.csta-cest.ca/*. Of particular note is the report LINKS (Linkages in the National Knowledge System), released in February, 2005, which not only recognizes the value of partnerships but calls for much greater cross-connection of S&T work in government. The response of government to these reports can be found at *http://www.innovation.gc.ca/* (follow the sidebar link to Reports on Science and Technology). In particular, the report *In the Service of Canadians: A Framework for Federal Science and Technology* describes the movement to create a more integrated and partnered approach to federal S&T.

To show how differently critical science is done today compared to in the past, consider the example of toxins in our environment. Thirty years ago, specialists in a particular toxin typically studied it at its fundamental level: for example, where it came from, what its chemistry was, how it was measured, and where it showed up. There was a budding awareness that toxins were showing up in unexpected places (such as DDT). Today, we must undertake all these scientific activities we did in the past but also track the toxin's impact on biological processes; all the physical, chemical, and biological processes that move it around or carry it into the food chain; and how it interacts with our socio-economic system. Not only people's health, but their livelihoods and sense of safety, which can dramatically affect our economy, are at stake.

Decision making based on sound science affecting the health, economic well-being, and future of Canadians is increasingly complex and must not only be addressed well, but with a much wider view. Federal government research must find ways to factor in more complex interactions, and only by linking to a wider community of researchers, specialists, and people who help bridge these specializations can we move forward. We need to build solid, reliable, and flexible partnerships. The community of the major Science and Technology (S&T)-performing federal departments and agencies, including the BIO departments of DFO, NRCan, EC, and DND, has been working on a major initiative to identify and plot the removal of barriers to effective and increased collaboration within departments and with all our partners. This work will proceed in the years ahead in an effort to make collaboration a normal part of business for S&T in government. Linked to this are efforts to significantly improve the coordination and ease of sharing personnel, equipment, facilities, and approaches to the management and funding of S&T programs.

Federal studies have revealed that large centres of excellence, such as BIO, are the best approach for getting the most from government investment in science. From its founding vision more than 40 years ago, BIO was intended to be part of the wider world. Partnerships underpin much of the work of

BIO: they can be with the private sector, educational institutions, other organizations within all levels of government, and even with governments in other countries. Examples include teaming up to look for answers to fundamental questions in research; partnering with universities in the hands-on education of the next generation of scientists; or sharing equipment, laboratories, and ship time. Partnerships can apply existing research to questions important for the future of Canada, or they can help local partners in business build on publicly funded research to develop innovative products or expertise.

If we are to rely on increased partnerships to help us face future challenges, we must be sure those partnerships are sound and can deliver accountably what we need and depend on. It is encouraging that how we do our work at BIO is held up not just as a "best model" for science inside government laboratories, but also as a guiding model for how government as a whole should try to achieve its science-related goals.

The projects described in this section, *BIO Science In Partnership*, build on a successful approach to partnerships and help us prepare for an even greater degree of interdependence and collaboration.

Two Generations of Optical Plankton Counters: A History of Development and Commercialization

Alex Herman

Zooplankton are the food of fish and are thought to be a critical link in the successful recruitment of these consumer populations. Zooplankton also influence biogeochemical cycles by the consumption and production of particles and can control the dynamics of algal blooms. Traditionally, these marine organisms in our coastal waters were sampled by towing plankton nets from ships, a methodology that was slow, consumed ship time, and provided insufficient spatial detail. In the laboratory, the analysis of the data also was slow since samples had to be identified and counted by microscope. New means to provide higher resolution data that would address the zooplankton component of pelagic food webs and biogeochemical models were needed. Because ship time was clearly becoming a serious cost issue, this improved data would not come from more ship use but rather from more efficient use.

In the mid-1980s, DFO's Metrology Division (now the Ocean Physics Section), an instrument development group at BIO, embarked on the development of an optical device that would count and size zooplankton while being towed in coastal waters. The sys-

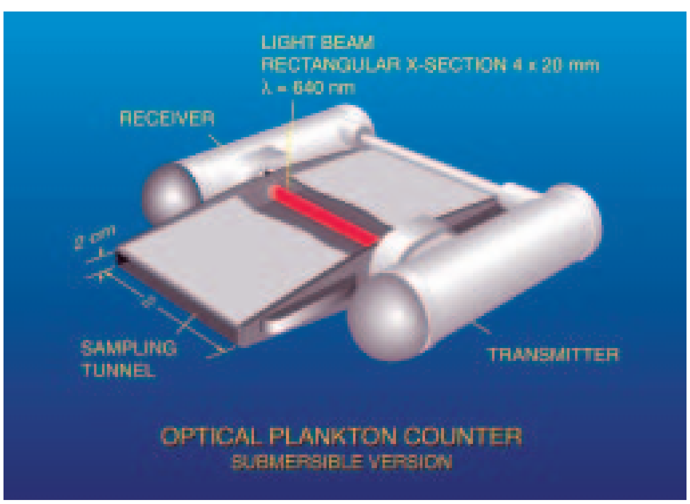


Figure 1. The original OPC (developed in the mid-1980s) showing the light beam used to detect plankton passing through its tunnel

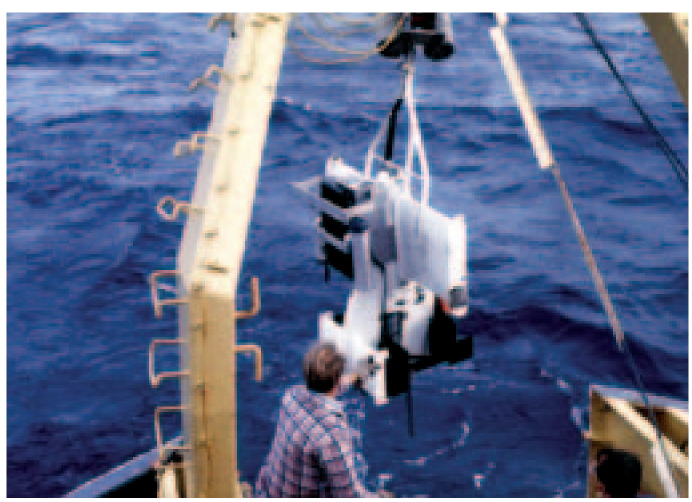


Figure 2. The OPC mounted on Batfish, a towed undulating vehicle

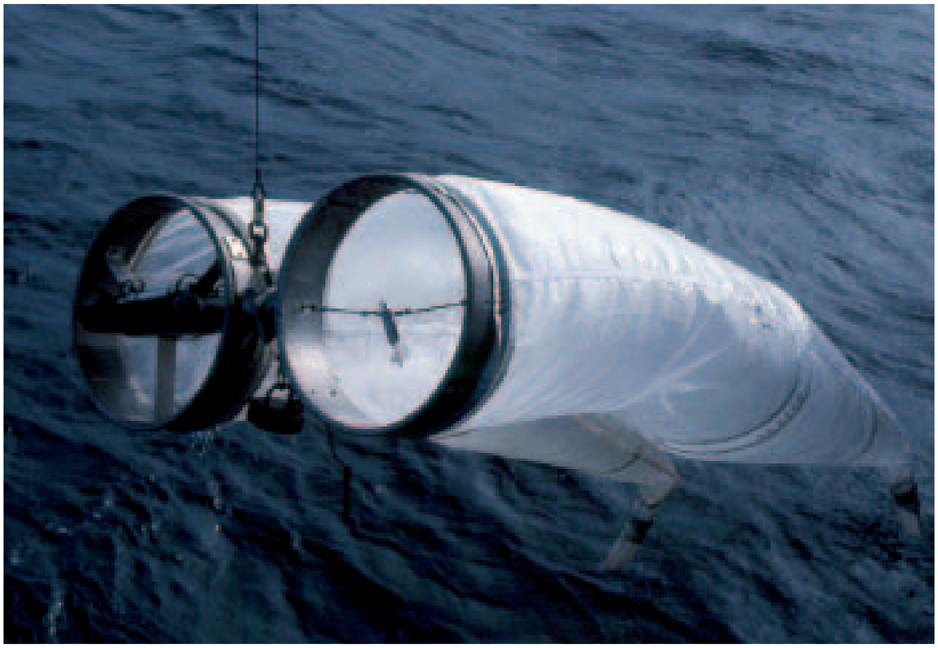


Figure 3. The OPC mounted inside a bongo net used in California coastal waters to sample zooplankton

tem had to be small, portable, provide real-time data, and be easily attached to any moving underwater platform. The first unit took on the configuration shown in Figure 1, and after approximately five years of development and testing at BIO and at the urging of other institutes to commercialize, BIO transferred the technology to Focal Technologies Ltd., a small but rapidly growing technology company in Dartmouth, Nova Scotia. At that time, Focal was developing its expertise in fiber-optic technology and was a natural fit to commercialize the BIO Optical Plankton Counter (OPC). Production and sales began in 1990 and over a period of 13 years, Focal sold approximately 120 units to scientists and institutes worldwide, generating sales of over $4 million, not including custom modifications and servicing. Although the transfer of technology to any company requires much time and effort, this transfer resulted in great benefits to both Focal and BIO, as over the years, the two labs shared considerable staff time and expertise.

The OPC's operation consists of a parallel light beam that traverses a tunnel (Fig. 1) and measures any plankton in seawater passing through the tunnel while the OPC is being towed. Individual plankton interrupt the light beam while internal OPC electronics measure the area of the passing plankton and send the digital information up the towing cable to the ship's lab for computer storage and processing. A multitude of OPC applications utilizing many vehicles and platforms were developed. Examples are the OPC mounted on a Batfish vehicle which is towed behind a ship in a sawtooth, undulating pattern (Figure 2), and the OPC mounted inside towed plankton nets (Figure 3), as used by the California Cooperative Fisheries Investigation (CalCOFI) monitoring programs in the USA.

As the number of scientific users of OPC grew, its applications, the development of analytical tools, and modelling of zooplankton ecosystems using OPC data were broadened. Our needs for greater communication grew, so an OPC Workshop was organized in Tromso, Norway in 2001. Sponsored by International Global Oceans Ecosytems (GLOBEC), the workshop brought together 35 users for four days to discuss applications, methodology, and some data results—basically establishing the status quo of OPC science. It was agreed that future OPC gatherings would focus on data results. The report of the Norway meeting was published as part of the GLOBEC Report Series and can be found at (http://www.pml.ac.uk/globec/products/reports/globecrep.htm). In 2004, a further collection of OPC studies was presented at the annual ASLO-TOS Oceans Conference, Honolulu at the session entitled: Analysis of Zooplankton Data using an Optical Plankton Counter. These collected works are reported in a special, peer-reviewed 2005 issue of Journal of Geophysical Research. The OPC scientific community was now well-established.

At the Norway meeting, the OPC inventor, Alex Herman of BIO, presented a paper on the development of the second genera-

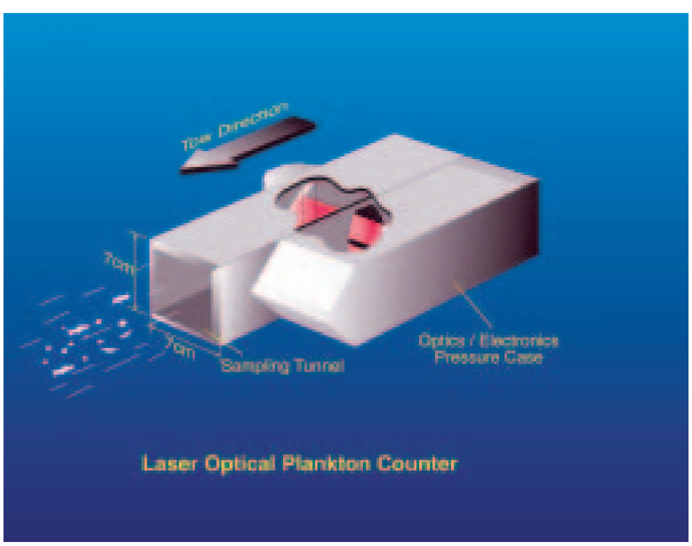


Figure 4. The Laser-OPC showing the laser beam (1x35mm) traversing the sampling tunnel

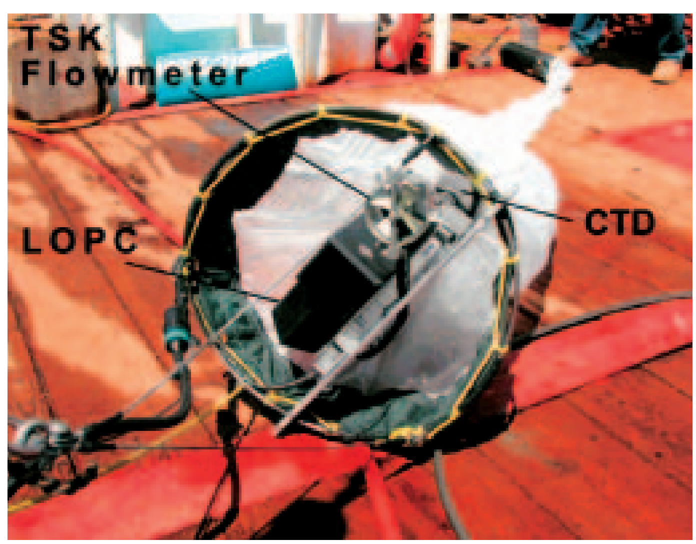


Figure 5. The LOPC mounted inside a plankton net and preparing to be towed

Figure 6. The LOPC mounted on a tow body preparing to survey the Hudson River

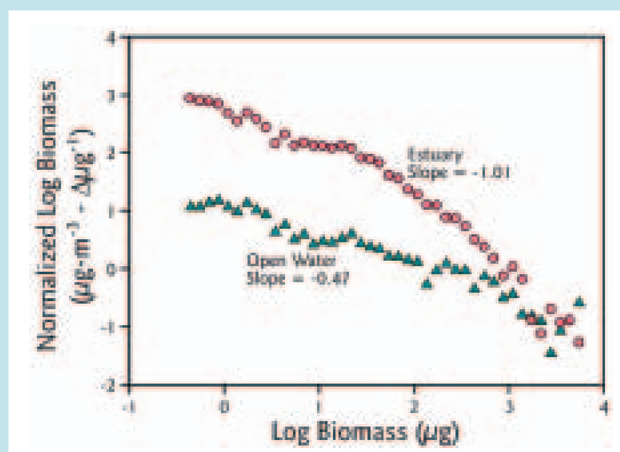
Figure 7. Prototype SOLOPC deployed in CalCOFI regional waters in September 2005 and consisting of an LOPC integrated with a SOLO drifter float

tion of OPC, the new Laser-OPC (LOPC). The LOPC was designed to solve the deficiencies of the first generation OPCs, as identified by user feedback. There were two major issues: the first was operation in waters with high densities of plankton, and the second was lowering the detection limit to measure smaller size plankton. The development of the LOPC commenced at BIO in 1997 and an operational unit (Figure 4) was fully developed and tested by 2003. By designing a more clever optical path, the resulting configuration was also a smaller, more compact unit.

With user demand for the new design growing, the transfer of LOPC technology began in 2003 with Brooke Ocean Technology (BOT) Ltd. of Dartmouth. To date, some 25 LOPC units have been delivered, representing over $1 million in sales for BOT. It is interesting to note that the technology transfer process does not have a finite time limit but is an ongoing process between the two labs. New applications from users place demands on the company which often relies on the expertise available from the scientists and engineers at BIO. On the other hand, new technology/designs from BOT are passed freely to BIO for implementation within our operational programs such as the Atlantic Zonal Monitoring Program. Herein lies the great benefit of such activities with industry, in that staff, ideas, and design expertise continually are exchanged.

The operational applications of the LOPC continue to evolve. The LOPC has been mounted inside a towed plankton net (Figure 5), allowing LOPC measurements to be compared to zooplankton caught by the net. Surveys of the Hudson River were made with the LOPC mounted on an undulating towed body, the Nu-shuttle (Figure 6). In collaboration with BIO, a recent and exciting development of Lagrangian drifter applications originated at the Scripps Institution of Oceanography (SIO). The LOPC developed at BIO and the Sounding Oceanographic Lagrangian Observer (SOLO) drifter float developed at SIO have been integrated and tested in CalCOFI regional waters in a collaborative development project (D.Checkley [SIO], R.Davis[SIO], A. Herman [BIO], G. Jackson [Texas A&M University]). The first protoype SOLOPC (Figure 7) was successfully tested in September 2005 over a 3-day period, when 64 profiles were secured to a depth of 100 m. Once sampling is complete, the SOLOPC breaks surface and transmits its data via top-mounted antennae to an Iridium satellite.

The effectiveness of the LOPC is its ability to capture a wide range of the zooplankton community in a single rapid measurement. Slowly the LOPC is evolving into a practical new tool used worldwide and is allowing us to achieve our originals goals of securing more detailed zooplankton information with lower shiptime demands.



One of the more powerful analytical tools that has emerged from the user community is the Normalized Biomass Size Spectra (NBSS), a log-log tool to represent the zooplankton biomass probability density. Shown is the NBSS representation of profiles from two different areas of the Gulf of St. Lawrence. Each distribution exhibits a different slope: the greater negative slope (-1.01) showing a very growth-productive regime with an excess of small size zooplankton available to larger size predators. The less-negative slope (-0.47) exhibits a less growth-productive environment that is not energetically sustainable.

BIO Contributes to Studies of the Great Sumatra-Andaman Earthquake and Tsunami

David C. Mosher and C. Borden Chapman

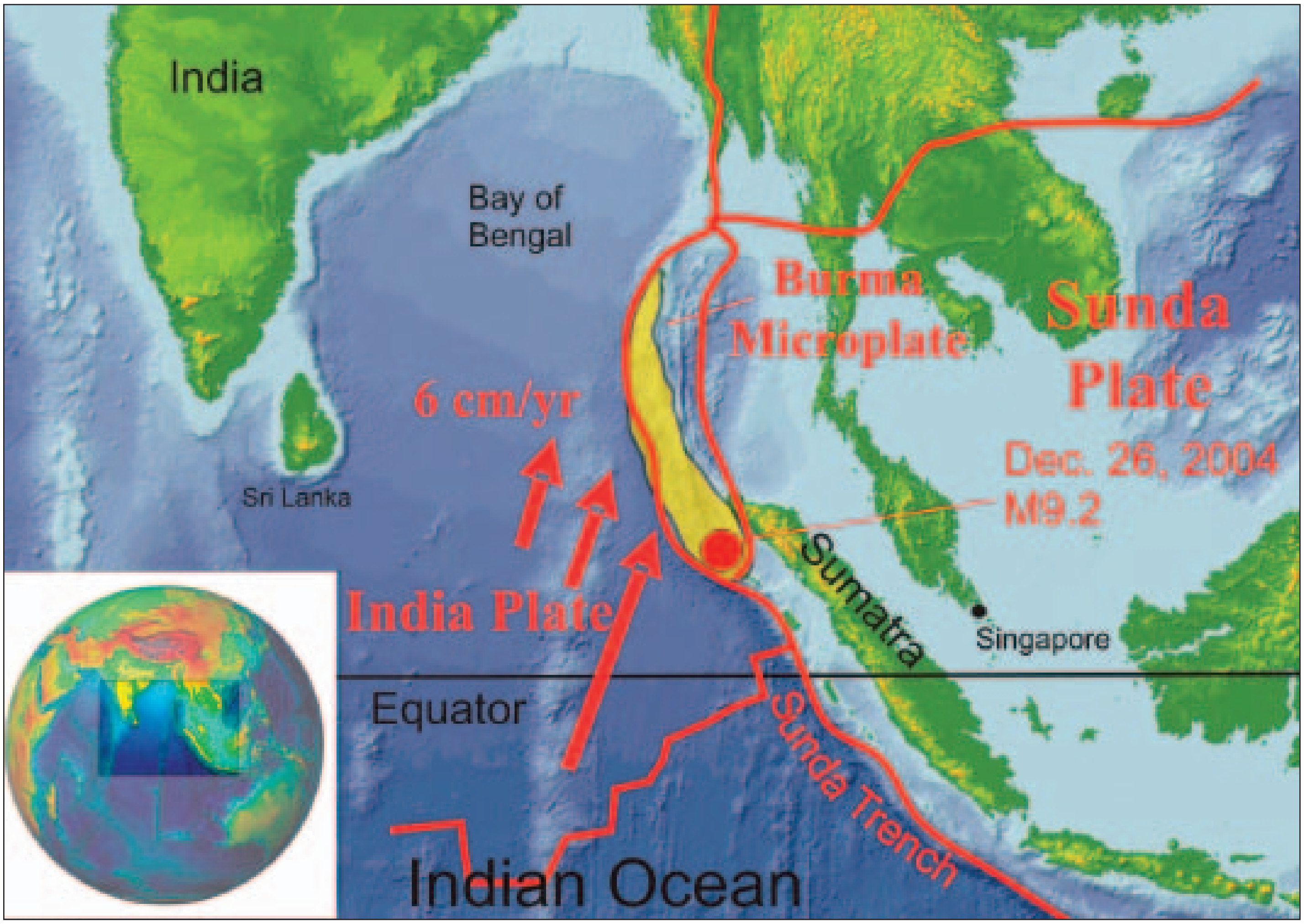


Figure 1. Location and tectonic setting of the Great Sumatra-Andaman earthquake

The great Sumatra-Andaman earthquake of December 26, 2004 resulted in a tsunami that killed more than 300,000 people and devastated coastal communities around the Indian Ocean. The earthquake occurred because of subduction[1] of the Indian plate beneath the Burma-Sunda plate (Asian plate). It was a Moment Magnitude (Mw) 9.2 earthquake, which is the third largest in recorded history. The earthquake occurred along a 1200 km-long rupture zone (Ishii et al. 2005) (Figure 1). A number of scientists from Natural Resources Canada were invited to participate in two separate studies to help understand the earthquake, consequent seafloor displacement, and the nature of the resulting tsunami.

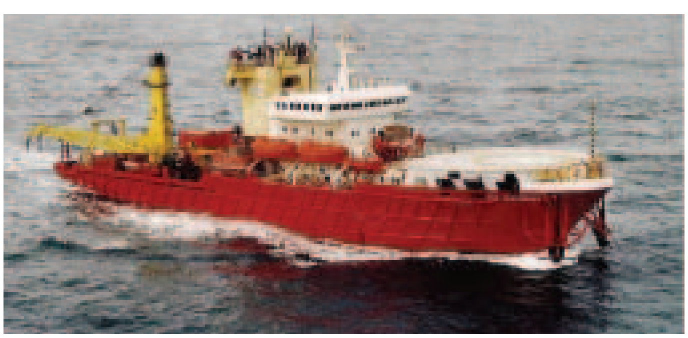


Figure 2. M/V The Perfomer

SUMATRA EARTHQUAKE AND TSUNAMI OFFSHORE SURVEY (SEATOS)

The Geological Survey of Canada (GSC) (Atlantic) participated in a program to investigate seafloor displacement and its links to tsunami generation in the region of the Great Sumatra-Andaman earthquake. The expedition took place in May, 2005 on an oceaneering vessel, M/V *The Performer* (Figure 2). The vessel was equipped with a Remotely Operated Vehicle (ROV) capable of diving to 7000 m and used for visual observations, film and still

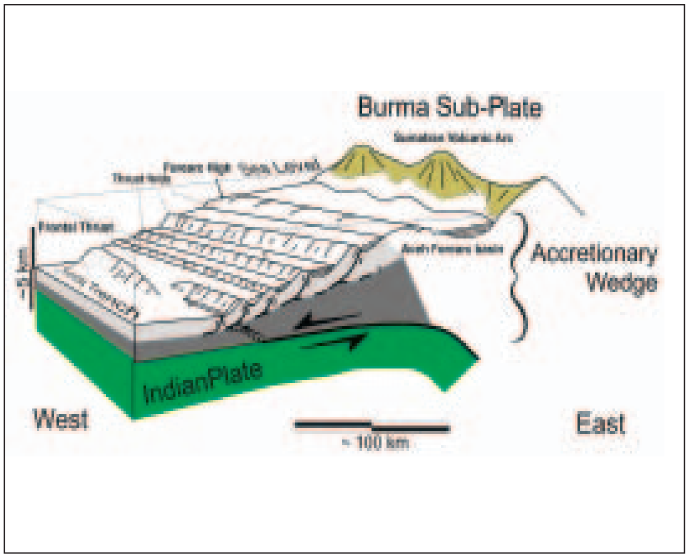


Figure 3. Schematic block diagram showing subduction of the Indian Plate beneath the Burma sub-Plate and the overriding Aceh accretionary prism

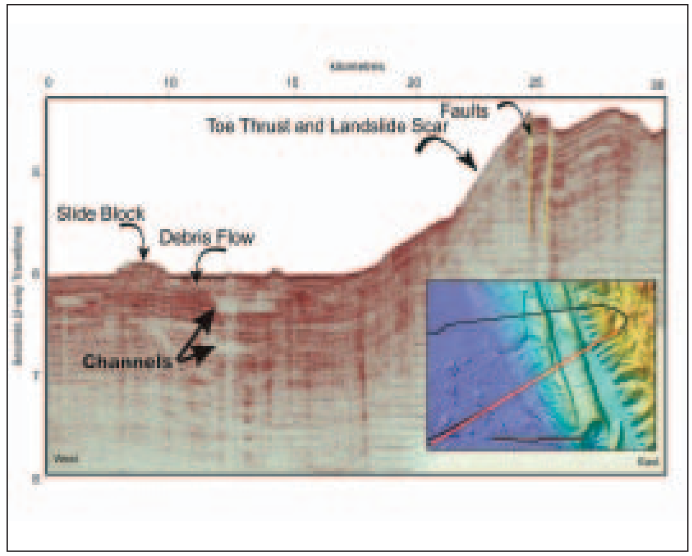


Figure 4. Seismic reflection profile across the frontal thrust and over a submarine landslide, with inset of a multibeam image (from Tappin et al. 2005) showing the location of the seismic line in red

photography, and sediment/specimen sampling. A team of biologists, seismologists, geologists, geophysicists, geotechnical engineers, data visualization experts, and tsunami modellers, hailing from Canada, United States, England, France, and India, participated on the expedition. GSC Atlantic contributed equipment and personnel to operate, acquire, and interpret seismic reflection data. The expedition included a film team producing a documentary for the Discovery Channel and the British Broadcasting Corporation that premiered on television for the first anniversary of the catastrophe.

Sumatra lies along a convergent plate boundary, where the Indian plate is verging NNE relative to the Burma-Sunda plate at a rate of about 6 cm per year (Fig. 1). To accommodate this convergence, the Indian plate subducts obliquely beneath the Burma-Sunda plate. During subduction, some of the sediments from the Indian plate are scraped off and thrust up to form a wedge of faulted and folded sediment (Figure 3). The region is at the farthest limits of the Bengal fan, so sedimentation rates in deep water are relatively high. Subduction over millions of years has resulted in the formation of a 250 km-wide accretionary wedge of unknown thickness.

Although most earthquakes along the Sumatran margin are strike-slip[2] because of the oblique direction of subduction, the truly strong events are thrust[3] (normal or reverse normal). Focal mechanisms[4] of the December 26 earthquake show the earthquake occurred along a reverse thrust fault at 30 km depth. The fault was shallow dipping (8°) and oriented 329° strike (Harvard CMT catalog, http://www.seismology. harvard.edu). Tsunami generation requires significant seafloor displacement. Determination of the location and amount of this displacement remains problematic. Early estimates of such displacements did not accurately reconstruct either the observed waves (i.e., from tide gauge records, satellite observations) or the coastal run-up measured by field survey teams along the coasts of the Indian Ocean. The British survey vessel HMS *Scott* conducted a detailed multibeam bathymetric survey over the Sunda accretionary prism off northern

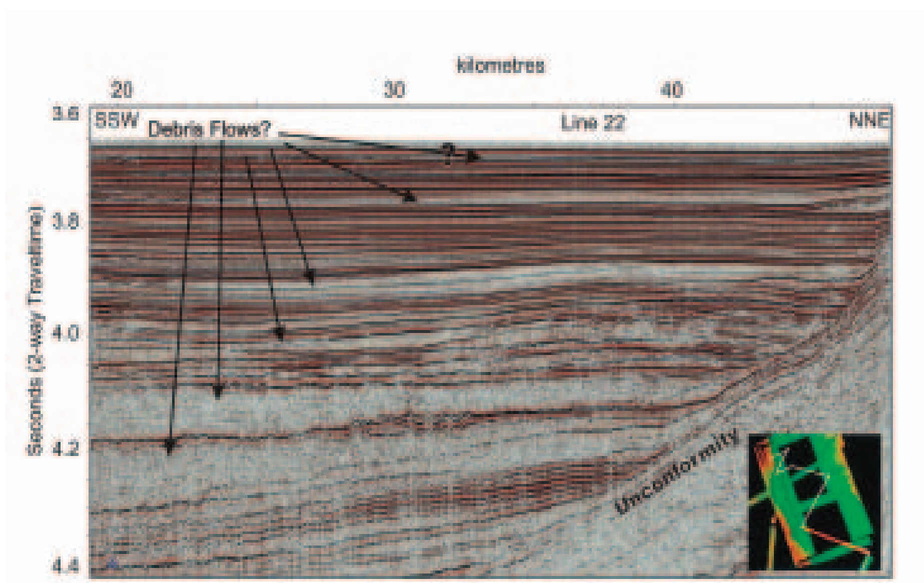


Figure 5. Seismic reflection profile of the Aceh Forearc basin, with inset showing the line location on multibeam data (from Tappin et al. 2005)

[1]Subduction: the sinking of one crustal plate under another as they collide [2]Strike slip refers to the relative motion of the two sides of a fault; in this case, the motion is horizontal and parallel to the fault. [3]Thrust refers to the relative motion of the two sides of a fault; the motion is vertical with one side pushed up relative to the other. [4]Focal mechanism refers to the orientation and sense of motion along a fault plane resulting from an earthquake, derived from seismic (sound) signals generated by the earthquake.

Sumatra following the earthquake (Tappin et al. 2005). Although the surficial morphology (shape) is incredibly complex, as expected from an accretionary wedge at a subduction margin, the expedition identified numerous features speculated to have resulted from this earthquake. Groundtruthing of features identified on multibeam data and quantifying seafloor displacement was the mission of SEATOS.

Mobilization and demobilization of the vessel M/V *The Performer* took place in Singapore (Fig. 1). The entire campaign required 30 days in May 2005 and included a transect through the pirate-infested waters of the Strait of Malacca. During the 17 days on site (70-250 km west of Sumatra), more than 850 line km of seismic reflection data were acquired in addition to data gathered during seven dives with the ROV. The contact between the Burma sub-Plate and the Indian Plate is expressed at the seafloor at the Sunda Trench (Fig. 3). This trench is in 4500 m water depth and the accretionary wedge rises to 1300 m water depth within about 30 km east of the trench. A series of thrust blocks and folds with intervening basins comprise the wedge. The seismic reflection profiling focused on a regional transect across the accretionary prism, on the deformation front at the leading edge of the prism, and on the forearc basin near the epicentre of the earthquake.

The combination of seismic profile data and ROV dive observations indicates that in fact there is surprisingly little evidence of widespread seafloor disruption across the margin, suggesting only small ground motions occurred during the earthquake. Preliminary analysis shows that the sediment at the seafloor is soft and not very strong, and yet it lies on steep slopes. This sediment should fall in the event of an earthquake with strong ground shaking. In fact, a significant landslide at the frontal thrust was imaged with the multibeam dataset. However, seismic profile data and observations of in situ benthic fauna from the ROV indicate the feature was not likely the result of a recent earthquake (Figure 4).

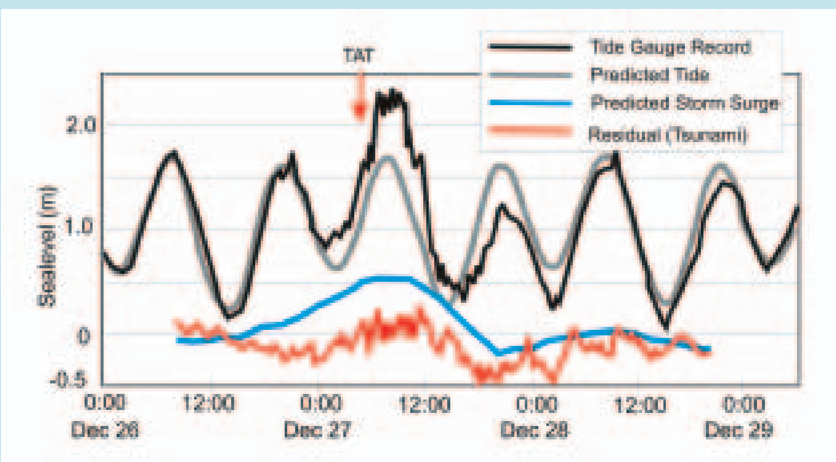
The forearc basin has accumulated a sedimentation record since early in the formation of the accretionary wedge. Seismic profiles through this basin show coherent, well-stratified sediment layers, interbedded with mass-transport deposits (Figure 5). It is possible that these mass-transport deposits resulted from landsliding during previous large earthquakes; thus, the basin records a history of earthquakes. However, no large mass transport deposit nor faulting and disruption of reflectors that could be attributed to this most recent earthquake were noted.

A trench (~20 km long, 200 m wide and 15 m deep) referred to as "the ditch" along one of the frontal thrust folds was noted from seafloor imagery. Seismic reflection profiles and an ROV dive were conducted to attempt to explain its origin. It was possible to image the ditch in seismic profile (Figure 6), but no clear underlying structures (faults) were imaged to explain its origin. ROV observations showed a fresh looking cliff face about 12 m high on the seaward wall of the ditch (Figure 7). This cliff face could be the result

TSUNAMI EFFECTS REACH HALIFAX

The 2004 Sumatra tsunami was clearly recorded by many tide gauges throughout the world's oceans, including those located in the North Pacific and North Atlantic. DFO scientists examined these gauges, which identified significant wave heights even in Halifax, 20,000 km from the tsunami source area.

Global tsunami propagation models show that mid-ocean ridges serve as topographic wave-guides, efficiently transmitting tsunami energy from the source area to far-field regions. In the case of the Atlantic Ocean, the Mid-Atlantic Ridge acted as the primary waveguide. At about the latitude of the Tropic of Cancer, the orientation of the Mid-Atlantic Ridge turns rapidly from northwestward to northward. Here, "filaments", or branches of tsunami energy, separated from the waveguide, propagated through the Bermuda Islands, and hit the east coast of North America. Halifax was enduring a storm surge at that time, so tide gauge records are complex. Removal of predicted tide and storm components of these signals results in an estimated tsunami wave height of 43 cm (the highest recorded in the North Atlantic). The record is undersampled, however, as the gauge recorded only every 15 minutes. Interpolation suggests the true tsunami wave height was likely more than 60 cm.



Tide gauge record from Halifax for December 26 to 28, 2004: tsunami arrival time (TAT) is determined to be between 08:30 and 09:30 UTC on Dec. 27, about 32 hours after the main shock of the earthquake (modified from Rabinovich et al.).

Rabinovich, A.B., R.E. Thomson, and F.E. Stephenson, in press. *The Sumatra tsunami of 26 December 2004 as observed in the North Pacific and North Atlantic Oceans.* Surveys in Geophysics.

Titov, V., A.B. Rabinovich, H.O. Mofjeld, R.E. Thomson, and F.I. Gonzalez, 2005. *The global reach of the 26 December 2004 Sumatra tsunami.* Science, v. 309, p. 2045-2048.

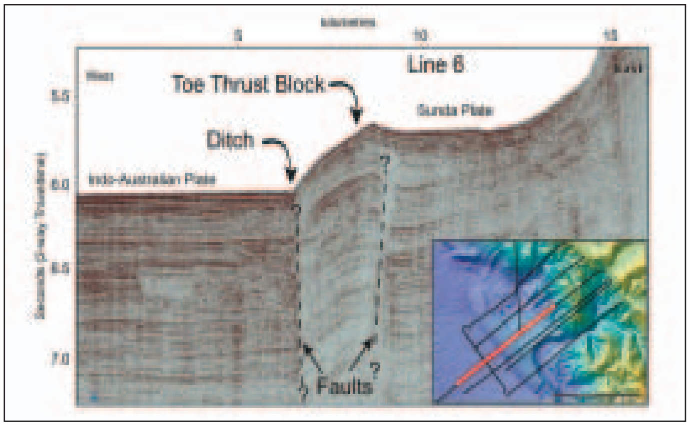


Figure 6. Seismic reflection profile across "the ditch", with inset showing the line's location (in red) superimposed on multibeam data (from Tappin et al. 2005)

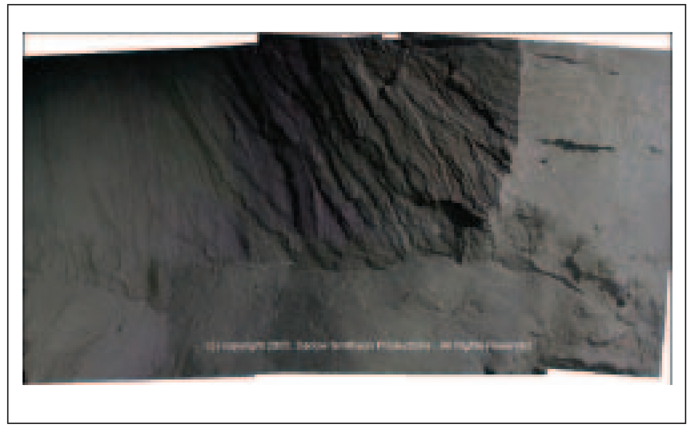


Figure 7. Photo mosaic from the ROV in "the ditch" showing a fresh looking vertical scarp face

of a major thrust fault or collapse of the ditch wall due to ground shaking during the earthquake. Of all sites investigated, this site shows the most compelling evidence of recent ground movement, but the origin of the ditch is still not clear.

Although coverage is still sparse, lack of evidence of widespread seafloor disturbances in the vicinity of the Great Sumatra-Andaman earthquake of December 26, 2004 suggests that only small ground motions occurred during this event. This observation implies that to generate a tsunami, the margin must have behaved much like a single mass in its displacement. This conclusion warrants further study to better understand seismic energy dissipation on active margins.

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Tsunami Impacts in the Republic of Seychelles Following the Sumatra Earthquake of December 26, 2004

John Shaw, Lionel E. Jackson Jr., Donald L. Forbes, J. Vaughn Barrie, Gavin K. Manson, and Michael Schmidt

INTRODUCTION

Following the earthquake and tsunami of December 26, 2004, Natural Resources Canada was asked to contribute to an international effort to document the impacts in the Indian Ocean. Site selection was coordinated by the International Tsunami Information Center in Hawaii and the Intergovernmental Oceanographic Commission of UNESCO. The Canada-UNESCO Indian Ocean Tsunami Expedition landed on the island of Mahé in the Republic of Seychelles on January 22, 2005 and worked there and on nearby Praslin Island for 12 days. The team's final report to UNESCO contains detailed descriptions of their findings and can be ordered at: (http://ioc.unesco.org/iosurveys/seychelles/sey1.htm).

THE SEYCHELLES ARCHIPELAGO

The Republic of Seychelles comprises an archipelago of about 115 islands lying in the western Indian Ocean north-northeast of Madagascar (Figure 1). The northern group of islands is predomi-

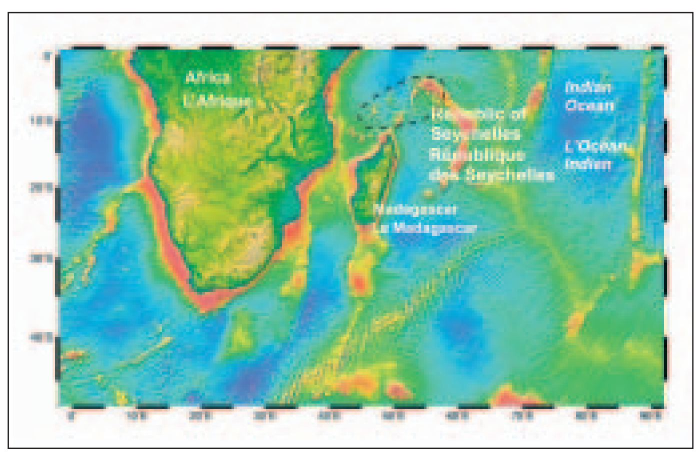


Figure 1: Location of the Seychelles Archipelago is shown inside the dashed line. The granitic islands lie on the shallow underwater plateau at the northeast end of the archipelago. (Image based on data by Smith, W. H. F., and D. T. Sandwell, Global seafloor topography from satellite altimetry and ship depth soundings, *Science, v. 277, p. 1957-1962, 26 Sept., 1997.)*

nantly composed of granite and sits on a broad, shallow continental shelf; the remaining islands are coral atolls rising abruptly from depths of more than 4000 m.

THE TSUNAMI EVENT IN THE SEYCHELLES - EMPIRICAL DATA

The tsunami waves propagated across the Indian Ocean and encountered the Seychelles around noon, local time, on Sunday December 26. The Mahé tide gauge (Figure 2) shows that, beginning between 12:08 and 12:12 (08:08 and 08:12 UTC), the water level rose to 0.59 m above mean sea level datum (MSLD), then fell to -1.53 m at 12.56. The first high wave arrived at 13:12 UTC and peaked at 1.16 m. The water level oscillated with decreasing amplitude over the next few days. Both at 13:36 and at 13:40 a water level of -1.53 m was again recorded on the gauge. This was the lowest water level that the instrument was capable of recording. The water level dropped to approximately 4 m below MSLD, based on observations by dive masters and other mariners.

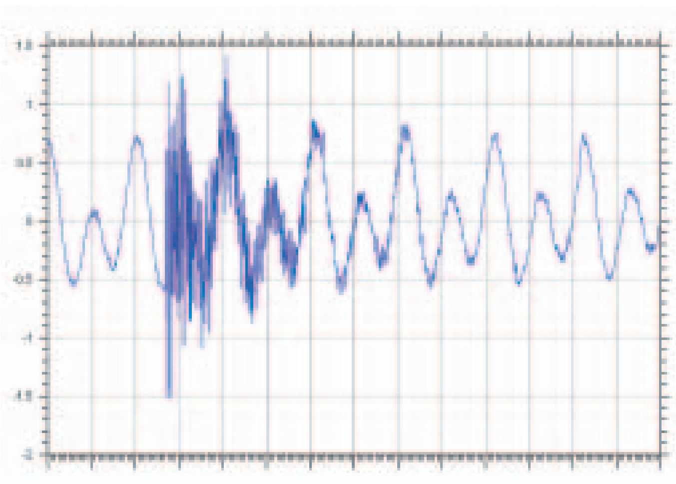


Figure 2: The 4-minute water-level record from the tide gauge at Mahé (Seychelles), showing the arrival of the tsunami wave train and ongoing oscillations over several days (data courtesy of SOEST, University of Hawaii)

THE TSUNAMI WAVES

Although there was an initial water-level rise, most witnesses recalled only the great withdrawal of water, mainly because it completely exposed coral reefs normally submerged, even at low tide (Figure 3). This withdrawal was followed by a rapid uprush of water that inundated low-lying areas (Figure 4). Witnesses variously claimed that the turbulent and turbid water sounded like an aeroplane, a river, a thousand pots boiling, rain on the roof, and a bomb. Then the water withdrew, exposing the reefs once more (Figures 5 and 6). The water constantly rose and fell during the day. While the amplitude of the tsunami waves was decreasing, the tides were functioning as normal, and fortunately the highest flood levels were not attained during the earliest and highest tsunami waves, but later in the day when the smaller tsunami waves were superimposed on a higher tide.

HIGH WATER LEVELS AND INUNDATION DISTANCES

Flood levels above 4 m (maximum was 4.6 m) occurred on both Mahé and Praslin islands. Extensive flooding occurred on the west coasts of both islands, which initially surprised the investigating team, because the tsunami waves came from the east. We realized that two factors dictated flooding extent: 1) local topography, with the severest inundation occurring where funnel-shaped embayments focused waves; and 2) the shallow shelf (Seychelles Bank) which amplified and refracted the tsunami waves, so that they reached the rear of the islands. Observers on Mahé reported walls of water approaching from both north and south, and converging near the severely flooded hamlet of Anse à la Mouche.

Damage to coastal infrastructure was severe where natural

Figure 3: Coral reefs around Mahé were exposed during the tsunami event. This photograph shows turbid water draining off the reefs into the ocean. Photograph courtesy of local witness, Dan Holtzenhanse

coasts had been modified, e.g., where beach berms had been removed to allow hotel construction. Tourism is a mainstay of the economy and hotels are located close to the water's edge. Our survey of damaged sites became a tour of the islands' hotels! Most impacts consisted of minor structural damage: demolished walls and fences; floor and wall cracks; and damage to appliances, electrical equipment, computers, cars, furnishings, and personal effects. Structural damage occurred at a hotel on the north coast of Praslin (Figure 4) and in homes in the same area.

DAMAGE TO PUBLIC WORKS

Damage to public works was greatest in the capital, Victoria. The downtown core was inundated at 13:00 when the tide was low, at 16:30 to 17:00 at high tide, and again at 05:00 the following morning (the highest water level recorded by the tide gauge during the December 26-27 event). Along the north side of the fishing harbour, high pore pressures generated by submergence, followed by rapid drawdown of water levels, turned the sheet pile wall forming the face of the wharf into a dam. The wharf was not designed to function in this way and its partial failure caused extensive surface fissuring, damaging other wharves, buildings, walls, parking areas, and park land. These failures were among the most costly and perhaps least expected impacts to infrastructure. Washouts on two sections of a highway causeway south of Victoria resulted from repeated inflow and outflow of flood waters.

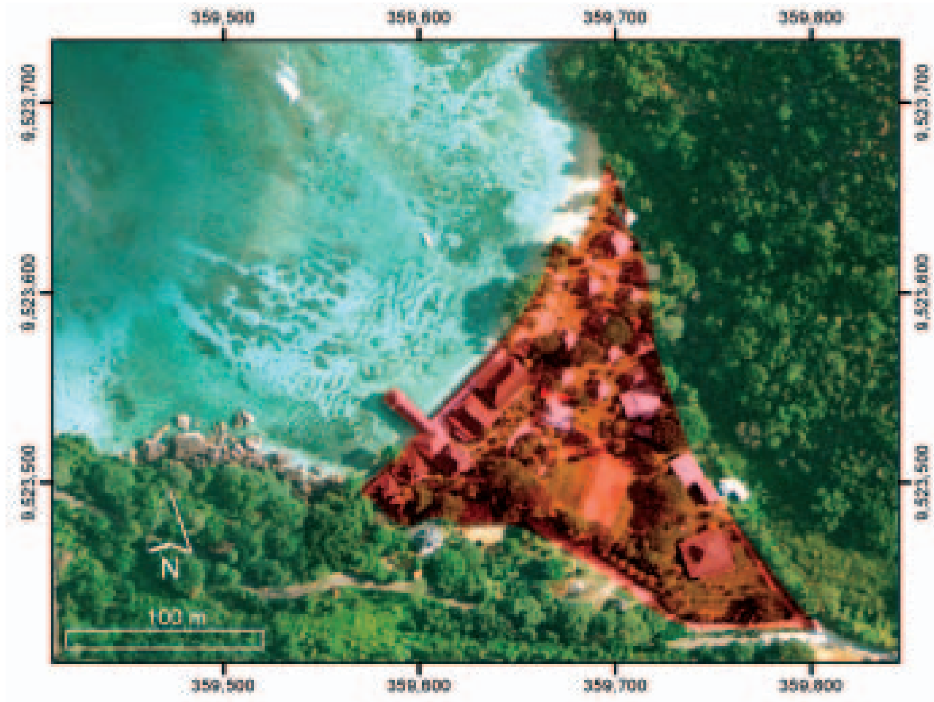


Figure 4: The red-shaded area shows the extent of inundation at La Reserve Hotel complex, Praslin Island. The hotel received extensive structural damage; its location right on the edge of the beach is a typical situation in the islands.

DAMAGE ELSEWHERE IN THE SEYCHELLES

The coral atolls, located on seamounts that rise from abyssal depths, experienced no damaging effects. This was paradoxical, given their low elevations, but is explained by lack of wave amplification in the deep water.

SUMMARY

The Republic of Seychelles had a lucky escape, in that the first high tsunami wave struck at low tide on a weekend, when the port was inactive and schools closed. The death toll (two persons) would have been much higher otherwise. Unusual water-level fluctuations were observed once in the 1950s; the tsunami following the Krakatoa eruption in 1883 was measured in Victoria; and fluctuations in 1833 were almost certainly a product of the great earthquake along the plate margin on the west side of Sumatra in that year. Clearly the 2004 event was not a unique occurrence in this region.

Figure 5: View towards La Reserve Hotel, Praslin Island, during the visit of the Canada-UNESCO team (low tide)

Figure 6: View towards La Reserve Hotel during a low-water stage of the tsunami - photograph courtesy of local witness, P. Pomeroy

Offshore Clam Research

Dale Roddick

The offshore clam fishery on Canada's east coast is a relatively recent enterprise. It got underway in 1980 when DFO engaged the United States (US) National Marine Fisheries Service research vessel *Delaware II* to conduct a series of offshore clam surveys on the Scotian Shelf. The purpose of the surveys was to assess the extent of the offshore resource of commercial bivalves, and in particular, that of ocean quahogs (*Arctica islandica*). Although the surveys did find a large resource of quahogs on Sable Bank, it was the stock of Arctic surfclams (*Mactromeris polynyma*) on Banquereau that raised commercial interest. Following a test fishery in 1986, licences were issued and the offshore fishery began. Since that time, the fishery has expanded to Grand Bank and developed into an industry employing approximately 450 people, with annual sales exceeding $50M. The fishery uses three large freezer-processor vessels (Figure 1) to harvest the surfclams, most of which are exported to Japan. The clams have a purple color on the outer section of the foot, siphon, and mantle, which turns red when blanched, similar to lobster and shrimp. The red-and-white coloration makes this clam attractive to the Japanese sushi and sushimi market, where it commands a high price (Figure 2). As well, the industry has expanded the market to China and southeast Asia. As the fishery has progressed, it has started looking at other large clam species, especially ocean quahogs, Greenland smoothcockles (*Serripes groenlandicus*) and northern propellerclams (*Cyrtodaria siliqua*) (Figure 3).

Figure 1. The Ocean Concord*, one of three commercial clam freezer processors operating in the offshore clam fishery*

Figure 2. Package of processed blanched surfclams: the main product is the foot portion, and blanching produces the red coloration, similar to lobster or shrimp

Development of the clam fishery during a period of dwindling DFO resources meant that DFO could not fund surveys or a full research program to support scientific advice for the management of the stock. Recognizing this, the industry and DFO entered into a series of Joint Project Agreements to fund resource surveys, studies on the habitat impacts of hydraulic clam dredges, genetic studies, and technical and professional support staff at DFO. In addition, quality control personnel on board the vessels carry out sampling programs for catch composition, length frequencies, and

*Figure 3. Shown are large clam species of commercial interest in the Maritimes Region. There is a commercial fishery for the Arctic surfclam (*Mactromeris polynyma*) and a licence for ocean quahogs (*Arctica islandica*). The Greenland smoothcockles (*Serripes groenlandicus*) and northern propellerclams (*Cyrtodaria siliqua*) are currently caught as bycatch in the Arctic surfclam fishery.*

conversion factors (to convert the weight of processed products back to whole clam weight). They also ship frozen samples to DFO for measurement and ageing studies.

Although some of the species, such as ocean quahogs, are well studied, others, including the Arctic surfclam, Greenland smooth-cockle, and northern propellerclam are not, and very little is known about their life history. Growth rates for these species on the Scotian Shelf are being studied. The longest lived of these species is the ocean quahog. To date, the oldest quahog from Sable Bank that has been aged was 210 years old, and there has been one from the US aged at 225 years. This has important implications for management of a fishery, as it means that productivity will be low and the allowable catch will be a very small percentage of the biomass. Although faster growing than ocean quahogs, most of the major clam species of commercial interest also have long life spans. This influences management methods and types of scientific studies to provide advice on these species.

Low harvest rates and long life spans mean that there will be little detectable change in biomass due to fishery or natural processes, on time scales of a few years to a decade or more. This lack of contrast in data time series gives very little information to use in fitting parameters for modelling approaches. Age-structured models may also not be applicable, as the slow growth rate makes ageing some of these species very time consuming, and so it is not practical to age large samples of the catch. Therefore, modelling approaches will probably not be able to provide accurate estimates of population parameters for a long period of time as the fishery develops. Initial management of this fishery will depend on survey biomass estimates and life history parameters to give empirical estimates of sustainable catch rates.

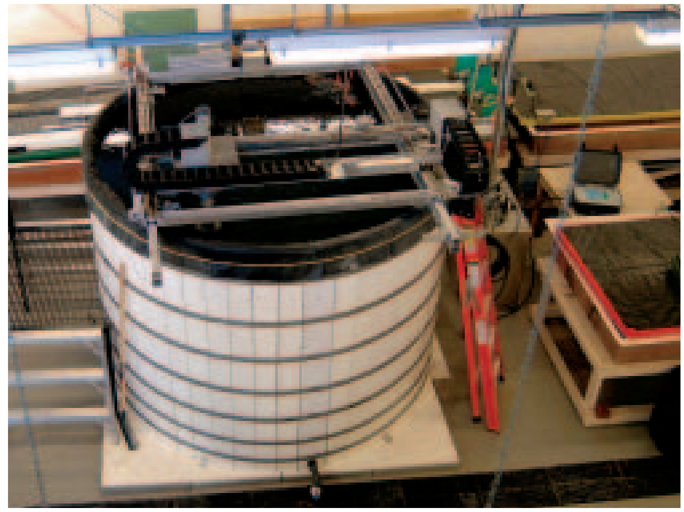


Figure 4. Shown is a quahog acoustics tank with DRUMS scanning frame mounted on top. Acoustics readings are taken on a 25 x 26 station grid at a spacing of 10 cm. The position of the quahogs in the sediment is then mapped.

Thus, one research focus is on the accuracy of the survey biomass estimates. The largest sources of error in the survey estimates are felt to be in the effective area dredged and the dredge efficiency. Area dredged can be inaccurate both in terms of the estimated tow length, and the percentage of that distance that the dredge is fishing properly. These errors may over- or under-estimate the biomass. The dredge will not be 100% efficient, and so the catch rate would also underestimate the biomass. Dredge efficiency involves more than just the mechanics of dredging. The experience of US commercial clam vessels is that hydraulic dredges are 80-90%

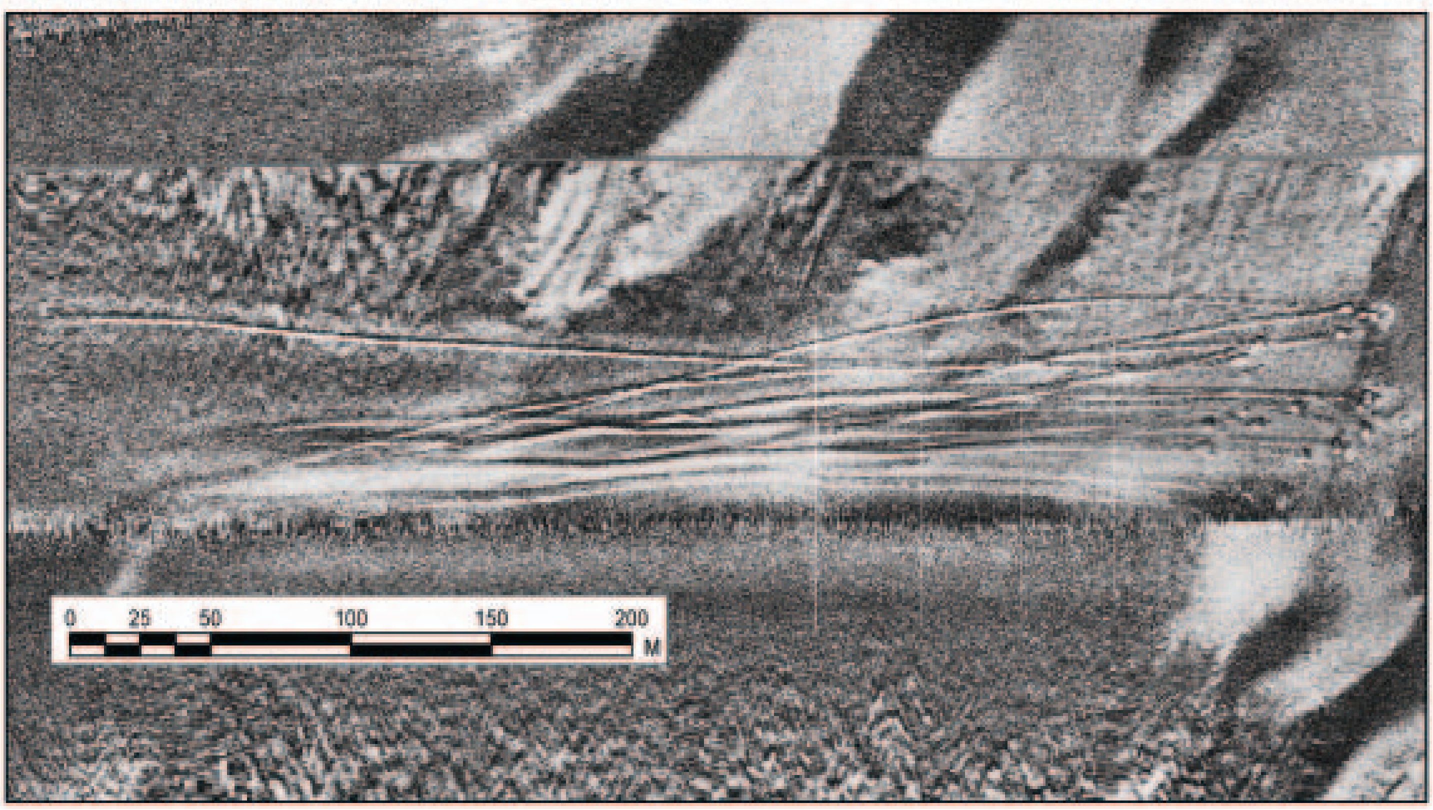


Figure 5. Sidescan of depletion experiment dredge tracks in metres: depressions formed at start of tows where the dredge sat with the water jets on as the cable was paid out can be seen on the right side of the image.

efficient when fishing Atlantic surfclams, but only around 60% when fishing ocean quahogs. It is postulated that the major difference is in the behaviour of the two species. Laboratory studies of ocean quahogs have shown that they occasionally burrow deeper into the sediment and may stay there for up to a week at a time. If they burrow deeper than the fishing depth of the dredge, this would account for the difference in efficiency.

Laboratory experiments are being conducted using the acoustics system Dynamically Responding Ultrasonic Matrix System (DRUMS) designed by Guigné International Ltd., of St. John's, Newfoundland and Labrador, to track the burrowing depth of ocean quahogs to determine how deep they burrow and how long they remain at depth (Figure 4). To obtain more accurate estimates of the effective area dredged, the industry will purchase a sensor system for the survey dredge which will indicate when the dredge is sitting flat on the bottom, and what percentage of time during a tow that it is fishing effectively. In the meantime, during the surveys, gear selectivity experiments on the different species and depletion experiments to estimate dredge efficiency are being carried out.

In conjunction with the 2003 Sable Bank quahog survey, NRCan conducted a sidescan survey of 20 survey tracks one year after dredging, and of two depletion experiment sites shortly after completion of the experiments (Figure 5). This work will be used to refine the depletion experiment estimates and to examine tow distances. It will also examine the recovery time for the dredge tracks on Sable in comparison to the habitat impact work done previously on Banquereau.

Surveys were conducted for ocean quahogs on Sable Bank in 2003 and Arctic surfclams on Banquereau in 2004. Surveys on Grand Bank will be conducted during the next two to three years. With the low growth rates of most of the species involved, it is not necessary to have annual survey estimates, and so the research plan is to conduct one survey each year, rotating through the areas so that each one is surveyed approximately every five years. During these surveys, sampling for all major bivalves is carried out, as well as sampling of the total catch composition. Comparisons of the distribution of major bivalves from the Sable and Banquereau surveys show that, although the two banks are similar in terms of substrate (both well sorted sands), Sable Bank is dominated by ocean quahogs, while Banquereau is dominated by Arctic surfclams and northern propellerclams. Atlantic surfclams (*Spisula solidissima*) dominate the shallow (<30 m) areas of both banks, while sea (*Placopecten magellanicus*) and Iceland scallops (*Chlamys islandica*) are found in areas with a gravel substrate (Figure 6). This type of information is of increasing importance as fisheries management moves towards an ecosystem approach.

The offshore clam fishery is one of few fisheries where surveys and associated research have taken place at the start of the fishery. This means that data from the unfished populations are available for comparison as the fishery develops. This should aid in the development of a sustainable and stable fishery.

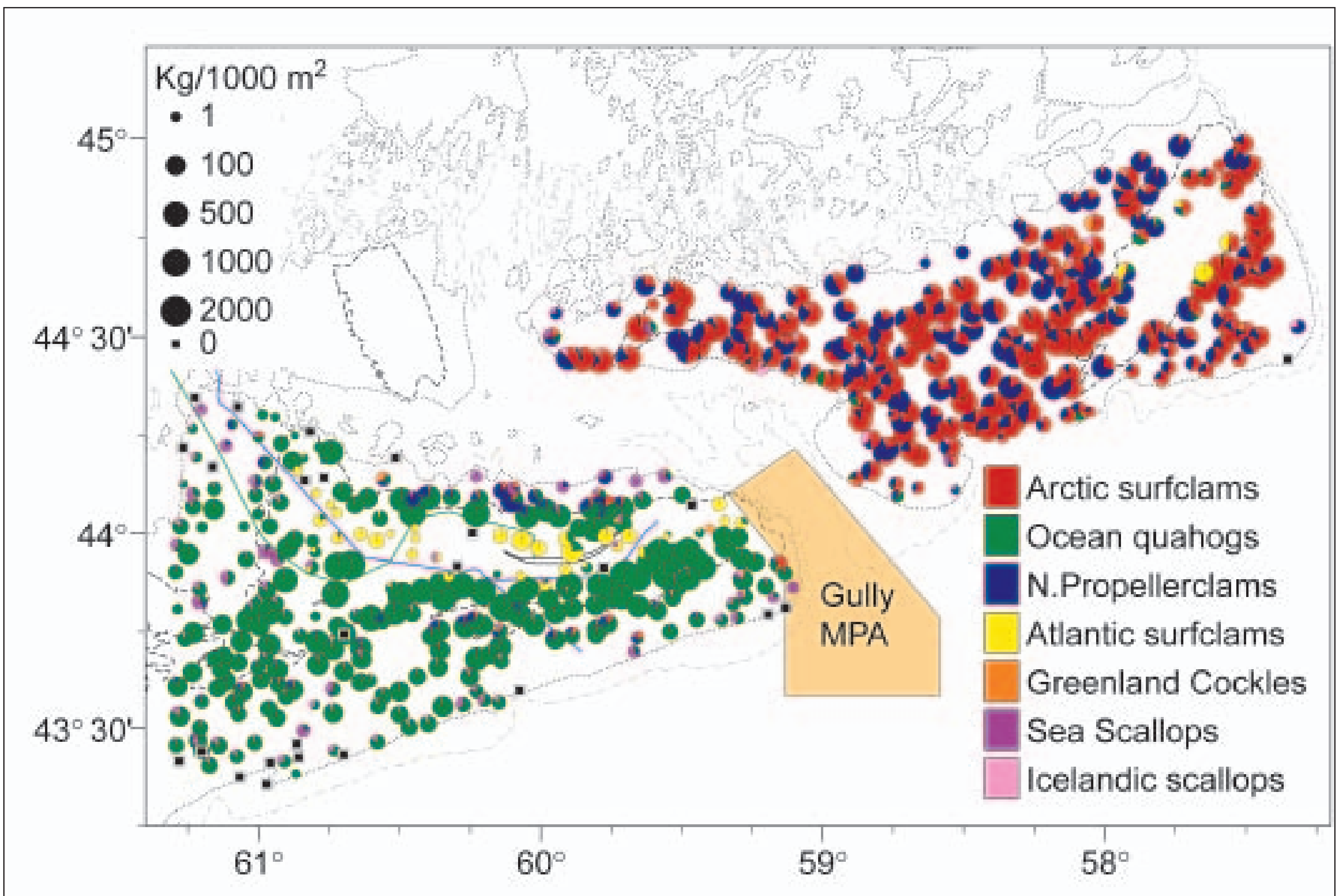


Figure 6. Catch of major bivalve species caught during the Sable Bank (right) (2003) and Banquereau (2004) offshore clam surveys

SPECIAL PROGRAMS

The Discovery Corridor – Exploring our Continental Shelf and Deep-water Ecosystems

Ellen Kenchington and Peter Lawton

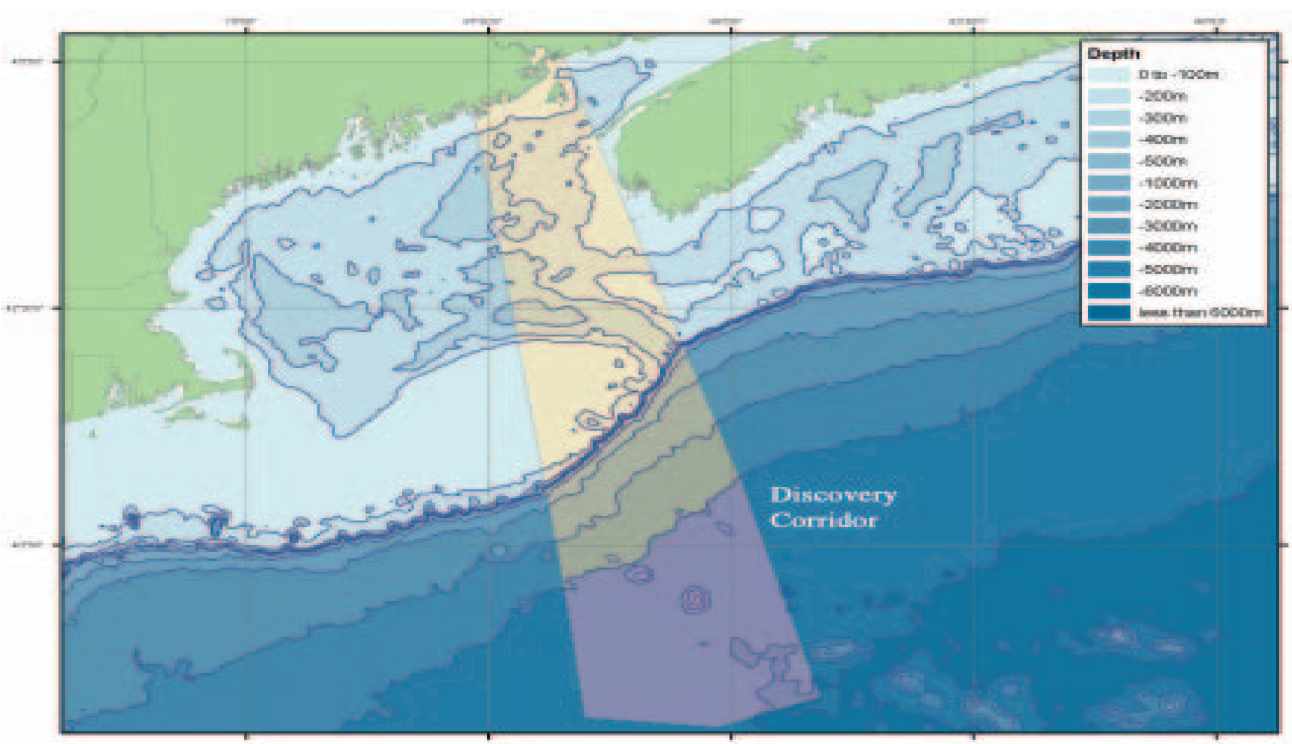


Figure 1. The location of the Discovery Corridor in the Gulf of Maine

Discovery Corridor …a swath of ocean bottom and the water column above it, encompassing a variety of ecologically inter-linked seascapes/habitats that may support a range of biodiversity and may support previously unknown species and processes. Corridors may cut across gradients of depth, productivity, human activity or any other ecologically relevant variables, and may serve as focal points for collaborative scientific studies. (http://www.marinebiodiversity.ca/en/corridor.html)

In 2003, scientists from across the country developed a five-year (2004-2009) national research, development, and technology strategy for marine biodiversity in Canada's three oceans. This document, entitled *Three Oceans of Biodiversity* (http://www.marinebiodiversity.ca/en/reports.html), recommended the establishment of Discovery Corridors as a means of focusing regional research efforts in order to maximize our knowledge of species' distributions in relation to their environment. Corridors would transect a variety of seascapes, and would contain gradients of depth, productivity, human activity, and any other ecologically relevant variables. They would serve as focal points for collaborative scientific studies and for education. The notion of *discovery* is seen as including elements of enhanced inventory (species to seascape level), elucidation of processes related to biodiversity, development of methods and approaches related to

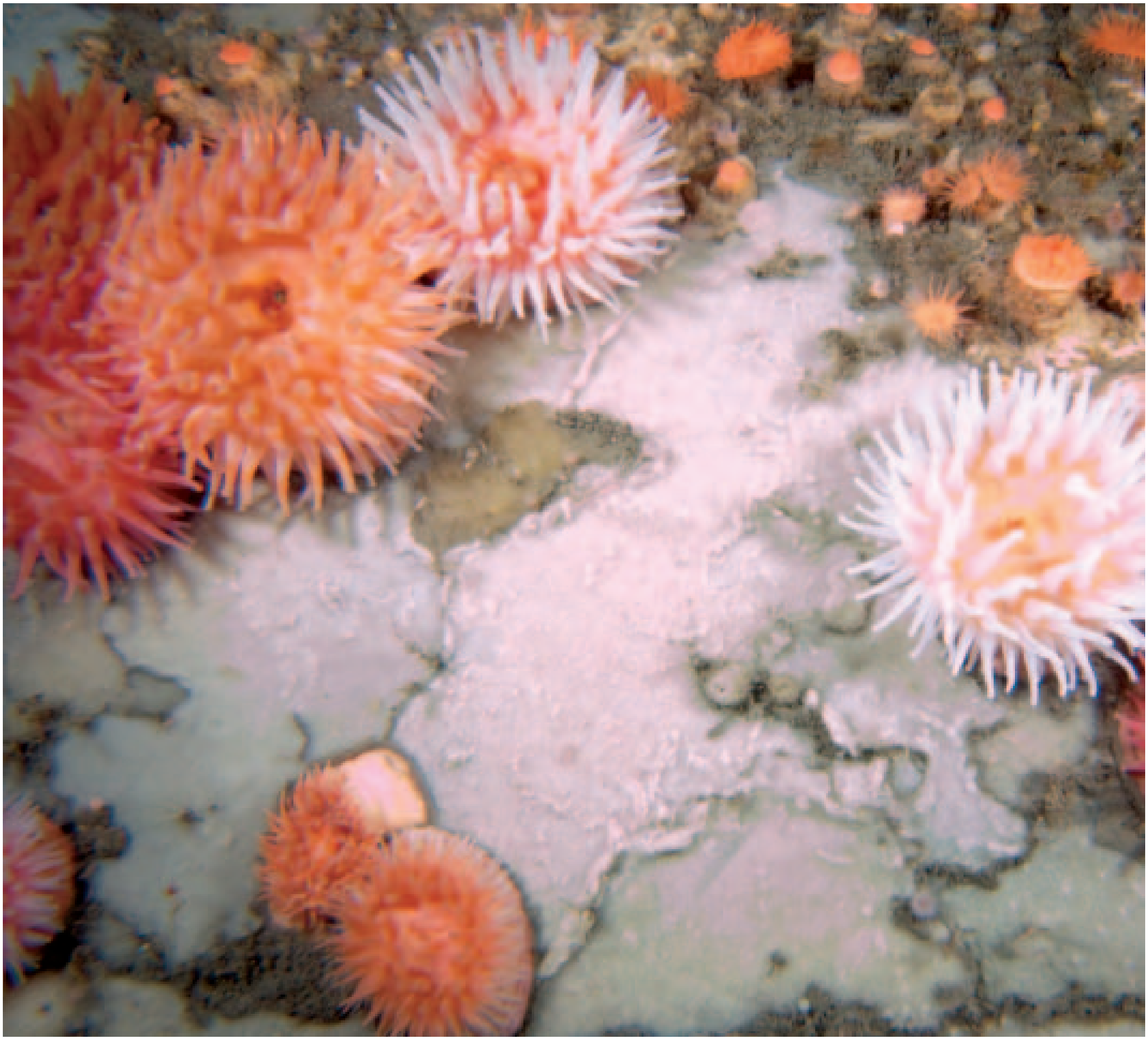


Figure 2. Colourful anemones colonize the bottom in the Rock Garden, an area of high biodiversity in Jordan Basin.

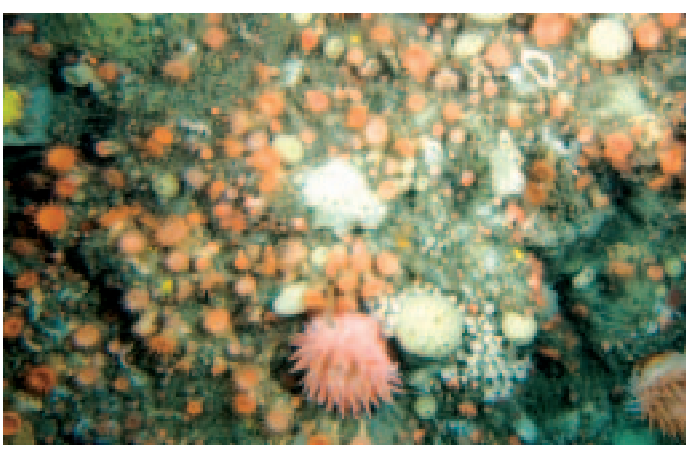


Figure 3. The rock garden appears to be an area of high species diversity

diverse scales, testing of new technologies, and studies of productivity across gradients.

The Centre for Marine Biodiversity (CMB) launched the Discovery Corridor Initiative in 2004 under the guidance of a steering committee chaired by Dr. Peter Lawton, St. Andrews Biological Station (SABS), DFO. The committee, through consultation with CMB members and invited experts, established the boundaries of a corridor in the Gulf of Maine that encompasses a variety of biogeographic regions, diverse habitats, and gradients (Figure 1). The corridor provides access to deep water habitats relatively close to shore, and includes areas that are both well and poorly known. The Canada-United States boundary approximately bisects the Discovery Corridor, which has been endorsed as one of the foundation projects for the US-based Gulf of Maine Pilot Census of Marine Life (http://www.usm.maine.edu/gulfofmaine-census).

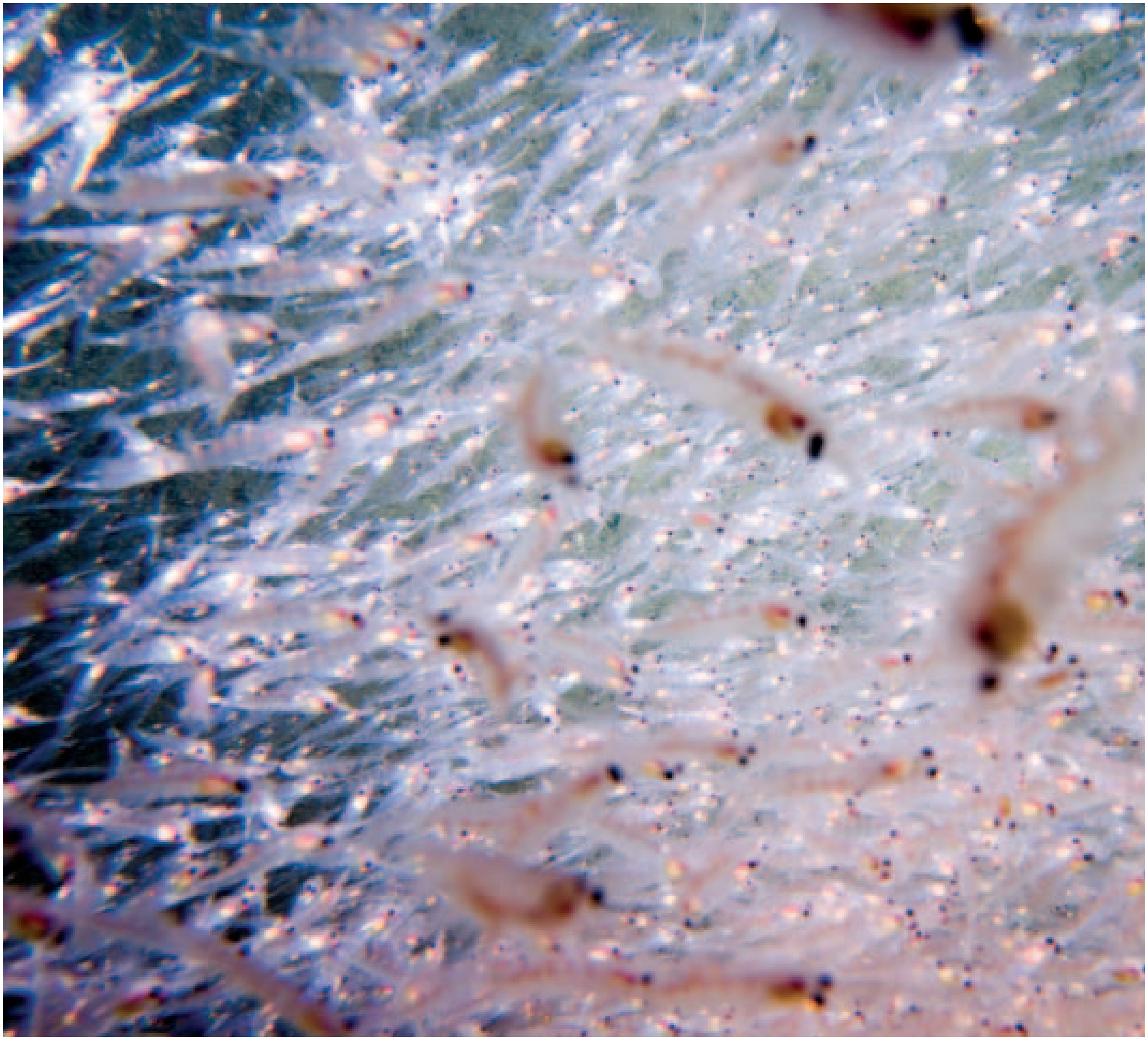


Figure 4. Rich concentrations of krill were found in the Rock Garden, Jordan Basin.

With the establishment of the corridor in the fall of 2004, the CMB organized the first Discovery Cruise in June 2005. Led by Dr. Ellen Kenchington, Director of the CMB, with Dr. Erica Head (CMB and DFO) as Chief Scientist, a mission set out to explore the ocean floor and water column in Jordan Basin, Crowell Basin, and the Northeast Channel of the Discovery Corridor. On board the CCGS *Hudson* were scientists and students from BIO, SABS, Huntsman Marine Science Centre, Dalhousie and Acadia universities, and the universities of New Brunswick and Maine. Several berths were made available for non-scientists and educators to experience and interpret marine research from their own perspective. (These included Michael Head, a junior high school teacher from Sir James Dunn Academy in St. Andrews, New Brunswick; Halifax artist Al Chaddock; and volunteer Bruce Graves).

Figure 5. Redfish shelter under a deep-sea coral (Primnoa) *in the Northeast Channel*

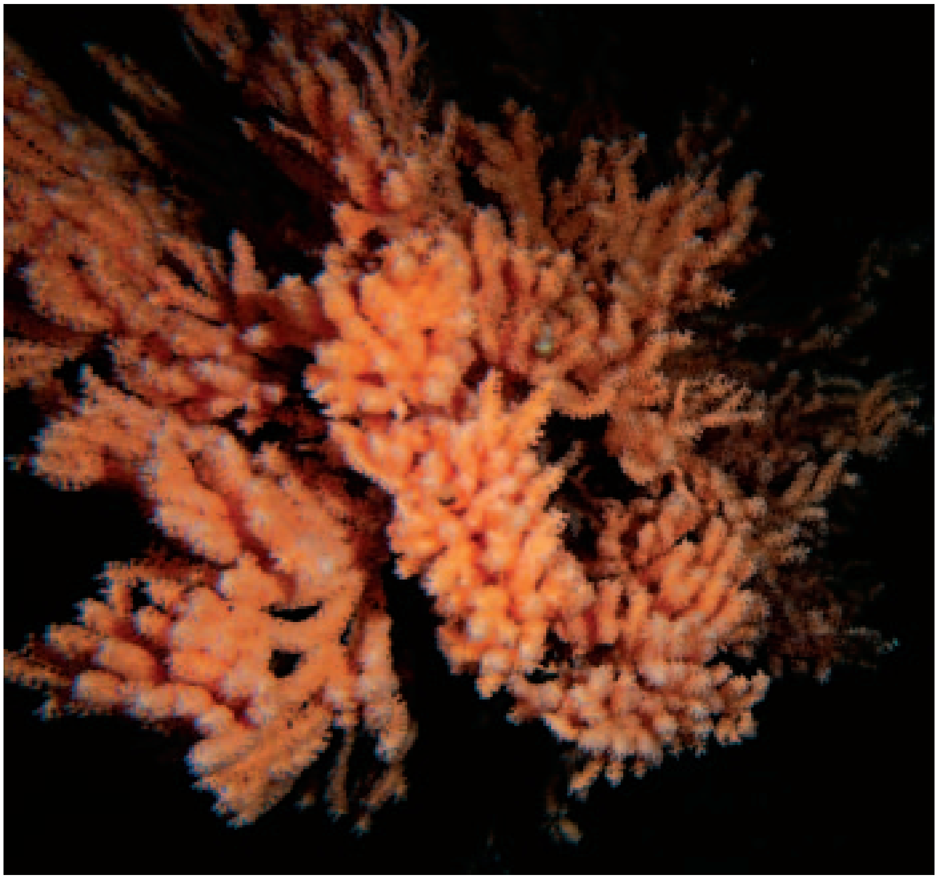


Figure 6. Primnoa *colony in the coral conservation area*

Figure 7. The bubblegum coral, Paragoria, *actively feeding in the Northeast Channel*

The mission met all of its specific scientific objectives, which were:

1. collect hydrographic data at Atlantic Zone Monitoring Station 2;
2. conduct benthic habitat surveys and hydrographic and plankton sampling in Jordan Basin, Crowell Basin, and the Northeast Channel using specialized equipment; and
3. record sightings of migratory Right Whales and other cetaceans.

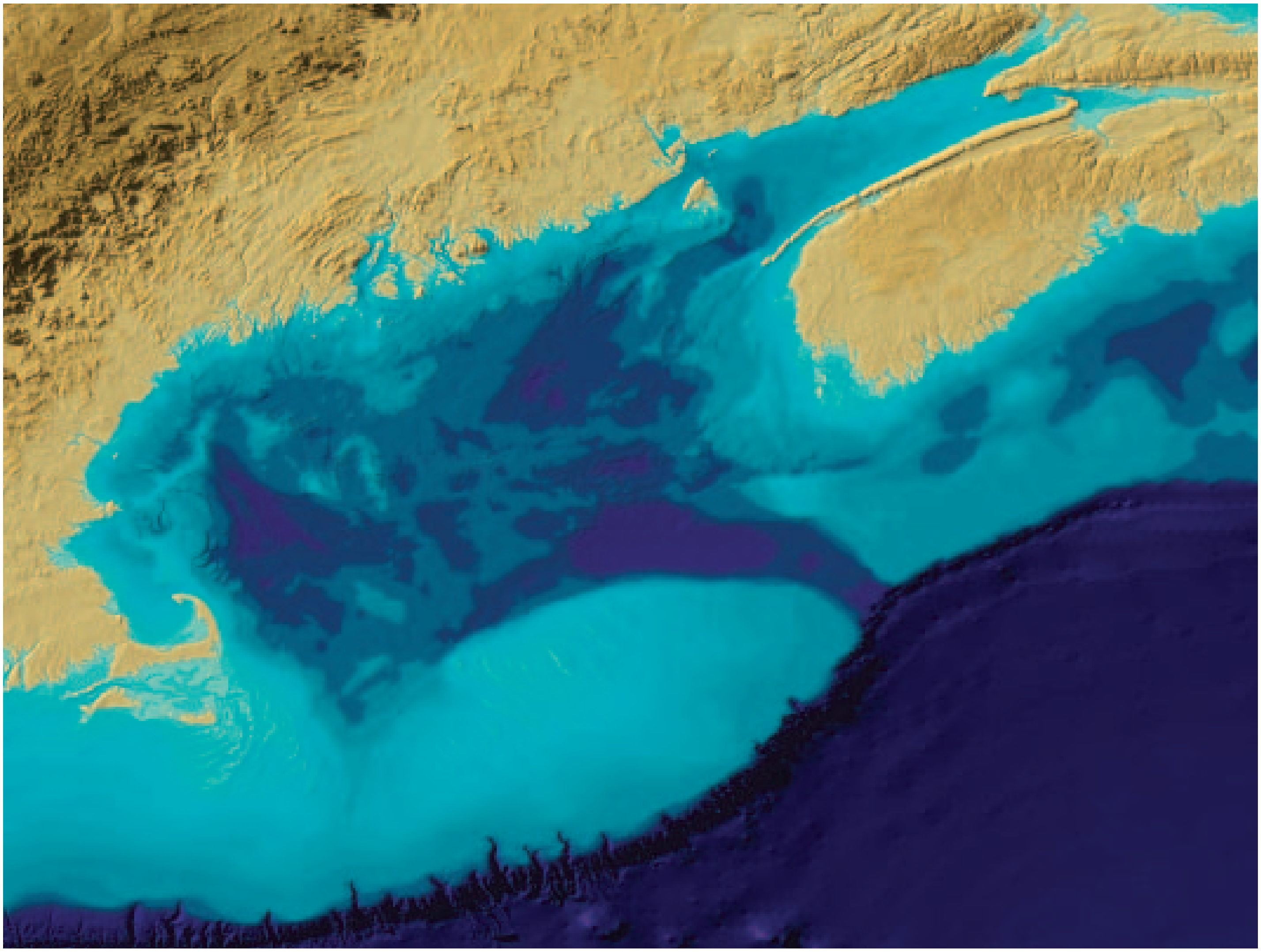
Four different types of sampling gear were used. Campod, a mounted underwater camera system developed at BIO, took video and still photos of the seafloor. Videograb, also developed at BIO, was used to collect samples of the seafloor, while BIONESS, a multiple net sampling system, sampled zooplankton from the water column. Finally, a conductivity, temperature, and depth (CTD) recorder was cast overboard to measure physical characteristics of the ocean.

While the benthic surveys were broad ranging and included both soft and hard bottom areas, a particular interest was given to the discovery of new locations where deep-sea corals grow.

The cruise was highly successful with 219 benthic stations surveyed. One of the highlights was the discovery of a highly diverse area in Jordan Basin, dubbed the Rock Garden by researchers, which is colonized by filter feeding organisms such as sponges, anemones, and hydrozoans (Figure 2). This area is interesting in that the surrounding bottom in most of the basin is a mixture of mud and clay with very little epifaunal biomass. The water column over the rock garden was also very productive with rich concentrations of krill (Figure 4), an important dietary item for many fish and cetaceans. In Northeast Channel, researchers further explored the area closed to bottom fishing gear (otter trawl, longline, scallop dredge, lobster fishing, etc.) for the protection of deep-sea corals and we discovered rich and extensive coral habitat within the closure. Extensive stands of the gorgonian corals *Primnoa* and *Paragorgia* (Figures 5, 6, and 7) were documented and will be the focus of further study in 2006.

The information collected in the Discovery Corridor will allow scientists to synthesize data from benthic and pelagic realms towards a fuller appreciation of ecosystem functioning.

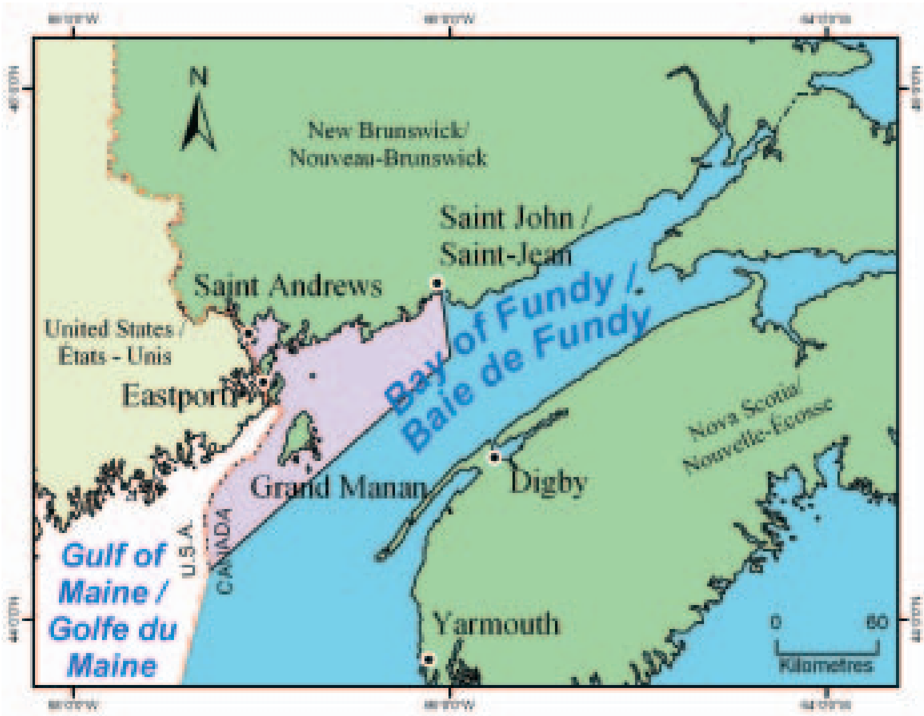
HIGHLIGHTS AND NEW INITIATIVES



Gulf of Maine and surrounding waters - courtesy Gulf of Maine Census of Marine Life (http://www.usm.maine.edu/gulfofmaine-census/, with data from http://pubs.usgs.gov/of/of98-801/bathy/data.htm)

During 2005, **DFO at BIO underwent reorganization**, to better carry out federally mandated research. In the Science Branch, the Marine Fish, Diadromous Fish, and most of the Invertebrate Fisheries divisions were amalgamated into the Population Ecology Division (PED). The biotechnology unit of Invertebrate Fisheries, most of the biological oceanographers of the Ocean Sciences Division (OSD), and the Marine Environmental Sciences Division were amalgamated into the Ecosystem Research Division (ERD). The other divisions within Science Branch remain the OSD and the Canadian Hydrographic Service.

In June, as part of Habitat Management's Environmental Process Modernization Plan, a new division was created within the Oceans and Habitat (O&H) Branch. The new **Environmental Assessment and Major Projects Division** (EA & MPD) will be in charge of environmental reviews for major projects under the *Canadian Environmental Assessment Act* for the Habitat Management Program in Maritimes Region. They will lead DFO's involvement in panel reviews, comprehensive studies, and screening of major projects. Science Branch supports this group by providing Science Expert Opinions or by holding Regional Advisory



The southwest New Brunswick Marine Resource Planning Area

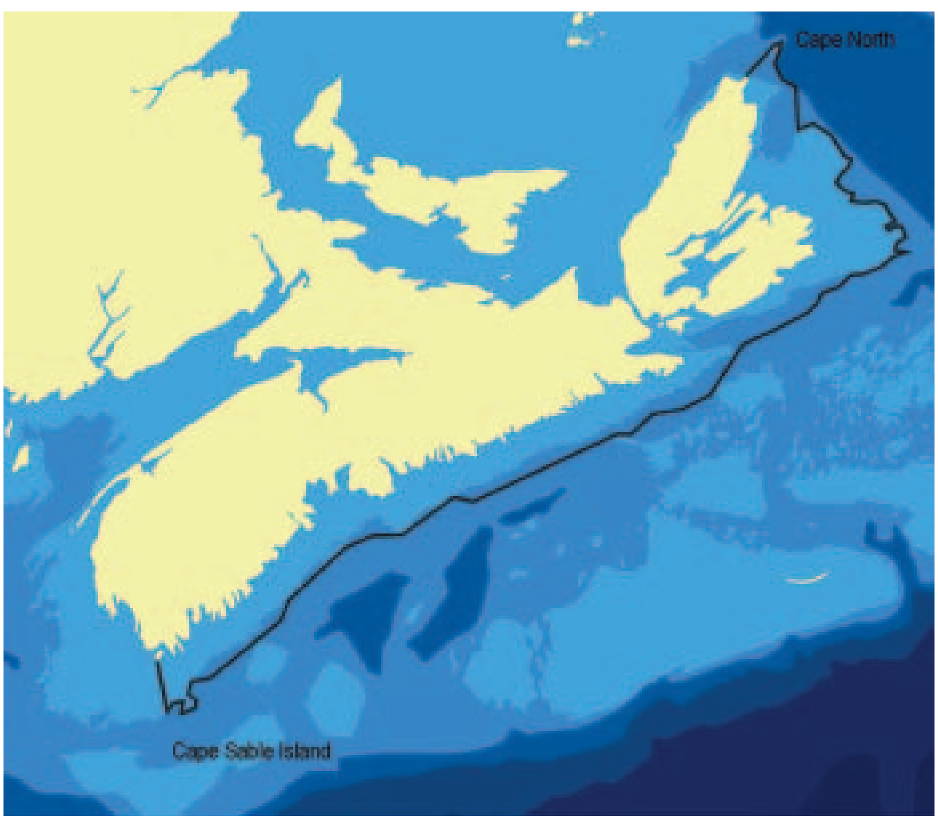
Process meetings to discuss matters pertinent to the environmental reviews. Some projects under review by EA & MPD include the Sydney Tar Ponds Remediation Project, Keltic Petrochemical, Deep Panuke Offshore Gas, White's Point Quarry, Highway twinning in New Brunswick, and Canaport LNG.

O&H's Oceans and Coastal Management Division (OCMD) and the Science Branch have received funding to implement eight national deliverables under three of the four pillars of the **Oceans Action Plan** (OAP): 1) International Leadership, Sovereignty and Security; 2) Integrated Oceans Management for Sustainable Development; and 3) Health of the Oceans (Marine Protected Areas [MPA]). Projects are underway in several priority areas, including Eastern Scotian Shelf Integrated Management (ESSIM), Canada-US collaboration in the Gulf of Maine, and Musquash Marsh MPA development. These will continue until the end of OAP Phase I in March 2007, and will contribute towards Phase II implementation.

The draft ***Eastern Scotian Shelf Integrated Ocean Management Plan*** was released for broad public review in February. The aim of this strategic-level plan is to provide long-term direction and a common basis for integrated ocean management in the region. A multi-stakeholder advisory group was established in October to review the plan and provide ongoing support for ocean planning and management activities. The goal for the upcoming year is to achieve designation as Canada's first integrated management plan under the *Oceans Act*.

From the passage of the *Oceans Act* in 1997 to the release of the OAP in 2005, we have seen an evolution of integrated oceans management concepts. A similar evolution has occurred in the United States (US), culminating in the 2004 release of the US Ocean Action Plan. These complementary efforts have laid the groundwork for the development of a collaborative approach to integrated ocean management with our US partners. The transboundary Gulf of Maine/Bay of Fundy ecosystem represents a significant resource to both Canada and the US. Commitments under the Security and Prosperity Partnership of North America direct us to enhance Canada/U.S. collaborative ocean resource management in this area. **Collaborative Management of the Gulf of Maine/Bay of Fundy Ecosystem**, formalized in Canada's OAP as an International Leadership initiative, will build upon existing mechanisms with an emphasis on multi-sectoral planning.

In February 2000, DFO announced that **Musquash Estuary** was accepted as an Area of Interest in the MPA program under the *Oceans Act*. On June 18, 2005 the proposed regulations to protect the area were published in *Canada Gazette I*. DFO continues to work with the Province of New Brunswick (NB) to complete an implementation agreement to cooperatively manage



Geographical scope of Scotian Shelf inshore area to be researched for the DFO-FSRS Inshore Ecosystem Research on the Scotian Shelf Project

Pilot projects in Clare to restore fish habitat:
a: Salmon River with crushed scallop shells (seen in upper river)
b: CKD being applied

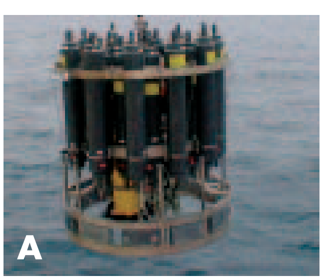
The Oden *breaks its way through the Arctic Ocean*

the MPA and surrounding salt marsh ecosystem with the intent to go to full designation as an MPA in spring 2006. DFO continues to work with the multi-stakeholder Musquash Advisory Committee to advance the Musquash MPA.

Both the federal and NB governments are interested in furthering **integrated management within the coastal and marine areas of southwestern NB**. A planning process, co-led by the OCMD and the NB Department of Agriculture, Fisheries and Aquaculture, will take a two-phased approach. It is expected that the plan will provide a basis for informed decision-making under federal and provincial legislation. As additional provincial and federal authorities are engaged in the development of the plan, the scope may be expanded.

Recently, the geographic scope of integrated management planning under the OAP has been extended to include inshore waters of the Scotian Shelf, which are critical nursery and feeding areas for many marine species. The joint **Inshore Ecosystem Research Project** between the Fishermen and Scientists Research Society (FSRS) and DFO aims to bring together existing knowledge from a range of sources, and to collect new data on the use of the inshore by marine and diadromous fish, marine mammals, invertebrates, and marine plants and their habitat associations. The project relies heavily upon the participation of inshore fishermen for both local ecological knowledge and the collection of new data; FSRS fishermen have been involved in the design of the project, the geographical scope of which is the inshore area of the Scotian Shelf (Figure 3) from Cape North to Cape Sable Island. At its finish, the goal is to have a draft Ecosystem Overview and Assessment Report for the inshore Scotian Shelf, provisional descriptions of potential Ecologically and Biologically Significant Areas (EBSA), and data, identification of data gaps, and a plan of research for future EBSA research in the inshore area.

DFO's Habitat Management Division (HMD) is participating, with DFO Science Branch, community groups, environmental non-governmental organizations, and industry, in **three pilot projects to restore habitat and water quality in Nova Scotia rivers**. Acid rain has destroyed salmon populations in at least fifty rivers along the Atlantic coast of Nova Scotia. Development projects, farming, forestry, and other land-use practices represent other human activities that have also degraded our waters. The three pilot projects are using innovative methods to restore fish habitat. At experiments in Clare and Chester, crushed scallop shells are being used to clean rivers that have lost their natural ability to maintain sweet (higher pH) waters. In another project at Clare, an overall ecosystem approach is underway using cement kiln dust (CKD), a by-product of cement manufactured by LaFarge Canada. CKD is spread on land to address problems with acid rain in the



An oceanographic bottle rosette and CTD (conductivity/salinity-temperature-depth) system being brought up from the Labrador Sea on board the Hudson
b: CCGS Hudson

Polar Bear seen during the Beringia expedition

Salmon River. At West River, Sheet Harbour, limestone from a local quarry is being used to reverse the effects of acid rain. This 10-year liming project aims to reduce acidity levels so that enough habitat is restored for the successful stocking of 10,000 Atlantic salmon smolts. An indicator of success in these projects will be the survival of all threatened species. The HMD is playing a supportive role in these projects by providing technical advice as part of the regulatory requirements. The success of these unique projects will have national implications for aquatic resources and habitats.

DFO Maritimes was identified in spring 2005 as the host region for a national Virtual Centre of Expertise in ocean modelling in DFO Science Branch. John Loder of the OSD is Director for this **Centre for Ocean Model Development and Application (COMDA)** which involves participants from all DFO regions and collaborations with other organizations, including universities. COMDA's two initial projects are: participation (with Environment Canada and the Department of National Defence) in the inter-agency development of an operational, global coupled atmosphere-ice-ocean assimilation and prediction capability for Canada; and, the development and application of ocean hindcast, nowcast, and forecast models as part of a national Operational Oceanography system for Canada.

In May-June, the **Ocean Sciences and Ecosystem Research divisions** of DFO Maritimes completed the **16th annual oceanographic section on the international sampling line (AR7W) across the Labrador Sea**. This section is a component of DFO's ocean climate monitoring program, as a contribution to the Global Ocean Observation System.

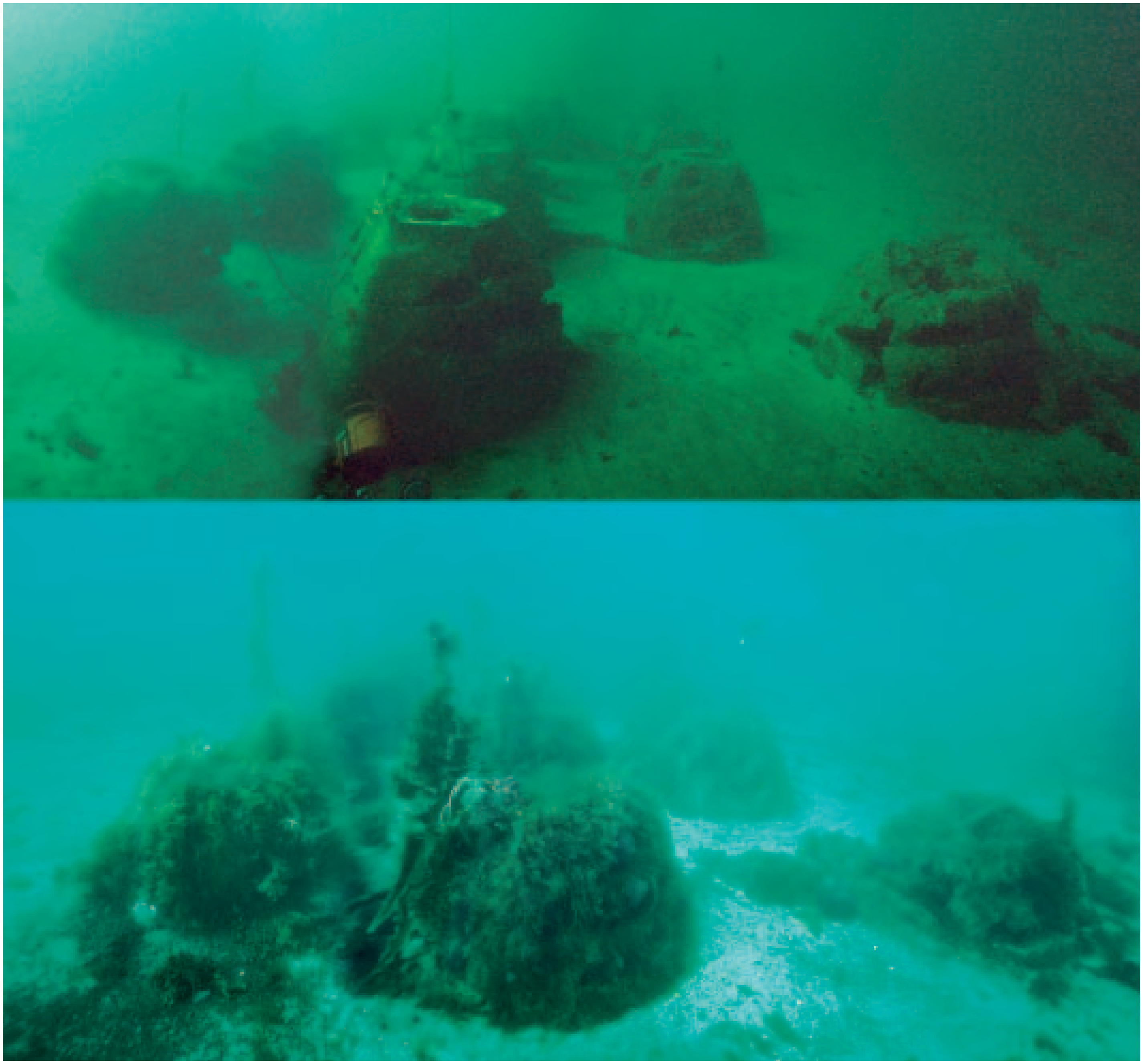
Peter Jones and Frank Zemlyak of the OSD participated in the international **trans-Arctic Beringia expedition** on the Swedish ice-breaker *Oden* during September–October. The expedition made oceanographic measurements on a section from the Barents Sea through the North Pole and across the little-sampled Canada Basin to Alaska. This was the first full oceanographic crossing of the Arctic Ocean by a surface vessel.

Dr. Simon Prinsenberg is the OSD's liaison person on Arctic and sea ice research with other DFO and government departments (NRCan and NRC). He represents the OSD at workshops and is helping with OSD proposals for Canadian **International Polar Year** funding. The OSD proposals include modelling work on wave erosion in the Beaufort Sea, ocean-ice modelling, and mooring work in Canadian Archipelago and Davis Strait, and Arctic and sub-Arctic ship surveys for chemistry tracer and for plankton ecosystem studies.

The **Regional Advisory Process** (RAP) is increasingly being used to review Oceans, Habitat, and Species at Risk issues, in addition to those of fisheries stock assessment. Among the 11 RAP meetings in 2005 was one addressing the establishment of an approach to the classification of benthic communities on the Scotian Shelf, based on their sensitivity to human impacts. This classification approach will be used by DFO Oceans in its efforts to manage a full range of human activities (from fishing to oil and gas exploration) impacting the bottom communities. RAP meetings to review the recovery potential of porbeagle shark and winter skate represented the most in-depth analyses to date of fishery populations off our coast and will be important to the recovery plans of these species. The thorough review of the Georges Bank yellowtail assessment model uncovered issues with the stock assessment that will lead to improvements in scientific advice on this resource.

The PED's **Shark Research Program** initiated a new program on migration pathways of sharks, using technological advances in satellite tracking. Beginning in 2005, archival satellite pop-up tags were used to track the depth, water temperature, and approximate location of individual porbeagle and blue sharks for periods of up to a year. The Shark Program will use the tag information to locate and protect the pupping grounds of porbeagles and to determine the survival rate of blue sharks caught accidentally by commercial longline fishermen.

In a cooperative effort between Oceans and Science branches to examine one option for habitat compensation, the PED marine plants group has been working on a project which involves monitoring **reef balls**—artificial structures designed to replace damaged coral habitat. The group deployed and monitored the colonization of these concrete habitats in two very different sites: 20 in Halifax Harbour at McNabs Island and 12 in St. Margaret's Bay at Paddy's Head. The group is following flora and fauna development on the structures over time, including the habitation of lobster in the hollow balls. The reef balls rapidly developed a community of invertebrates, marine plants, and fish over the two years since their deployment. Some fauna such as snails and crabs are year-round residents, while lobsters and fish are seasonal. Overall, the balls



Photos taken in December 2004 (upper) and in June 2005 show rapid development of seaweeds on reef balls at Paddy's Head.

have added to the complexity of the bottom and the productivity of each site. This project has led to other more comprehensive laboratory and field experiments to closely examine the relationship between habitat architecture and macroinvertebrate shelter behaviour.

The **Route Survey Office (RSO) was instrumental in the recovery of a Canadian Coast Guard (CCG) helicopter** that crashed into the sea off Marystown, Newfoundland and Labrador, on December 8. The bodies of the pilot and passenger were recovered that night from Mortier Bay, and the Transportation Safety Board (TSB) quickly assembled Coast Guard ships and local boats to look for the helicopter. When the helicopter's underwater beacon was not found inside the bay or its approaches, the shallow areas were searched using small side scan sonar, but by December 12 the helicopter had not been located. TSB investigators, aware of the RSO's capabilities from joint efforts during the Swiss Air recovery, requested help from the RS team and a small team from the Canadian Navy's Fleet Diving Unit. The RS Team brought its Klein 5500 side scan sonar and the divers their Phantom Remotely Operated Vehicle (ROV) to the search, which began on December 17. The RSO passed ten targets of interest to the underwater identification team; the *Atlantic Osprey* with her two ROVs started surveying the seafloor and the helicopter was located on top of an underwater pinnacle. The helicopter was lifted clear of the water the next evening by the *Atlantic Osprey*.

TECHNICAL SUPPORT

Research Voyages in 2005

Donald Belliveau

CCGS Alfred Needler *on the Scotian Shelf, June 2005*

Researchers at the Bedford Institute of Oceanography utilize the following research vessels based at BIO, 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.

In addition, scientists at the Institute conduct field programs on Coast Guard research vessels from other DFO regions, vessels of opportunity such as Coast Guard buoy tenders and icebreakers, commercial fishing and survey ships, and research vessels of other countries. One multibeam survey was conducted on the DND vessel CFAV *Quest* in support of the DFO/NRCan fish habitat project. The CCGS *Creed*, based in Quebec Region, was used by both the Canadian Hydrographic Service (CHS) and NRCan for multibeam survey work. Surveys normally conducted on the CCGS *J.L. Hart*, a 20 m inshore research vessel, were conducted on a series of charter vessels in 2005 as the *Hart* was removed from service due to severe rust and mould damage.

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 and for fisheries research programs. With the planned reduction of the research trawler fleet in the Atlantic Zone from three vessels to two, most of the year the *Needler* was involved in comparative fishing with the CCGS *Teleost* and CCGS

Templeman, based in St. John's, Newfoundland and Labrador. The annual winter ecosystem surveys on Georges Bank and the Scotian Shelf were completed in February and March, although some time on Georges Bank as well as the Browns Bank research cruise were lost due to winch problems. Because the *Hudson* was unavailable due to refit delays, in April the *Needler* completed the annual spring Atlantic Zone Monitoring Program (AZMP) sampling, then sailed for Newfoundland Region for comparative fishing with the *Templeman*. Further winch problems caused the loss of two days at the end of this cruise and the entire Gulf of St. Lawrence fish disease survey. After refit, the *Needler* returned for the July Scotian Shelf survey and scientists from the Institut Maurice Lamontagne, Quebec Region, conducted the annual Northern Gulf of St. Lawrence survey in August. The *Needler* struggled with winch problems during this cruise and eleven days were lost to repairs at the beginning of the southern Gulf survey in September. The cruise to study fish habitat on the Scotian Shelf in October was completed, the final cruise of a four-year project. The *Needler* then returned to Newfoundland for more comparative fishing with the *Templeman*. Its stay was extended to cover for breakdowns on both the *Teleost* and *Templeman*. After participating in a Search and Rescue call to rescue a sailing vessel north of Newfoundland, the *Needler* returned to BIO on November 22 and prepared for winter lay-up/refit.

CCGS *Hudson* started late after a delayed refit period. The first cruise of the year serviced moorings in Orphan Basin and Flemish Pass off Newfoundland. The vessel then sailed to the Labrador Sea to service oceanographic moorings and conduct conductivity-, temperature-, and depth- (CTD) related hydrographic survey operations as part of Canada's contribution to global climate studies. The *Hudson* headed next for the Bay of Fundy to start a multi-year project studying biodiversity in the Discovery Corridor, which extends from the coast of New Brunswick/Maine across Georges Bank and out past the shelf break. Next, NRCan used the vessel for a cruise down the Scotian Shelf to the Northeast Channel, conducting sidescan surveys, bottom photography, and geophysical sampling. The *Hudson* then headed for Hibernia to investigate the impacts of "produced" water on the environment around the platform. ("Produced" is water that is recovered with the oil as it is brought from deep underground.) NRCan took control of the vessel again in July for a 35-day trip across the Scotian Shelf and onward to conduct geophysical surveys north of Newfoundland and on the Labrador coast. After a short break, at the end of August the Hudson headed north again to Davis Strait. On the first portion of the cruise, NRCan studied the heat flow dynamics of sediments in the Strait. The Hudson then proceeded to Nuuk, Greenland, the ship's first foreign port visit in several years, to embark scientific staff from BIO and the University of Washington. This portion of the cruise serviced an array of fourteen moorings stretching across the Strait, and collected CTD and other data. Autonomous gliders were deployed to enhance the dataset being collected to study the fresh water and ice fluxes coming out of the Arctic. The final cruise of a four-year program to explore the relationships between groundfish and their seabed habitats on Emerald, Western, and Sable Island banks was completed in early October. The Maritimes Region fall AZMP cruise was completed in late October. From early November to mid-December, oceanographers from the Institut Maurice Lamontagne and the Northwest Atlantic Fisheries Centre conducted cruises to obtain their autumn AZMP physical and biological oceanographic datasets and the Gulf of St. Lawrence ice forecast dataset. The season concluded on December 15 when the ship was docked at BIO for the winter.

CCGS Matthew at LaPoile, on Newfoundland's south coast, during the course of hydrographic work. Photo by Michael Lamplugh

CCGS *Matthew* began its field season in early June after completion of repairs to the hull necessitated by the grounding off the west coast of Newfoundland in July 2004. As part of the repairs, a new Kongsberg EM710 multibeam transducer (mounted on a gondola) was installed, replacing the EM1002 transducer lost during the grounding. The "topside" electronics were installed at BIO after the *Matthew* returned from dry dock. The new system is capable of 2000 m (twice the depth of the old system), and provides up to 200 soundings across the swath (almost double the old system's 111 soundings per ping). The expandability and future potential of this system is impressive. This fourth generation system is the first EM710 operational in the world and will be capable of providing up to 800 soundings per ping (8 times higher seabed resolution) with the installation of a few yet-to-be-built electronic boards. An additional advantage is that water column information can be logged concurrently. Testing and acceptance trials of the new system took place in the first two weeks of June. Subsequent to the successful completion of these trials, the new system was put through its paces in a shakedown survey in the Halifax Harbour Approaches for the next two weeks. The *Matthew* left BIO over the July 1 weekend and proceeded to the Cheticamp area to conduct a three-day joint CHS and NRCan survey before heading for the south coast of Newfoundland. The vessel spent July collecting multi-beam data to ensure the navigational safety of new ferry routes on the south coast, then participating in the ongoing multibeam survey off Placentia Bay, a continuation of work started in 2004 for NRCan. August was spent surveying the first multibeam corridor up the Labrador coast from Nain to Cape Chidley, the farthest north the *Matthew* has ventured. Most of September and October were lost to a series of vessel equipment failures and weather. First, the *Matthew* returned to St. John's for repairs to her emergency generator. The return to the Labrador coast was delayed by weather and a breakdown in the propulsion control system. After finally reaching the Labrador coast and working for a few days, the *Matthew* had to make an emergency run to Sydney, Nova Scotia, with a shaft tube leak. The vessel then returned to Cartwright, Labrador for a few days to retrieve two tide gauges and a GPS survey station. NRCan staff took over the vessel on October 21 in Sydney to complete the geophysical sampling part of their Placentia Bay program. The *Matthew* returned to BIO Nov 9. CHS conducted trials of the Free Fall Cone Penetrometer with the ship's Moving Vessel Profiler the week of November 14. The vessel entered lay-up for the winter after spreading the ashes of Johnny Cliff at sea on November 24; Johnny was CSS *Baffin's* longest serving engineer.

Replacement of our ageing Science fleet is a high priority. Plans are underway to replace the *J.L. Hart* by the winter of 2007. Preliminary design is taking place now, with detailed design and construction to take place in 2006/2007. Two replacement trawlers, one for each of the east and west coasts, were announced in the spring 2005 federal budget. The Statement of Requirements is complete and contracts will soon be let to start the preliminary design. Delivery is planned for 2010. These new vessels will be a start in rejuvenating our ageing Science fleet.

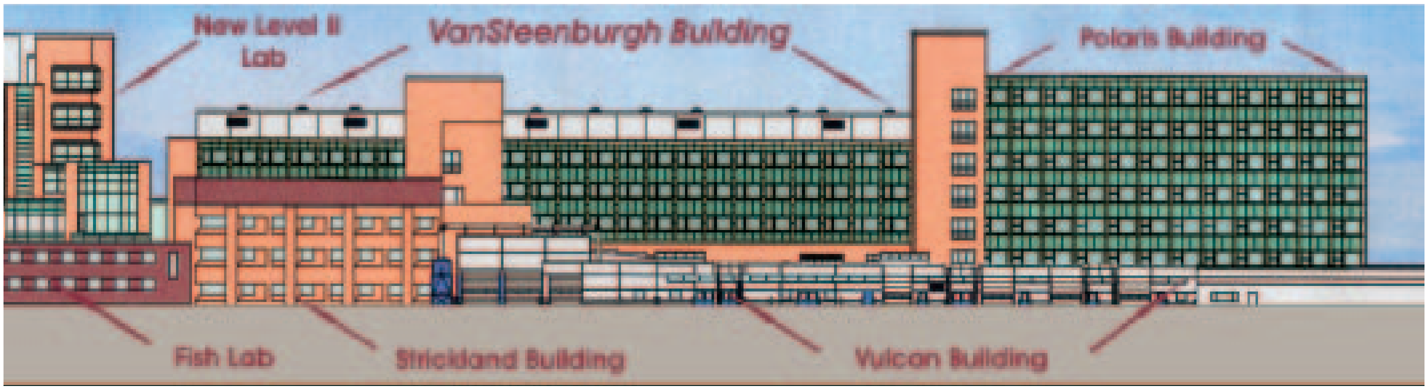
BIO Redevelopment – A Multiple-Project Long-term Program

Brian Thompson

Construction of the new Level II laboratory at BIO began in the fall of 2004, when heavy excavators prepared the foundation. Since then, tremendous progress has been made on the building. Structural features, such as the cantilevered hallway gathering areas along the eastern face, the physical connection to the Van Steenburgh Building, and access to the docks, are now evident.

While Phase I components were being completed, tenders were advertised for Phase II. In October 2005, a contract was awarded to Herve Pomerleau for this new work, which includes electrical and mechanical systems, construction of the interior partitions, fume hood installations, and exterior landscaping. Laboratory casework and fixtures will be installed as a separate project phase, proposed for early in 2006. Occupancy of the new facility is expected to begin as planned in late summer 2006.

Structural elements of the new lab nearing completion



Conceptual drawing of reconstructed van Steenburgh Building (bounded by the new lab on the left and the Polaris Building to the right)

It is safe to assume that few BIO staff give much thought to the roofs above them. Yet the roof system on the BIO campus covers and protects an area of approximately 22,300 square metres. This is equivalent to 14 NHL hockey arenas or five NFL football fields. Only when problems develop with the roofing systems do employees tend to become interested or concerned. Several roofs at the Institute have now reached the end of their service life. Consequently, Occupational Health and Safety issues could arise as well as disruption of facility use. DFO's Real Property Safety and Security Branch was successful in obtaining approval for the replacement of the existing roofing systems for the Polaris, Holland, and Murray Buildings, a total roof area of about 5200 square metres. All work is expected to be completed by early 2006.

In February, 2005, a contract was awarded to Davison Simone Rickard Adams for the design of the van Steenburgh Building Reconstruction project. Conceptual designs were prepared and detailed engineering and architectural drawings will be completed by early 2006. The van Steenburgh project is a major component of the BIO redevelopment. Before actual reconstruction can take place, this undertaking will require the removal of both interior and exterior walls, leaving only steel and concrete structural elements in place. Since the Institute's heating plant is located in the van Steenburgh and because the building serves as a physical connection between various parts of BIO, special provisions will be required to ensure continued operation of the heat distribution system and passage via a temporary pedway. To be consistent with the overall character of BIO and to meet suggested heritage considerations, the exterior facia of the building will bear a strong resemblance to the Polaris Building. The target in-service date for the reconstructed van Steenburgh Building is late 2008.

OUTREACH, SEMINARS, AND SPECIAL EVENTS

Outreach Activities from the Bedford Institute of Oceanography

FISHERIES AND OCEANS CANADA

Joni Henderson

Science student at the Science Fair Showcase explains his innovation in automobile safety.

2005 marked the 14th year of BIO's guided tour program and was our most successful year ever. The 5,664 visitors during the four-month period was an all-time high, surpassing the previous record of 4374 set in 2003. Since the suspension of the self-guided tour, demand for guided tours has increased dramatically, especially from schools in the province. It is hoped that resources will be found to enable us to offer this service on a year-round basis.

The most popular features on the tour route continue to be the Fish Lab and Sea Pavilion, followed by the Species at Risk (SARA) and Titanic exhibits. The SARA display offers "hands-on" activity and therefore is very popular with younger visitors. Refurbishment of the Gully Room, now underway, includes the development of more of these popular hands-on activities.

DFO staff members remain active members of The Nova Scotia Youth Experiences in Science Committee, a not-for-profit, registered society that initiates, promotes, and supports science experiences for Nova Scotia youth. The fourth annual Team Nova Scotia Science Fair Showcase took place at BIO in April, bringing together 40 of our province's brightest young scientists and innovators to display their award-winning projects in an open house. These students, from grades 7-12, displayed their research and design achievements in the fields of biotechnology, computing and mathematical sciences, earth and environmental sciences, engineering life sciences, and physical sciences, before heading to Vancouver to represent Nova Scotia at the Canada-wide Science Fair. Global television meteorologist Cindy Day delivered the keynote address at the Showcase: *The Evolution of Weather Forecasting…from "Grandma Says" to Computer Models*.

The annual Oceans Day poster contest, "Discover the Ocean in Your Back Yard", open to junior and senior high schools around the province, attracted more than 100 entries. The top ten winners received a framed photograph of their winning entry and an Oceans Day sweatshirt. As well, the top three were treated to a tour of BIO and lunch on board Canada's largest icebreaker, the CCGS *Louis S. St-Laurent*. Also on Oceans Day, BIO welcomed participants in the 2005 International Oceans Institute – Canada training program. Over the course of the day, staff presented these students from around with world with several informative talks. Their visit was capped off by a guided tour of the Institute that included visits to the CCGS *Hudson* and the Shannon Hill Vessel Traffic Management Centre.

Requests to DFO staff for job shadowing and speaker presentations also increased in 2005 and were accommodated where possible. This increase in demand for BIO resources is representative of the value placed on our employees by the community.

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

NATURAL RESOURCES CANADA: EDUCATION OUTREACH AT THE GEOLOGICAL SURVEY OF CANADA (ATLANTIC)

Jennifer Bates, Sonya Dehler, Gordon Fader, Rob Fensome, David Frobel, Iris Hardy, Nelly Koziel, Bill MacMillan, Bob Miller, Patrick Potter, John Shimeld, and Graham Williams

Interest and participation in education outreach is increasing steadily at the Geological Survey of Canada (Atlantic) (GSC Atlantic) where geologists are collaborating with other like-minded people representing geological surveys, museums, science centres, universities, and schools on a varied slate of activities. NRCan's core programs—the EdGEO workshop series and EarthNet website—remain popular. Their success, and that of many other activities, is due primarily to the collaborative nature of the Atlantic Geoscience Society (AGS) Education Committee of which GSC Atlantic is a member and Jennifer Bates is Chair. As well, GSC staff continue to judge science fairs, answer questions from the public, and give invited talks at schools, universities, and libraries.

EdGEO is a national program that supports local workshops on earth science for Canadian teachers. In 2005, the Nova Scotia EdGEO Workshop Committee celebrated its 12th year by offering two workshops: one as part of the outreach program of the *Halifax 2005* GAC-MAC-CSPG-CSSS[1] conference, and another in August at the Fundy Geological Museum in Parrsboro. Participants in the 2005 workshops were not only Kindergarten to Grade 12 teachers, but also educators from museums, science centres, and national parks. The Committee views this growth beyond school teacher-only enrolment as positive; education happens in many places.

The May workshop, held at Dalhousie University, attracted about 20 participants from across Canada: teachers, Parks Canada interpreters, staff from CBC television's *The Nature of Things*, and museum interpreters. Attendees experienced a whirlwind of activity that covered the rock cycle, geological time, plate tectonics, and a condensed version of the geological history of Nova Scotia (NS). Part of the afternoon was dedicated to a geological tour of the university campus. Our workshop was just one element of the outreach program at the three-day national conference, where a highlight was the display from the Canadian Museum of Nature's valuable Pinch mineral collection, one of the finest in the world.

In August, more than 20 EdGEO registrants from throughout Nova Scotia gathered at the Fundy Geological Museum in Parrsboro for three days of engaged learning. Day One centred on the basics of rocks and minerals and included a hands-on activity which required participants to understand the connections between the new NS geological highway map and the kit of NS rocks and minerals. In the evening, participants viewed the museum galleries and heard lab manager Kathy Goodwin explain the preparation of the renowned fossils discovered at nearby Wassons Bluff. Day Two included a short session on fossils and geological time, a tour of the Joggins Fossil Centre, and an afternoon at the

Rebecca Jamieson of Dalhousie University explains the intricacies of the underlying Meguma Group metasediments to attendees of the May EdGEO workshop. Photo by Andrew MacRae, Saint Mary's University

At the Nova Scotia Department of Natural Resources (NSDNR) Core Library in Stellarton, EdGEO Workshop Committee members prepare rock kits for the August workshop. The NSDNR generously donated samples and staff time which ensured all participants would receive a superb kit of Nova Scotia rocks and minerals. Shown, from left: Nancy Muzzatti, Jennifer Bates, Nelly Koziel, Paul Batson, Henrietta Mann, Andrew Casey, and Iris Hardy.

[1]Geological Association of Canada-Mineralogical Association of Canada-Canadian Society of Petroleum Geologists-Canadian Society of Soil Scientists

Participants, presenters, and organizers of the August EdGEO workshop visited the Joggins Fossil Centre.

Discovering the hidden secrets of the Joggins cliff section was a delight for participants of the August workshop. Well preserved Carboniferous flora and fauna make Joggins a unique and world class geological site.

Joggins fossil cliffs. Day Three offered sessions on soil, plate tectonics, and sedimentary rock with its oil and gas treasures.

Financial support was provided by the National EdGEO Committee. The GSC Atlantic, NS Department of Natural Resources, NS Museum of Natural History (MNH), Dalhousie and Saint Mary's universities, various school boards, and Atlantic Science Links Association generously provided in-kind support. A special thank you goes to the staff of the Fundy Geological Museum for its donation of space and assistance.

The success of the Nova Scotia EdGEO Workshop Program depends upon the knowledge, experience, enthusiasm, and dedication of its Committee. Presenters and Committee members represent both the geoscience and education communities: Dottie Alt, (Tatamagouche Elementary School); Paul Batson, (NS Community College: Institute of Technology); Henrietta Mann and Anne Marie Ryan (Dalhousie University); Andrew Casey, Murray Metherall, and Kathy Silverstein (Halifax Regional Municipality School Board); Howard Donohoe (NSDNR); Cindy Hiseler and Wendy Spicer (Annapolis Valley School Board); Heather Johnson (Halifax Independent Elementary School); Nancy Muzzatti and Deborah Skilliter (NSMNH); Melanie Oakes (consultant); Bev Williams (NS Association of Science Teachers); and Jennifer Bates, Sonya Dehler, Rob Fensome, Iris Hardy, Nelly Koziel, Bill MacMillan, Patrick Potter, John Shimeld, and Graham Williams (GSC Atlantic).

The GSC is a major partner in EarthNet, the online resource for earth science information for Canadian educators and students (http://www.earthnet-geonet.ca) sponsored by the Canadian Geoscience Education Network. Achieving the goal of coast-to-coast-to-coast coverage is closer as geologists from across Canada donate learning activities, images, and field trip materials, and recommend resources and local information sources. The Development Committee, operating at GSC Atlantic, is concentrating on comprehensive national coverage and top-level topic and region search capability.

The AGS project of telling the geological history of the Fundy Basin through paintings and a printed booklet is moving toward completion. New Brunswick artist, Judi Pennanen, is the artist of the five, 18 x 24 inch (45.72 x 60.96 cm) watercolours. Four of the paintings highlight life and landscapes in the time of the Wolfville, Blomidon, North Mountain, and McCoy Brook formations. The fifth stars a prosauropod family. The paintings have been framed and will move to their permanent on-loan location at the Fundy Geological Museum in 2006. A first draft of the booklet is in the review stage.

The evening public talk series, Beyond *The Last Billion Years*, continues to attract a crowd to the Nova Scotia Museum of Natural History. Though the 2005-06 season is shorter than usual (four talks), it will include a major event—the unveiling of the new AGS video *Halifax Harbour: A Geological Journey* in March 2006. GSC Atlantic staff, as active members of the AGS Video Committee, have been working on this key resource for educators.

Through the AGS Education Committee, GSC Atlantic staff are contributing to the outreach component of the University of New Brunswick-St. Francis Xavier NSERC CRYSTAL[2] program, one of five from across Canada. The CRYSTAL project is analyzing the effectiveness of outreach in the community; the long-run-

[2]Natural Sciences and Engineering Research Council (of Canada), Centres for Research in Youth, Science Teaching and Learning

One of five watercolours by Judi Pennanen that tell the Fundy Basin story, this landscape depicts the early Jurassic sedimentary environment deciphered from the rocks at Wassons Bluff, NS. This site is probably the best in the world for rocks of this age. The prosauropod bones found in the rocks are considered Canada's oldest dinosaur skeletons.

ning Nova Scotia EdGEO program could provide valuable data for this research.

Theme collaboration is important to the success of any outreach program. GSC Atlantic will continue to participate in multi-partner working groups to bring together a broad knowledge and varied experience to outreach activities.

Workshops

The 3rd Eastern Scotian Shelf Integrated Management (ESSIM) Forum Workshop was held in Halifax, February 22-23. Convened by the Oceans and Habitat Branch, the purpose was to discuss the draft ESSIM Plan with stakeholders. The 160 people attending represented federal agencies (the Canadian Environmental Assessment Agency, Environment Canada, Natural Resources Canada, Transport Canada, Industry Canada, and Parks Canada); United States government organizations (state and federal); academia; consultants; industry and industrial associations (particularly fisheries); and local and national NGOs, as well as DFO staff from Eastern Canada. The acceptance of the directions and implementation of the plan allowed DFO to move forward on several next steps. Workshop Proceedings were published as *Canadian Manuscript Report of Fisheries and Aquatic Sciences 2719*, and the plan was released for further stakeholder public review. A stakeholder advisory council was established. Three community workshops were held in fall 2005 and the draft was revised based on stakeholder input. It will be put forward for Ministerial recognition under the *Oceans Act* during 2006. The 4th ESSIM Forum Workshop will be held February 2007. http://www.mar.dfo-mpo.gc.ca/oceans/e/essim/essim-intro-e.html

In June, BIO hosted the inter-agency **Atlantic Tsunami Warning Workshop**, involving representatives from six federal or provincial agencies in Canada and the United States, and five DFO regions. An initial plan for the development and implementation of an interim Canadian Atlantic Coast Tsunami Warning System was produced.

Allyn Clarke of DFO's Ocean Sciences Division (OSD) was on the local organizing committee for the **Second Session** of the international **Joint Commission for Oceanography and Marine Meteorology** (referred to as **JCOMM-II**), held in Halifax, September 19-27. JCOMM was set up in 1999 by the World Meteorological Organization and the Intergovernmental Oceanographic Commission to coordinate, regulate, and facilitate a fully-integrated global marine observing, data management, and services system. Over 130 delegates from 42 countries participated in the second session. Allyn was also the Program Chair for a JCOMM Science **Conference on Operational Oceanography and Marine Meteorology for the 21st Century** held in Halifax on September 15-17.

ESSIM workshop

Seminars and Speakers

Over the course of the year, BIO welcomes scientists from around the world to lead seminars and to lecture at the Institute.

BIO SEMINAR 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 2005, the Seminar Series featured the following:

Science and Technology for the 21st Century: Opportunities and Challenges for Canada
Dr. Arthur Carty, National Science Advisor to the Prime Minister of Canada, Ottawa, Ontario

Impact of Climate Change on the Oceans
Dr. Ken Denman, DFO Research Scientist, Canadian Centre for Climate Modelling and Analysis, Victoria, British Columbia

What's up with the Weather?
David Phillips, Senior Climatologist, Environment Canada, Ottawa, Ontario

NRCAN SPECIAL SEMINARS

Smooth Sailing on a Rough Lake: High-Resolution Seismic Acquisition on Lago Fagnano, Tierra del Fuego, Argentina
Dr. Jamie Austin, Senior Researcher at the University of Texas Institute for Geophysics, University of Texas, Austin, Texas, US

Characterization of Paralic Paleoenvironments and Identification of Hurricane Deposits based on Benthic Foraminiferal Analysis of Early Cretaceous Sediments (Scotian Shelf)
Dr. Flavia Fiorini, Post Doctoral Fellow, Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia

Proterozoic Mafic Dyke Swarms in Arctic Canada and Greenland: Paleomagnetism, U-PB Geochronology and Implications for the Nares Strait Problem
Steve Denyszyn, Department of Geology, University of Toronto, Ontario

Australia's Continental Shelf Submission: Approaches and Implications
Phil Symonds, Senior Advisor – Law of the Sea, Petroleum and Marine Division, Geoscience Australia

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.

CENTRE FOR MARINE BIODIVERSITY SEMINARS

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

Climate Change and Parasitism in Inter-tidal Ecosystems
Professor Robert Poulin, FRSNZ, Department of Zoology, University of Otago, Dunedin, New Zealand

Nekton Diversity Associated with Bear Seamount, NW Atlantic Ocean
Dr. Michael Vecchione, Director, National Systematics Laboratory, National Museum of Natural History, Smithsonian Institution, Washington, DC
Following this seminar a panel discussion on *science in support of the conservation of marine biodiversity* was held. Panelists were Rob North (CBC), Greg Peacock (DFO, Fisheries Management), Bob Rangeley (World Wildlife Fund), and Tony Charles (Saint Mary's University).

GSC MUD CLUB

Mud Club provides an informal opportunity to present findings in marine geoscience by showcasing GSC and DFO research. The following were outside speakers to Mud Club in 2005:

Foraminifera from the Mackenzie Trough, Beaufort Shelf … a Work in Progress - Another Exciting Contribution from Canadian Arctic Shelf Exchange Study
Trecia M. Schell, Ph.D., Post-Doctoral Research Fellow, Centre for Environmental and Marine Geology, Dalhousie University

Advances in Seabed Habitat Mapping: Studying Biology using Sound
Craig Brown, University of Ulster, Northern Ireland

DSE Next-generation Time-lapse Imaging in Natural Resources Monitoring
Ulrich Lobsiger, Oceanographic and Field Services Consultant, Nova Scotia

COGS Application of Terrestrial LIDAR Technology for Flood Risk and Geological Mapping
Timothy Webster, Centre of Oceanographic Sciences, Nova Scotia Community College, Lawrencetown, Nova Scotia

Multibeam Surveying, Bedform Migration, and Bedload Sediment Transport on the Mispec Bay Banner Bank, Saint John
Garrett Duffy, Ocean Mapping Group, University of New Brunswick, Fredericton, New Brunswick

HARVEST FISHERIES SEMINAR SERIES

The Harvest Fisheries Seminar Series began in 2002. Hosted by the Population Ecology Division, 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 of BIO are encouraged to give their presentations at the Institute. The program also features speakers from local universities and visiting researchers.

River Inputs and Marine Benthic Food Webs: Terrestrial Particulate Organic Matter Use in Marine Flatfish off the Rhone River Delta (NW Mediterranean)
Dr. Audrey Darnaude, Center for Environment, Fisheries, and Aquaculture Science, Lowestoft, United Kingdom

The Movement of Lobster in the Northumberland Strait
Cornelia Den Heyer, Ph.D. Candidate, Dalhousie University

Measuring Marine Fish Biodiversity: Population and Life History Correlates of Recovery
Dr. Jeff Hutchings, Dalhousie University

Multiple-scale Distribution of Demersal Fish on Western Bank as determined from Towcam Video
Dr. Bob Gregory, Northwest Atlantic Fisheries Centre, St. John's, Newfoundland and Labrador

Lies, Damn Lies, and Landings Statistics
Dr. Tim Hammond, Defence Scientist, Defence Research and Development Canada (DRDC) Atlantic, Dartmouth, Nova Scotia

History of Multiple Human Impacts and Successive Changes in Coastal Ecosystems Worldwide
Dr. Heike Lotz, Dalhousie University

How to Count the Fish in the Sea: Statistical Problems in the Census of Marine Life
Dr. Ransom Myers, Dalhousie University

The History of Ocean Resources: Modelling Cod Biomass using Historical Records
Dr Andrew Rosenburg, University of New Hampshire, Durham, New Hampshire, US

Groundfish Distribution and Bottom Type in Hecate Strait and Queen Charlotte Sound
Alan Sinclair, Pacific Biological Station, Nanaimo, British Columbia

Global Decline of Predator Diversity in the Open Ocean
Dr. Boris Worm, Dalhousie University

OCEAN SCIENCES DIVISION COFFEE TALKS

The Ocean Sciences Division Coffee Talks are weekly seminars covering topics in physical, chemical, and biological oceanography. The series provided a forum for both local researchers, and visiting scientists in 2005:

Underwater Sensing of the Concorde Sonic Boom
Dave Chapman, DRDC Atlantic

A Shared Atmosphere-Ocean Dynamical Core: First Validation
Hal Ritchie, Dalhousie University and Environment Canada

Vortical Structures Generated by a Localized Forcing
Vasily Korabel, Memorial University, St. John's, Newfoundland and Labrador

C-DOGS (Conference of Dalhousie Oceanography Graduate Students)
Special Session I

The Ocean Surveillance Game - from Submarines to Smugglers
Francine Desharnais, DRDC Atlantic

C-DOGS
Special Session II

Why Isn't the Ocean Black?
Marlon Lewis, Dalhousie University

Constructing A Tsunami and Storm Surge Model with Local Domain but Global Boundary
Zhigang Xu, Institut Maurice-LaMontagne, Mont-Joli, Quebec

Laboratory, Numerical, and Observational Studies of Upwelling Flow of Submarine Canyons
Susan Allen, University of British Columbia, Vancouver, British Columbia

Theories and Observations of Biomass (size) Spectrum: Interpreting Plankton Population Dynamics Processes and Trophic Structure
Meng Zhou, University of Massachusetts, Boston, Massachusetts, US

A Labrador Sea Modelling Studied by a Coupled Sea Ice-Ocean Circulation Model
Hideaki Kitauchi, Frontier Research Center for Global Change, JAMSTEC, Japan

20th Century Sea-level Rise
John A. Church, Senior Researcher, Commonwealth Scientific and Industrial Research Organization, Australia

Particles are Better than Dye: An Intelligent Application of Old Technology
Barry Ruddick and **Chris Taggart**, Dalhousie University

Mesoscale Eddies in the Eastern Indian Ocean: Are They Death-traps or Nurseries for Fisheries Recruitment?
Anya Waite, University of Western Australia, Perth

Enhanced Open Ocean Storage of CO_2 from Shelf Sea Pumping: Results from a Pilot Study in the North Sea
Helmuth Thomas, Dalhousie University

Designing an Integrated Arctic Ocean Observing System for the International Polar Year
Bob Dickson, Senior Scientist, Centre for Environmental, Fisheries, and Aquaculture Science, Lowesoft, United Kingdom

The A. G. Huntsman Award

The A.G.Huntsman Award was established by BIO scientists in 1980 to recognize excellence of research and outstanding contributions to marine science. The award honours marine scientists of any nationality who have had and continue to have a significant influence on the course of marine scientific thought. It is presented annually in one of three categories:

- Marine geosciences
- Physical/chemical oceanography
- Biological/fisheries oceanography

The award is named in honour of Archibald Gowanlock Huntsman (1883-1973), a pioneer Canadian oceanographer and fisheries biologist.

The 25th A.G. Huntsman Award ceremony took place September 6, 2005 in Ondaatje Hall at Dalhousie University. To mark the 25th anniversary, four medals were presented: the three

The 25th anniversary Huntsman medallists, from left: Dr. Sallie Chisholm, Dr. Edouard Bard, Dr. Trevor McDougall, and Dr. Robert Anderson

disciplinary awards and a special one-time award for excellence in interdisciplinary research. The recipients were:

- **Interdisciplinary - Dr. Robert F. Anderson, Lamont-Doherty Earth Observatory of Columbia University**
  Dr. Anderson is a world leader in the investigation of the ocean carbon cycle and how it is linked to climate. A leader in past international research programs, he is currently leading an international effort to determine the cycling of trace elements (such as iron, a major factor in ocean productivity) in the global ocean. Dr. Anderson has received several awards for excellence in research and teaching.

- **Biological/Fisheries Oceanography - Dr. Sallie (Penny) W. Chisholm, Massachusetts Institute of Technology**
  Dr. Chisholm discovered a whole new genus of marine microorganisms which led to fundamental changes in our understanding of marine ecosystems and of their function in the global biosphere. She is also spearheading efforts to describe the genome of marine organisms and is a leader in the public discussion of controversial issues such as proposals to fertilize the oceans with iron to alleviate build-up of greenhouse gases. Dr. Chisholm is a recipient of the Rosenstiel award in Ocean Sciences and is a member of the prestigious U.S. National Academy of Sciences.

- **Marine Geosciences - Dr. Edouard Bard, Université d'Aix-Marseille and Collège de France**
  Dr. Bard is a leader in global change science. His work has been instrumental in documenting abrupt climate changes during the last ice age and in quantifying variability in the sun's output. He is involved in the public sphere, explaining complex climate issues to the general public and aptly countering the arguments of climate change sceptics. He has received several medals for national and international organizations and has been elected to the prestigious Collège de France.

- **Physical/Chemical Oceanography - Dr. Trevor J. McDougall, Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia**
  Dr. McDougall is the foremost world authority on many aspects of oceanic mixing. Many aspects of his work have become basic building blocks of state-of-the-art ocean general circulation models. He has been recognized for his work by the Australian Academy of Sciences and the Royal Society of Tasmania.

The awards were presented by: Dr. Gilles Paquet, President of the Royal Society of Canada; Dr. Arthur Carty, National Science Advisor to the Prime Minister of Canada; the Honourable Chris d'Entremont, Nova Scotia Minister of Agriculture and Fisheries; and Hector Jacques, Chairman, Jacques Whitford Group of Companies. Dr. Tom Traves, President of Dalhousie University, opened the ceremony and the Lieutenant-Governor of Nova Scotia, the Honourable Myra A. Freeman, gave a closing address. Following the ceremony, the recipient of the interdisciplinary award, Dr. Robert F. Anderson, gave a public lecture which dealt with the role of the oceans in regulating the concentration of carbon dioxide in the atmosphere.

That evening a celebratory dinner at the University Club was attended by approximately 150 people and featured an address by the Honourable Geoff Regan, Minister of Fisheries and Oceans, as well as a speech by Dr. Paul Leblond, retired oceanography professor at the University of British Columbia.

On September 7, the medal recipients each presented a public lecture at BIO. Dr. Peter Harrison, senior researcher at the National Research Council of Canada, gave an opening speech on the future of marine sciences in Canada. The Huntsman lectures addressed topics such as the climate during the last ice age and what it tells us about our own future; the critical role marine microbes play in maintaining the health of our planet; and the unusual ways ocean waters mix and the implications for climate simulations. A reception followed the presentations.

The events were made possible by generous contributions from DFO, NRCan, Dalhousie University, the Nova Scotia Department of Agriculture and Fisheries, and a number of private sector companies. The award is funded principally by interest earned on financial contributions from DFO, NRCan, the Canadian Association of Petroleum Producers, and the Province of Nova Scotia, and is administered by the BIO-based A.G. Huntsman Foundation. The Board of Directors includes representatives from DFO, NRCan, Dalhousie University, the Canadian Association of Petroleum Producers, the fishing industry, and the Royal Society of Canada. Nominations are provided by the international scientific marine science community and winners are chosen by a selection committee of Canadian marine scientists.

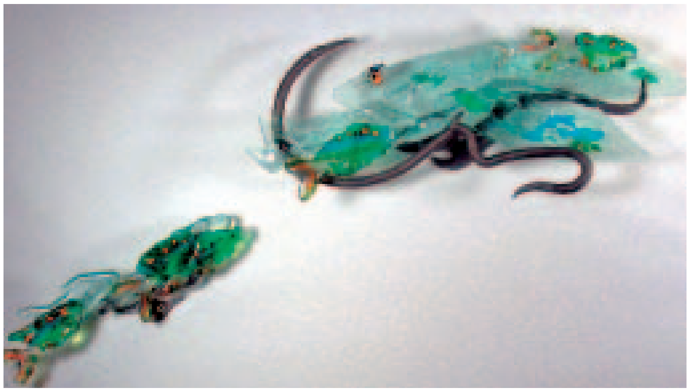
Visitors

Dr. Arthur Carty, National Science Advisor to the Prime Minister of Canada, visited the Institute on March 7. Dr. Carty gave a lecture to staff on research priorities for the Government of Canada. Following presentations on programs by BIO scientists, he was given a tour of the facilities and the CCGS *Matthew*.

Dr. Joe Borg, the European Union (EU) Commissioner of Fisheries, visited May 3-5. The focus of his visit was to discuss Canada's approach to integrated management of ocean uses, as developed under the *Oceans Act* beginning in 1997. Dr. Borg also gave an address on maritime affairs.

John Richardson, the Director General of the EU directorate responsible for ocean activities, visited June 8-9. Presentations and discussions were held on Canada's approach to integrated management of ocean uses.

Dr. Derek Jackson, Director of the Centre of Coastal and



Glass sculpture inspired by research at BIO, created by Suzanne White: Riding Slipstream

Marine Research at the University of Ulster met with scientists at BIO. Dr. Jackson's interests include contemporary coastal processes, aeloian sediment transport dynamics, sand dune management, offshore buoy systems, nearshore sediment dynamics, storm impacts, and deposits.

Research at BIO inspired two visual artists in the creation of their art. Nova Scotia-born, Ottawa artist **Suzanne White** interviewed several BIO scientists to stimulate her glass art sculpture series that celebrates the ocean, ocean diversity, and human relationships with the ocean.

Nova Scotian artist **Susan Feindel** joined BIO scientists on two missions on board the CCGS *Hudson*, where she observed research projects, painted from life, and collected video images and seafloor mud samples to incorporate in her art. In 2005, Dalhousie University Art Gallery hosted an exhibition of her varied work related to the ocean, some of which was inspired by her *Hudson* experiences exploring the marine environment on Canada's eastern continental shelf. Ms. Feindel, with over a hundred art works in the *Centre for Contemporary Canadian Art* database, received Canada's National Art Gallery Claudia De Hueck Art and Science Fellowship in 1999-2000.

Lucie McClung, DFO Associate Deputy Minister, visited on October 14. She was given a tour of the campus and short presentations on several multi-disciplinary projects including the benthic impacts of fishing, sea-floor mapping, and oceanographic modelling in a climate change context. **Wendy Watson-Wright**, Assistant Deputy Minister of Science, also visited to give a presentation at BIO on the Expenditure Review Committee cuts to DFO Science across the country.

King's Board by Suzanne White

People at BIO

Awards and Honours

Beluga Award winner, Jackie Dale

BIO Director, Michael Sinclair (left) presents Don Gordon with the BIO Display Award

Dr. Alan C. Grant of NRCan has been awarded the **Canadian Society of Petroleum Geologists Douglas Medal** for 2005. This medal is presented annually for outstanding contributions to the understanding of sedimentary geology in Canada, commending major contributions to regional tectonics, petroleum, and structural geology.

Jackie Dale was awarded the BIO-Oceans Association annual **Beluga Award** in recognition of her diversified career in ocean science at BIO and other laboratories. During this time Jackie's responsibilities ranged from microbiology, marine chemistry including fieldwork, conference planning, and scientific administration.

The display area outside the cafeteria provides a showcase for the work of BIO scientists. Displays are changed monthly, and at year-end a committee representative of the participating groups judges the presentations on visual impact, communication value, and science promotion value, among other factors. The winning team receives a small trophy, and both first- and second-place finishers receive gift certificates to a local restaurant. For 2004-2005, the **BIO Display Awards** went to:

1st: DFO's **Don Gordon, John Anderson, Stephen Smith, Mark Lundy, Michael Power, and Michael Strong** for *TowCam Surveys*;

2nd: NRCan's **John Shaw** for *Paleogeography of Atlantic Canada from 13,000 BP Onwards*;

3rd: NRCan's **Donald Forbes** for *Coastal Mapping for Climate Impacts, Prediction, and Habitat Delineation: Example from the North Shore of Prince Edward Island*.

For the second consecutive year, the **Unama'ki-Fisheries and Oceans Scholarship** was awarded to Dalhousie University Professor **Anna Metaxas** and doctoral 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*. This scholarship is awarded jointly by DFO and the Unama'ki Institute of Natural Resources for a graduate research project related to the natural resources of Cape Breton Island, in particular the Bras d'Or Lakes. The researchers undertake to mentor and include in their research activities a high school student from one of the Cape Breton First Nations.

John Shaw's Bras d'Or Lakes maps, prepared by **Gary Grant**, with help from **Sheila Hynes, Patrick Potter**, and **Phil O'Regan**, took 2nd place in the annual **ESRI (Environmental Systems Research Institute) Regional Users Conference** in Halifax in November.

NRCan Merit Awards honour staff for their support of NRCan's vision, mission, goals, and objectives; enhancement of the organization's profile; and contributions to its success. The following staff of the Geological Survey of Canada (Atlantic) received Earth Sciences Sector (ESS) Merit Awards:

Dr. Michael Parsons for his leadership of a multi-disciplinary project that examines the concentrations, dispersions, and fate of metals in the environment surrounding abandoned gold mines in Nova Scotia. The main goal of the project is to provide background geochemical data that can be used to assess environmental and human health risks.

Borden Chapman for his contribution to the success of the international ocean expedition to survey the seabed near the 2004 earthquake and tsunami in Southeast Asia. Under trying circumstances and tight deadlines, Borden mobilized and demobilized an unfamiliar vessel in a foreign port; his diligence and professionalism ensured the safe and secure transport, storage, set up, and operation of the equipment.

Donald Forbes, Gavin Manson, and John Shaw, as members of a team commended for the exceptional achievements of their fast, effective, and professional response to the international effort to collect data in the Seychelles in the wake of the Sumatra earthquake and resulting tsunami.

Phil Moir for his role as a member of a team that showed creativity and leadership in the planning and implementation of the

Several BIO staff received the 2005 DFO Deputy Minister's Prix d'Excellence to honour exemplary contributions to Fisheries and Oceans Canada. Awards were given in recognition of the designation of the Gully Marine Protected Area, and for fish habitat and public service excellence. Pictured are (front, from left): Faith Scattolon, Gerry Black, Paul Macnab, Paul Boudreau, Glen Herbert; (back) CCG Deputy Commissioner Kate Fawkes, Carl Myers, Derek Fenton, Jerry Conway, DFO Deputy Minister Larry Murray. (Missing are Joe Arbour, Tim Hall, and Stanley Johnston.)

Sector's Geoscience Data Repository. The team's efforts have underpinned a cultural shift within ESS geoscience that demands more comprehensive, efficient, and effective discovery and access to geoscience data and knowledge sets.

Evelyn Inglis for her contributions to the Scientific and Technical Publishing Services team assigned to the publication of a major bulletin. The team overcame challenges beyond the norm to deliver a quality scientific publication that reflects the dedication to quality shown by the team.

Philip Spencer for his contribution to the team of Webmasters that implemented a paradigm shift and achieved significant savings and efficiency improvement throughout the Sector.

NRCan Long Service Awards:

Heiner Josenhans: 35 years

Kimberley Jenner, Steve Solomon, and Mark Williamson: 15 years

FISHERIES AND OCEANS CANADA AWARDS

The **DFO Distinction Award** is granted to an employee for outstanding achievements and contributions that further the objectives of DFO 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 can be further honoured with the **Assistant Deputy Minister's (ADM) Award** and the **Deputy Minister's (DM) Prix d'Excellence**.

Paul Boudreau received the **Oceans and Habitat ADM's Award** for his participation on the Habitat Management Program's Policy and Guidelines Working Group which was instrumental in developing and consulting on DFO's new Risk Management Framework. This innovative approach to the review of projects under the habitat protection provisions of the *Fisheries Act* clarifies how DFO manages its regulatory responsibilities and makes decisions, significantly improving the department's credibility and relationships.

Dr. Kenneth Lee received the **Oceans and Habitat ADM Award** for coordination of scientific research programs and the provision of advice on the potential effects of seismic sound on the marine ecosystem. In collaboration with oil and gas regulators nationally and provincially, DFO recently created a Statement of Canadian Practice to provide a consistent and uniform approach to mitigating the impact of seismic noise in the marine environment.

The following received DFO Distinction Awards:

Jerry Black applied his sophisticated programming skills and knowledge of databases to develop the ACON graphical and plotting software system which is the core of the Virtual Data Centre (VDC), a national model for data management within DFO that is characterized by easy and intuitive access to the system. Jerry also played a key role in migrating the Scotian Shelf snow crab data set from the Gulf Region to the VDC.

Heather Breeze and **Derek Fenton's** approach to fishing industry consultation and to internal integration of operational issues and scientific advice were key to establishing the Deep Sea Corals Conservation Area in the Northeast Channel (2002) and the Stone Fence Lophelia Reef Conservation Area (2004), and to the release of the coral strategy in 2005. Their thorough analysis of research results and potential impacts of conservation measures on the fishing industry enabled DFO to implement management actions which were widely supported by fishers, environmental NGOs, and the public.

Jerry Conway was honoured for exemplary work as the Regional Marine Mammal Advisor and in the field of communications and media relations. His work with the Right Whale Recovery Team and Transport Canada has resulted in a 95% reduction in right whale deaths by ship strikes in Bay of Fundy shipping lanes and was instrumental in the development of a Memorandum of Understanding between the Centre for Coastal Studies in the United States and DFO on whale disentanglements in Canadian waters.

During 35 years at BIO, **Art Cosgrove** has been committed to getting the job done to the highest standards, within budget, and by the required deadline, while always being professional and approachable with clients. As head of the Drafting and Illustrations Unit, he led the formidable transition into the world of electronic drafting and desktop publishing. Among the wide variety of technical drawings, publications, and exhibits he has been involved with was a chart of the Quaternary geology of the Polar Arctic which former Prime Minister Mulroney presented to President Gorbachev during a state visit to the USSR.

Sharon Gillam-Locke joined the Word Processing Unit at BIO in 1977. Ten years later she became Secretary to the Ocean Circulation Section, where her tactical skills and understanding of electronic text processing involving scientific notation were invaluable. As Administrative Officer in the Ocean Sciences Division, she has been adept at dealing with corporate services and teaching DFO systems to new staff, while her personal skills are also much appreciated. Sharon contributes enthusiastically to various BIO activities, particularly the gift shop.

During **Donald C. Gordon's** 35-year career at BIO, he has made major contributions to our scientific knowledge, particularly the impact of human activities on the marine environment. To his stellar work for DFO he has brought strong organizational and human resource skills, including his skilled scientific leadership of multidisciplinary teams.

J. Richard (Dick) MacDougall was recognized for his contributions over 35 years at the Canadian Hydrographic Service (CHS). As Director in Atlantic Canada, he co-authored SeaMap, developed the concept into a funding proposal to systematically map Canada's submerged lands as basic infrastructure for integrated management, and assumed responsibility for coordinating the bathymetric portion of establishing the outer limits of Canada's continental shelf for submission under Article 76 of UNCLOS.

A multi-disciplinary hydrographer, **Christine Rozon** consistently exhibits outstanding quality of workmanship and high productivity at the CHS, where she is the internal ISO Auditor, performs the National Quality Control for all CHS Atlantic Region ENC production, and played a key role in moving the release of ENC to the Region from Ottawa. In her representation of the CHS on several working groups, she demonstrates leadership and commitment to the CHS and DFO.

Nancy Stobo joined DFO in 1970, and since 1976 has been the administrative assistant to a series of Marine Fish Division directors. Her responsibilities have included purchasing activities, financial monitoring, and personnel functions. A loyal, dedicated employee, Nancy's prime interests have been service to Division personnel and the facilitation of good relations with corporate personnel and clients.

Catherine Ann Wentzell was recognized for 35 years of public service, 24 of which were with DFO. She is always willing to assist with new initiatives and does well what it takes to deliver; her co-ordination of the turbulent Atlantic Fisheries Adjustment Program was declared "streamlined and timely as a result of her work." As Administrative Assistant for the Invertebrate Fisheries Division, and now the Population Ecology Division, she has been looking after their complex portfolio of Joint Project Agreements.

Frank Zemlyak joined the Chemical Oceanography Division at BIO in 1976, where he made many significant contributions to analytical protocols and instrument development associated with carbon and chlorofluorocarbon measurements at sea. Since moving to the Ocean Sciences Division in the mid-1990s, he has been making a major contribution to Canadian and international programs to describe and understand ocean climate and biogeochemical processes and variability in the sub polar North Atlantic and Arctic Oceans.

The BIO-Oceans Association: Highlights of 2005

Don Peer, President

The Bedford Institute of Oceanography - Oceans Associations (BIO-OA) was formed by a group of former BIO employees. The objectives of the association are to help maintain public interest in ocean studies, preserve oceanographic archival material, and provide the opportunity for members to maintain relationships formed at BIO. Membership is open to all who share these goals including both retirees and present employees. The OA's newsletter keeps members informed of its activities and those of its members. For more information, see our website at (www.bedfordbasin.ca).

LIBRARY ARCHIVES

The objective of the BIO-OA archives committee, chaired by Dr. Bosko Longcarevic, is to preserve all BIO records with research value that are not acquired by the National Archives of Canada.

Shown is the scientific party aboard USS *Bowditch* during the 1946 Bikini Island atomic bomb tests known as Operation Crossroads. Front row, from the left is Walter Munk, a famous physical oceanographer; William von Arx, who sailed on Hudson 70; and, Gordon Riley, a biologist who spent most of his illustrious career at Dalhousie University. Second from the right is Dr. William L. Ford, BIO's director from 1965 to 1978. This photo and a caption identifying all those pictured are included within the photographic archives in the BIO library.

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

The last part of the 20th century saw a rapid development of oceanographic equipment. The evolution was so rapid and equipment became obsolete so quickly that its use and operation can often be forgotten. The significance of historical data depends upon understanding the equipment used to collect them. The objective of the equipment archives committee, chaired by Dr. Charles Schafer, is to preserve the equipment, and the knowledge around it. Committee members have either used these instruments or been involved in their development. These artifacts are also valuable for education, because they demonstrate history of the achievements of BIO staff.

PHOTO ARCHIVES

This committee, chaired by Michael Latrémouille, has undertaken the task of identifying and cataloguing pre-1980 photographs. The accompanying photograph is an example of one that predates BIO, but has been incorporated into the archive for its historical value.

BELUGA AWARD

At the Annual General Meeting of the BIO-OA on May 17, Ms. Jackie Dale was awarded the Beluga Award. (*See* Awards and Honours.)

MEMBERSHIP ACTIVITIES

The BIO-OA seminar series continued. On February 13, the association hosted a talk in the BIO auditorium by Ivan Fraser, an artist, photographer, and art gallery owner from Glen Margaret, Nova Scotia. Ivan gave a lively presentation about his inspiration for publishing a series of illustrated books on the facts and the legend behind "Peggy of the Cove". Singer Melanie Ross then recounted the story in song. The OA summer barbeque and potluck was held on September 15 at the Peer home on Hubbards Cove. On December 23rd, many members enjoyed BIO's annual Christmas party with staff and their families.

Charitable Activities at BIO

Contributions from Bettyann Power (DFO), Maureen MacDonald (NRCan), Sheila Shellnut (DFO), and Andrew Cogswell (DFO)

The Government of Canada Workplace Charitable Campaign (GCWCC) is the oldest and largest workplace charitable campaign in Canada. In 2005, approximately 116 communities benefited from this campaign which brings together two main recipient organizations—United Way and Healthpartners—in a coordinated fundraising effort. Employees are also encouraged to give to their Charity of Choice(s). DFO employees at BIO donated a total of $54,211.88. This amount does not include the DFO/BIO retiree donations since these are tracked nationally. NRCan's campaign was successful with a total contribution to the GCWCC of $14,898.46.

Special events were held to start the campaign and also to add energy and money throughout the program. These included: a BIO kick-off where employees packed comfort kits for the Red Cross; a Leadership Thank You Breakfast (sponsored by Federal Council) at the CFB Halifax Officers' Mess; a used book sale coordinated by the library staff; a BIO parking space raffle; a raffle sponsored by the BIO Gift Shop whereby the winner donated the $1000 prize to a Charity of Choice; and an all BIO Christmas party that included a hockey game, family skate, light supper, and adult dance.

Several other organizations were supported throughout the year. Some proceeds from the BIO Christmas event paid for vehicle rentals for the Parker Street Food Bank's Christmas dinner delivery. At this annual event, BIO staff donate their time to pack and deliver food boxes to needy families. The food bank was supported also through an Institute-wide food and winter clothing drive.

The Ecosystem Research Division continued its tradition of

NRCan sponsored a pumpkin carving and recipe contest for the GCWCC. Iris Hardy is shown with her winning pumpkin.

Ecosystem Research Division employees and friends wrap Christmas presents: from left, Sheila Keizer, Lorraine Hamilton, Judy Simms, and Victoria Clayton.

making Christmas merrier for those less fortunate. Their popular coffee parties at Easter and Hallowe'en provided lots of good food and conversation, at the same time raising funds for food and gifts which they delivered at Christmas to 18 people, including older, single persons and single parent families. To bolster the funds, one very persuasive staff member sold tickets on Easter and Hallowe'en baskets, and carved pumpkins.

The Canadian Cancer Society received $1605 through a series of mini-fundraisers (bake sale, social), and a special hair-razing event. Division Managers Tom Sephton (Ecosystem Research) and Ross Claytor (Population Ecology) each agreed to an unusual hair-do in return for donations, and in a fun event in the BIO Auditorium, Tom had his hair dyed purple, while Ross had his head shaved to a Mohawk cut, with the help of hair stylist, Mary-Jane Lundy. The Cancer Society was supported also in its popular Institute-wide annual daffodil sale.

In 2005, BIO Friends of Symphony Nova Scotia supported the symphony's Celebrity Concert Series with a donation of $1630. The name, Bedford Institute of Oceanography Friends of Symphony Nova Scotia, appears in the Musical Chairs section of every concert program and is displayed at the entrance to the auditorium during all main stage concerts, to indicate our support of BIO's viola chair, occupied by musician Binnie Brennan.

Good sports Ross Claytor and Tom Sephton

BIO employees continue to support the SPCA with funds and supplies, as well as other charities on an occasional basis.

People at BIO in 2005

DEPARTMENT OF NATIONAL DEFENCE

LCdr Jim Bradford
Lt(N) Scott Bresnahan
Lt (N) Thomas Fredericks
PO2 Ghislain Charest
PO2 Elsa Telfer
PO2 Leslie Guyomard
PO2 Emile Roussy
PO2 Jeff Sooley
MS Carl St-Pierre
MS Mike Comrie
MS Karen Warren
LS William Brown
LS Shannon Klassen

ENVIRONMENT CANADA

Christopher Craig
David MacArthur
Margot Boudreau, Student
Alison Dube, Student
Bryan Heard, Student
Robbie MacLeod, Student
Matt Redgrave, Student
Lauren Steeves, Student

FISHERIES AND OCEANS CANADA
Canadian Coast Guard - Technical Services

Marine Electronics
Jim Wilson, Supervisor
Terry Cormier
Gerry Dease
Jason Green
David Levy
Robert MacGregor
Richard Malin
Morley Wright
Mike O'Rourke

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

Marine Aids and Maintenance
Richard Fleming
Martin LaFitte
Leonard Mombourquette
Richard Myers
Raymond Smith

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

Canadian Coast Guard - Operational Services

Michelle Brackett

Science Branch

Regional Director's Office
Michael Sinclair, Director
Bethany Johnson
Sharon Morgan
Sherry Niven
Bettyann Power
Tara Rumley

Innovation Office
Richard Eisner, Manager

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
Jon Griffin
Judy Hammond
James Hanway
Heather Joyce
Glen King
Mike Lamplugh
Christopher LeBlanc
Philip MacAulay
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

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2005.
* Retired in 2005 ** Passed away in 2005

Glenn Rodger
Dave Roop
Tom Rowsell
Chris Rozon
Mike Ruxton
Cathy Schipilow
June Senay
Alan Smith
Andrew Smith
Christian Solomon
Nick Stuifbergen
Michel Therrien
Herman Varma
Wendy Woodford
Craig Wright
Craig Zeller

Population Ecology Division
Ross Claytor, Manager
Doug Aitken
Peter Amiro
Shelley Armsworthy
Jerry Black
Shelley Bond
Don Bowen
Rod Bradford
Bob Branton
Dylan Buchanan
Alida Bundy
Steve Campana
Dollie Campbell
Henry Caracristi
Manon Cassista
Amy Chisholm
Jae Choi
Peter Comeau
Alan Cook
Michele Covey
Garry Dalrymple
Tania Davignon-Burton
Louise Demestral-Bezanson
Daniela Denti
Ron Duggan*
Wanda Farrell
Mark Fowler
Cheryl Frail
Jamie Gibson
Carolyn Harvie
Peter Hurley
Eric Jefferson
Brin Jones
Warren Joyce
Raouf Kilada
Peter Koeller
Rene Lavoie*
Mark Lundy
Bill MacEachern
Linda Marks
Larry Marshall
Jim MacMillan
Romney McPhie
Jeff McRuer**
Bob Miller
Bob Mohn
Kathy Mombourquette
Rachelle Noel
Steve Nolan
Patrick O'Laughlin
Shane O'Neil
Patrick O'Reilly
Doug Pezzack
Alan Reeves
Craig Reynolds
Jim Reid
Ginette Robert
Dale Roddick
Karen Rutherford
Bob Semple
Glyn Sharp
Mark Showell
Angelica Silva
Jim Simon
Steve Smith
Debbie Stewart
Nancy Stobo
Wayne Stobo
John Tremblay
Kurtis Trzcinski
Jennifer Voutier
Cathy Wentzell
Daisy Williams
Scott Wilson
Linda Worth-Bezanson
Gerry Young
Ben Zisserson

Population Ecology Division Offsite Employees:
Doug Aitken
Mary Allen
Leroy Anderson
Krissy Atwin
Denzil Bernard
Bev Davison
G. Donaldson
Jim Fennell
Claude Fitzherbert
Jason Flanagan
David Francis
Dawn Goff
Trevor Goff
Michael Goguen
Randy Guitar
Ross Jones
Craig Keddy
Beth Lenentine
Judy Little
Bill MacDonald
Danielle MacDonald
John Mallery
Sheehan McBride
Christian Nadeau
Kevin Nauss
Andrew Paul
Robert Pelkey
Greg Perley
Rod Price
Francis Solomon
Louise Solomon
Brian Sweeney
Michael Thorburne
Malcolm Webb
John Whitelaw
Gary Whitlock
Ricky Whynot
William Whynot
Emilia Williams

Gulf Fisheries Centre – Diadromous Fish Section
Paul LeBlanc

Ocean Sciences Division
Peter Smith, Manager
Gabriela Gruber
Meg Burhoe

Coastal Ocean Science:
Simon Prinsenberg, Head
Dave Brickman
Gary Bugden
Sandy Burtch
Jason Chaffey
Joël Chassé
Brendan DeTracey
Adam Drozdowski
Ewa Dunlap
Ken Frank
Dave Greenberg
Charles Hannah
Ingrid Peterson
Brian Petrie
Liam Petrie
Roger Pettipas
Trevor Platt
Charles Tang
Chou Wang
George White

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2005.
* Retired in 2005 ** Passed away in 2005

Yongsheng Wu

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
Helen Hayden
Ross Hendry
Jeff Jackson
Jing Jiang, Visiting Scientist
Peter Jones
David Kellow
Zhenxia Long, Visiting Scientist
Youyu Lu
William Perrie
Hui Shen, Visiting Scientist
Marion Smith
Adhi Susilo, Student
Brenda Topliss
Bash Toulany
Zeliang Wang, Visiting Scientist
Dan Wright
Fumin Xu, Visiting Scientist
Tonghong Yao, Visiting Scientist
Igor Yashayaev
Frank Zemlyak
Weiping Zhang, Visiting Scientist

Ocean Physics:
Michel Mitchell, Head
Brian Beanlands
Larry Bellefontaine**
Don Belliveau
Kelly Bentham
Rick Boyce
Derek Brittain
Norman Cochrane
John Conrod
Mylene Di Penta
Helen Dussault
Bob Ellis
Jim Hamilton
Bert Hartling
Alex Herman
Bruce Julien
Randy King
Mike LaPierre
Daniel Moffatt
Glen Morton
Neil MacKinnon
Val Pattenden
Todd Peters
Merle Pittman
Nelson Rice
Bob Ryan
Murray Scotney
Greg Siddall
George States
Leo Sutherby

Science Informatics Section
John O'Neill, Head
Lenore Bajona
Anthony Joyce
Kohuila Thana

Ecosystem Research Division
Thomas Sephton, Manager
Jim Abriel
Byron Amirault
Debbie Anderson
Carol Anstey
Matthew Arsenault
Robert Benjamin
Cynthia Bourbonnais
Chiu Chou
Pierre Clement
Matthew Coady, Student
Susan Cobanli
Andrew Cogswell
Stephanie Cooper
Peter Cranford
Carrie Cuthbert, Student
Rémi Daigle, Student
Jennifer Dixon
Kathryn Dunphy, Student
Grazyna Folwarczna
Don Gordon*
Lorraine Hamilton
Gareth Harding
Barry Hargrave
Jocelyn Hellou
Zhengkai Li, Post Doctoral Fellow
Rosalie Allen Jarvis
Paul Keizer
Thomas King
Brent Law
Ken Lee
Jim Leonard
Zhengkai Li, Post Doctoral Fellow
Barry MacDonald
Kevin MacIsaac
Paul MacPherson
Stephen Marklevitz, Student
Tim Milligan
John Moffatt
Rick Nelson
Lisa Paon
Ashley Parson, Student
Shawn Roach
Brian Robinson
Dawn Sephton
Sheila Shellnut
Judy Simms
Erika Smith, Student
John Smith
Karen Spence
Krystal Stevens, Student
Sean Steller
Peter Strain
Peter Thamer
Herb Vandermeulen
Bénédikte Vercaemer
Philip Yeats
Kees Zwanenburg
Biological Oceanography:
Glen Harrison, Head
Jeffrey Anning
Florence Berreville, Student
Bilal Bjeirmi
Jay Bugden
Benoit Casault
Carla Caverhill
Emmanuel Devred, PDF
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
Markus Pahlow, Research Associate
Kevin Pauley
Linda Payzant
Catherine Porter
Douglas Sameoto
Jeffrey Spry
Alain Vézina
Tim Perry

Centre for Marine Biodiversity:
Ellen Kenchington, Director
Victoria Clayton

Maritime Provinces Regional Advisory Process (RAP)/ Outreach
Bob O'Boyle, Coordinator
Guillian Doell, Student

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2005.
* Retired in 2005 ** Passed away in 2005

Steven Fancy, Student
Keli Fisher, Student
Joni Henderson
Valerie Myra
Tana Worcester

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

Oceans and Habitat Branch

Regional Director's Office
Carol Ann Rose, A/Regional Director
Trudy Wilson, Assistant Regional Director
Jane Avery
Bev Grant

Environmental Assessment and Major Projects Division
Ted Potter, Regional Manager
Ted Currie
Charlene Mathieu
Mark McLean
Reg Sweeney

Habitat Management Division
Paul Boudreau, Regional Manager
Joe Crocker
Karen Curlett
Rick Devine
Joy Dubé
Anita Hamilton
Tony Henderson
Darren Hiltz
Brian Jollymore
Darria Langill
Jim Leadbetter
Melanie MacLean
Shayne McQuaid
Stacey Nurse
Marci Penney-Ferguson
Joanne Perry
Peter Rodger
Tammy Rose
Carol Sampson
Heidi Schaefer
Carol Simmons
Phil Zamora

Oceans and Coastal Management Division
Joe Arbour, Regional Manager
Heather Breeze
Debi Campbell
Scott Coffen-Smout
Cameron Deacoff
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
Daniel Walmsley
Maxine Westhead

Aquaculture Management

Mark Cusack, Director
Darrell Harris
Cindy Webster
Sharon Young

Finance & Administration

Contract Services
Joan Hebert-Sellars

Material Services (Stores)
Larry MacDonald
Bob Page
Ray Rosse

Real Property Safety and Security Branch

Brian Thompson, Senior Site Leader
Judy Lutley

Communications Branch

Art Cosgrove
Francis Kelly
Carl Myers

Corporate Services

Valerie Bradshaw

Planning and Information Services

Technology Services
Gary Somerton, Chief
Chris Archibald
Keith Bennett
Patrice Boivin
Doug Brine**
Bruce Fillmore
Judy Fredericks
Pamela Gardner
Lori Gauthier
Marc Hemphill
Charles Mason
Sue Paterson
Andrea Segovia
Mike Stepanczak
Paul Thom
Charlene Williams
Paddy Wong

Client Services
Sandra Gallagher, Chief
Paul Dunphy
Ron Girard
Jeff Hatt
Florence Hum
Carol Levac
Dave MacDonald
Roeland Migchelsen
Juanita Pooley
Kevin Ritter
Tobias Spears
Krista Wry
Bobbi Zahra

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

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2005.
* Retired in 2005 ** Passed away in 2005

Carmelita Fisher
Don McAlpine
Judith Ryan

Shared Services Office
George McCormack, Manager
Cheryl Boyd
Terry Hayes
Cecilia Middleton
Julie Mills
Christine Myatt
Wayne Prime
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
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
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
Marie Baker
Darrell Beaver
Robbie Bennett
Steve Blasco
Austin Boyce*
Owen Brown
Gordon Cameron
Calvin Campbell
Borden Chapman
Robert Fitzgerald
Donald Forbes
Paul Fraser
David Frobel
Michael Furlong
Iris Hardy
Robert Harmes
Scott Hayward
Thian Hundert
Sheila Hynes
Kate Jarrett
Kimberley Jenner
Fred Jodrey
Heiner Josenhans*
Edward King
Vladimir Kostylev
Bill LeBlanc
Michael Li
Maureen MacDonald
Kevin MacKillop
Bill MacKinnon
Gavin Manson
Susan Merchant
Greg Middleton
Bob Miller
David Mosher
Bob Murphy
Alan Orpin
Kathyrn Parlee
Michael Parsons
Eric Patton
Dick Pickrill
David Piper
Walta Rainey
Angus Robertson
John Shaw
Andy Sherin
Steve Solomon
Gary Sonnichsen
Jennifer Strang
Bob Taylor
Brian Todd
Ethymios Tripsanas
Kevin Webb
Dustin Whalen
Bruce Wile

PUBLIC WORKS AND GOVERNMENT SERVICES

Leo Lohnes, Property Manager
Diane Andrews
Tim Buckler
Bob Cameron
Geoff Gritten
Paul Fraser
Jim Frost
Garry MacNeill
John Miles
Arthurina Smardon
Phil Williams
Bill Wood

COMMISSIONAIRES

William Bewsher
Paul Bergeron
Dave Cyr
Marilyn Devost
Roger Doucet
John Dunlop
Donnie Hotte
Leonard MonMinie
Francis Noonan
Dave Smith
Don Smith
Daniel Wynn

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
Nell den Heyer
Carl MacDonald
Judy Peizsche
Shannon Scott-Tibbetts
Megan Veinot

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2005.
* Retired in 2005 ** Passed away in 2005

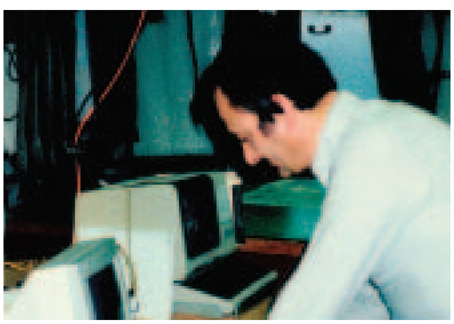
Geoforce Consultants Ltd.
Mike Belliveau
Graham Standen
Martin Uyesugi

Contractors
Michael Borek, Biological Oceanography
Derek Broughton, Population Ecology
Catherine Budgell, Library
Barbara Corbin, Records
Kevin Desroches, CHS
Yuri Geshelin, Ocean Circulation
Adam Hanway, CHS
Matt Hawley, CHS
Yongcun Hu, Ocean Circulation
Edward Kimball, Ocean Circulation
Alexander MacLean, Informatics: Special Projects Division
Louise Malloch, Biological Oceanography
Tara McIntyre
Peter Payzant, Biological Oceanography
Tim Perry, Biological Oceanography
Jeff Potvin, Informatics
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

Scientist Emeritus
Piero Ascoli
Ray Cranston
Subba Rao Durvasula
Jim Elliott
Gordon Fader
George Fowler
Ken Freeman
Alan Grant
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.

IN MEMORIAM



Larry Bellefontaine at work onboard the CCGS Hudson

Lawrence J. Bellefontaine, a long-serving employee of DFO's Science Branch, passed away February 7, after a brief illness. Larry joined the Ocean Circulation Section in 1973 after graduating from Saint Mary's University with a Bachelor of Commerce degree. As an oceanographic technician, he was involved in the collection and processing of scientific data. Larry soon became an important member of the sea-going team and took on the role of navigator, running the complex Loran C positioning system for the Science programs. He truly enjoyed his time at sea and willingly accepted these assignments even though, in the early years, it meant extended periods away from home. One of Larry's most memorable trips was the Norwegian Sea voyage onboard CSS *Baffin* in 1989 when staff and crew endured extended periods of exceptionally bad weather and other adversities, but the humour and camaraderie among staff kept morale high. In later years, Larry worked with the Instrumentation Group servicing the Aanderaa current meters; his thorough attention to detail resulted in high data return and the success of many mooring programs.

Larry was active in Local 80717 of the Public Service Alliance of Canada where he applied his accounting skills as Treasurer for 20 years. Away from BIO, his life centered on his wife Leslie and daughter Jennifer. He enjoyed their holiday trips to Prince Edward Island, the family cottage on Porter's Lake, and his fishing trips with the boys. Larry's humour and words of wisdom will be greatly missed.

Douglas Philip Brine

Douglas Philip Brine, an employee of DFO's Informatics Branch, passed away suddenly on April 30 at the age of 52. After two stints as a summer student, Doug started working at BIO full-time in 1971 as a computer operator on the earliest control data and plotting equipment using punched cards, paper tape, and magnetic tape. In the early 1980s, he did double duty as both Computer Room Supervisor and Senior Systems Operator. Over his 34-year career with DFO, Doug experienced many changes in computer technology.

Doug's outside interests included stamp collecting, fishing (especially mackerel fishing off the BIO jetty), and playing cards. Bowling was a passion, and his team won top prize in the two years he participated in the Dartmouth Men's City Tournament. Becoming more avid, he then joined the Men's Pro League at Beazley Lanes, where he carried an average of 105. Doug also had an entrepreneurial streak: he started a bingo business in the mid-1970s. Predeceased by his parents Marjorie and Marshall Brine, he is survived by two cousins and their families. Doug is fondly remembered, and will be missed by his colleagues in Informatics and friends throughout BIO.

Jeff McRuer

On December 18, many people at BIO lost a respected colleague and friend; after a courageous struggle with cancer, Jeff McRuer passed away peacefully at home, with his family around him. Jeff began his DFO career as a summer student with the Marine Ecology Laboratory (MEL). After graduation from the University of Guelph in 1972, he joined MEL where for the next 15 years he was indispensable to field research projects. He was a versatile and innovative participant in inter-disciplinary, inter-agency, and international programmes, in the roles of project leader, biologist, technical expert, and mentor. In 1987, Jeff joined the Marine Fish Division (MFD) and assumed responsibility for preparing BIO trawlers for fisheries and oceanographic research and data collection on the Scotian Shelf and Gulf of Maine areas. He built and maintained the oceanographic data collection system used by the MFD, applying his computer expertise to make modern technology-associated database management and acquisition software and data analysis and graphical packages function on less than state-of-the-art computer equipment. In addition, Jeff was involved in the research and stock assessments of a variety of commercial fish species, and is particularly remembered for his work with haddock and the Fisheries Ecology Project.

Jeff McRuer

Jeff readily adapted to the challenges of evolving work requirements at BIO. Enthusiastic and dedicated, his attention to detail was critical to the success of many projects. His commitment to his work was illustrated during his long struggle with cancer; he actively participated in research vessel operational issues until only a few weeks before his death. He fought his illness with grace, maintaining his humour and interest in others. Jeff enriched the lives of many at BIO through his friendship and compassion. He will be greatly missed.

Vicki Navjot Randhawa, an employee of the Canadian Hydrographic Service (CHS), passed away on April 15 at age 39. Vicki came to the CHS in 1991 after graduating as an industrial process engineer from the Technical University of Nova Scotia. As part of her training at the CHS, she attended the University of New Brunswick and the College of Geographical Sciences to upgrade her skills in cartography and hydrography. During her first years at the CHS, she trained in various departments, and it was with these brief rotations that staff experienced her youthful outlook on life. As her name "Navjot" means, Vicki really was "the new light, always bright".

She was initially involved with Cartography, but her strength in problem solving made her an asset in converting many manual processes into software driven routines. Vicki's contribution lives on also in a series of hydrographic surveys along the south coast of Newfoundland where, as a launch hydrographer, she put in many miles in fog to aid in vital surveys to connect the remote coastal communities.

Vicki Navjot Randhawa,

Vicki enjoyed the outdoors, particularly mountaineering, badminton, field hockey, and varsity soccer, and also enthusiastically participated in activities around BIO. In 1995, she was diagnosed with multiple sclerosis. By the end of the summer she was unable to work and went on disability leave. However, she enjoyed frequent contact with CHS colleagues, who will miss her warmth and friendship. Vicki is survived by two brothers and devoted parents Pyara and Satnam Randhawa.

RETIREMENTS IN 2005

Austin Boyce retired in May following a career with the Geological Survey of Canada (GSC), NRCan that lasted more than 30 years. Austin was an electronics technician with the Field Support Unit. He was the sidescan sonar expert with the support group, and maintained this equipment from the time of its introduction to the GSC.

Robert G. Burke retired in October, having completed 35 years with the CHS, Atlantic Region. Bob graduated from the Technical University of Nova Scotia with Bachelor's and Master's (1969) degrees in Electrical Engineering. After a year on the *Bluenose II*, he joined the CHS in 1970 as a design engineer in Hydrographic Development. He became Manager, Hydrographic Development in the early 1970s and upon his retirement he was the Manager, Marine Geomatics. During his career, Bob worked on many research and development projects, most notable being the autonomous semi-submersible Deep Ocean Logging Platform, and the Source Database project and associated Collaborative Agreement with ORACLE for HHCode technology transfer.

Bob was also involved with the acquisition of the DFO survey vessels—the *Smith*, *Matthew*, and *Creed*—and the CHS- and Science-related program equipment. His primary area of responsibility was the CHS Atlantic computer and software infrastructure necessary for this Region's hydrographic and production programs. Bob was respected for his technical knowledge, professional demeanour, respectful treatment of colleagues, keen sense of fair play, and his measured approach to problem solving. His love of storytelling, sense of humour, and his penchant for practical jokes and repartee will be missed by his colleagues in the CHS.

Allyn Clarke retired from DFO's Ocean Sciences Division (OSD) in September, after 35 years of distinguished service to the Canadian and international oceanographic communities. He was respected for his scientific productivity, strong leadership, and timely and sound advice as a DFO scientist and manager. Introduced to BIO as a summer student with the Department of Mines and Technical Surveys in 1962, Allyn formally joined Ocean Circulation Section, Atlantic Oceanographic Laboratory in 1970. The Gulf Stream system and deep ocean convection were the two central themes of his scientific research career. He designed and led major field programs to the Newfoundland Basin, the Labrador Sea, and the Greenland Sea. He served as Head of Ocean Circulation from 1985 to 1997 and as Manager, OSD from 1997 until 2002. The World Climate Research Programme benefited from his contributions to the World Ocean Circulation Experiment, the Climate Variability and Predictability (CLIVAR) project, and the Joint Scientific Committee. Allyn helped prepare the Global Climate Observing System and served as co-principal investigator of the Canadian Argo Program. He is a past President of the Canadian Meteorological and Oceanographic Society (CMOS) and past Chair of the Board of the Canadian CLIVAR Research Network. His professional honours include the Deputy Minister's Award of Excellence and the CMOS J.P. Tully Medal in Oceanography. Allyn will continue to work with Ocean Circulation at BIO as an Emeritus Scientist.

Ronald E. Duggan retired in October after more than 32 years of service to federal government science. Ron started his career with Environment Canada as a field technician in the toxicity bioassay group. In 1974, he became manager of the Ellerslie field station (Fisheries Research Board) in Prince Edward Island. He joined the Invertebrates and Marine Plants Division and moved to Nova Scotia in 1978. Over the next 27 years, Ron worked as an invertebrate field technician at both the Halifax Fisheries Research Laboratory and BIO on a wide variety of projects and species. He contributed most to projects related to nearshore lobster populations. Ron was happiest when on the water, where he was able to use his considerable skills operating small boats. With his sense of humour and enthusiasm, Ron became a friend and mentor to many people along the way. His retirement will be filled with new ventures, and you may see him in the harbour on his own sport fishing boat.

Donald C. Gordon retired from the Ecosystem Research Division in October. He began at BIO in 1970 when he joined the Marine Ecology Laboratory and took on the task of putting together a Marine Environmental Quality program. Initially, his research was on oil pollution, the follow-up to the tanker *Arrow* spill. Over the years, his research primarily focused on the impact of human activities on the marine environment, such as, tidal power development, offshore oil and gas exploration, and fish trawling. He made major contributions to our scientific knowledge in all of these areas. From his very early work on oil pollution to his latest research on trawling impacts, Don assembled multidisciplinary teams to study the problems. His ability to bring people to work together and to empower those who work with him are the hallmarks of a truly remarkable career. These strong organizational and human resource management skills, along with his broad understanding of marine science, were invaluable to DFO both regionally and nationally, and to the international scientific community.

Ken Hale retired in November from the GSC Atlantic, NRCan after a 30-year career. His previous government service included work as a draftsperson/illustrator for Parks Canada and a short stint in the Canadian Forces. Ken's expertise in graphic design was second to none and samples of his work can be seen gracing the BIO hallways. He was very active in his union (Public Service Alliance of Canada) and held positions at both the local and national levels. Coffee breaks were always lively when Ken added his wit and opinion. Ken and his wife Fran plan to travel in Canada and the United States while following the NASCAR race circuit.

David Heffler retired from the GSC, NRCan in January after 35 years. As a civil engineer, David provided invaluable leadership and support for the development of technology related to Canada's marine geoscience program. His knowledge, contacts, and skills were critical to the delivery of many science projects. He loved his work and often claimed he "would have done it without being paid."

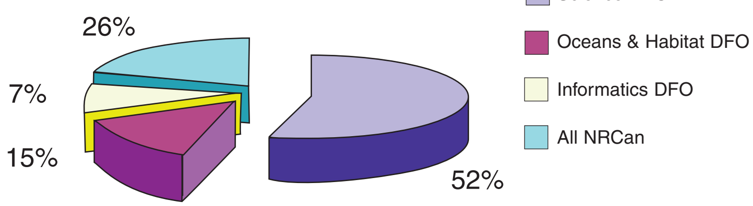
Heiner Josenhans retired in November after a 35-year distinguished career as a marine geoscientist with the GSC. His career spanned several disciplines and areas, including the Atlantic coast, the Saint Lawrence Seaway, and the west coast of Canada. During his last few years with the GSC, Heiner was involved with the Queen Charlotte Islands program which resulted in the discovery of evidence of prehistoric human occupation.

René Lavoie retired in October 2005 after nearly 35 years with DFO. For many years René was the oyster biologist for the Scotia-Fundy Region. During this time he forged numerous partnerships with the oyster industry and provincial governments. His efforts were instrumental in advancing both oyster science and the shellfish culture industry. After moving into management, he maintained these connections and was often called upon when there was a question about oysters, for example, on CBC's program *Ideas* where René explained the relationship between oysters and St. Valentine's Day. His work with the aquaculture industry brought him a Lifetime Achievement Award from the Aquaculture Association of Canada (2002) and recently the Jim McNeil Award from the Aquaculture Association of Nova Scotia. In July 2005, he was invited by the Japanese Foundation of Oyster Research Institute to present a paper at the First International Oyster Symposium in Tokyo, where he became one of the founding members of the World Oyster Society. Building bridges was the guiding philosophy of René's career. He developed a longstanding relationship with First Nations that led to many productive partnerships and projects to the benefits of all Canadians. Most recently, René was division manager for the Invertebrate Fisheries Division. In this role, René served as a mentor for many young people. He was proud to be a public servant and his influence will carry forward for many years.

Financial Resources

Where BIO obtains funding and how it is spent

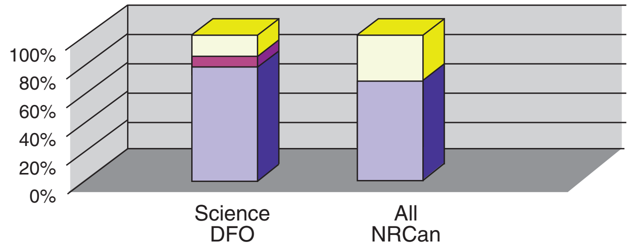
Annual appropriation from government by parliamentary vote



DEPARTMENT	SECTOR	AMOUNT ($000)
DFO	Science	20,681
DFO	Oceans & Habitat	5,760
DFO	Informatics	2,874
NRCan	All	10,166

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

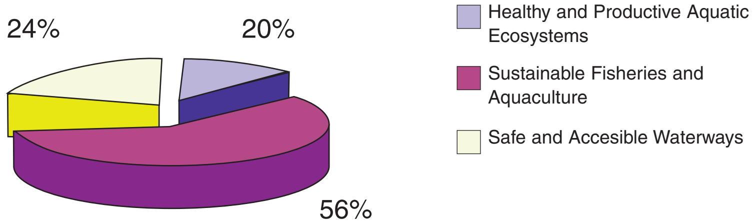


DEPARTMENT	SECTOR	GOVERNMENT ($000)	INSTITUTIONS ($000)	INDUSTRY ($000)
DFO	Science	7,779	462	2,330
NRCan	All	4,268		1,245

Industry Institutions Government

Program spending

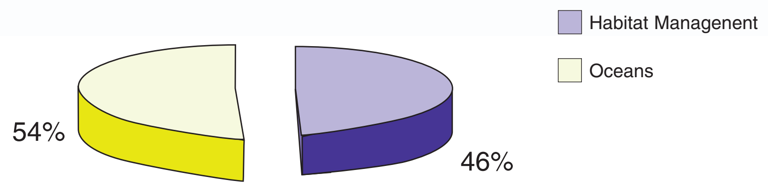
DFO Science



SECTOR	AMOUNT ($000)
Healthy and Productive Aquatic Ecosytems	6,316
Sustainable Fisheries and Aquaculture	17,550
Safe and Accessible Waterways	7,386

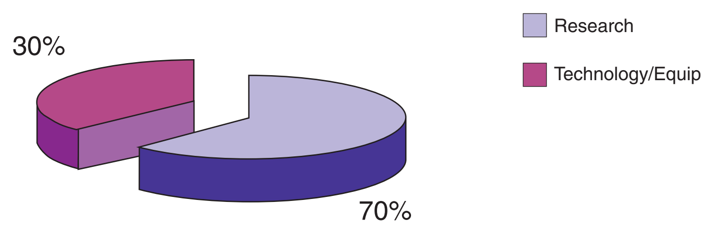
Program spending cont.

DFO Oceans and Habitat



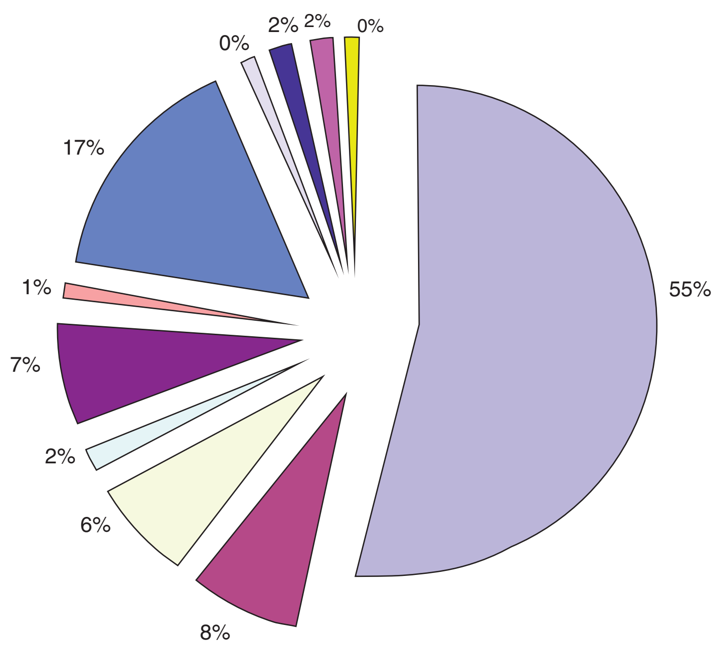
SECTOR	AMOUNT ($000)
Habitat Management	2,665
Oceans	3,095

NRCan



	AMOUNT ($000)
Research	10,975
Technology/Equipment	4,704

BIO staff by Division/Department



DFO - Science	342
DFO - Oceans & Habitat	51
DFO - Informatics	40
DFO - Other	10
DFO - Coast Guard Tech Services	44
DFO - Aquaculture Coordination	4
NRCan - GSC Atlantic	104
EC - Operational Laboratories	2
DND - Survey Office	13
PWGSC - Site Operations	12
Research Coordination Units	3
Total	625

PUBLICATIONS AND PRODUCTS

PUBLICATIONS 2005

FISHERIES AND OCEANS CANADA
Maritimes Region – Bedford Institute of Oceanography

SCIENCE BRANCH

1) Healthy and Productive Aquatic Ecosystems:

Recognized Scientific Journals:

Anderson, J.T., J.E. Simon, D.C. Gordon, Jr., and P.C. Hurley. 2005. Linking fisheries to benthic habitats at multiple scales: Eastern Scotian Shelf haddock (Melanogrammus aeglefinus). Am. Fish. Soc. Symp. 41: 251-264.

Azetsu-Scott, K., and S.E.H. Niven. 2005. The role of transparent exopolymer particles (TEP) in the transport of 234Th in coastal water during a spring bloom. Continental Shelf Res. 25: 1133-1141.

Azetsu-Scott, K., R.M. Gershey, and E.P. Jones. 2005. Distribution and ventilation of water masses in the Labrador Sea inferred from CFCs and carbon tetrachloride. Mar. Chem. 94: 55-66.

Blaise, C., F. Gagne, N. Chevre, M. Harwood, K. Lee, J. Lappalainen, B. Chial, G. Persoone, and K. Doe. 2004.* Toxicity assessment of oil-contaminated freshwater sediments. Environ. Toxicol. 19(4): 267-273.

Bundy, A. 2005. Structure and function of the eastern Scotian Shelf ecosystem before and after the groundfish collapse in the early 1990s. Can. J. Fish. Aquat. Sci. 62(7): 1453-1473.

Bundy, A., and P. Fanning. 2005. Can Atlantic cod recover? Exploring trophic explanations for the non-recovery of cod on the eastern Scotian Shelf, Canada. Can. J. Fish. Aquat. Sci. 62(7): 1474-1489.

Bundy, A., P. Fanning, and K.C.T. Zwanenburg. 2005. Balancing exploitation and conservation of the eastern Scotian Shelf ecosystem: Application of a 4D ecosystem exploitation index. ICES J. Mar. Sci. 62: 503-510.

Couillard, C.M., K. Lee, B. Légaré, and T. L. King. 2005. Effect of dispersant on the composition of the water-accommodated fraction of crude oil and its toxicity to larval marine fish. Environ. Toxicol. Chem. 24: 14961504.

Gilkinson, K.D., D.C. Gordon, Jr., K.G. MacIsaac, D.L. McKeown, E.L.R. Kenchington, C. Bourbonnais and W.P. Vass. 2005. Immediate impacts and recovery trajectories of macrofaunal communities following hydraulic clam dredging on Banquereau, Eastern Canada. ICES J. Mar. Sci. 62: 925-947.

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.

Hannah, C.G., and A. Drozdowski. 2005. Characterizing the near-bottom dispersion of drilling mud on three offshore banks. Mar. Pollut. Bull. 50: 1433-1443. 10.1016/j.marpolbul.2005.09.002

Harding, G.C., K.F. Drinkwater, C.G, Hannah, J.D. Pringle, J. Prena, J.W. Loder, S. Pearre, Jr., and W.P. Vass. 2005. Larval lobster (Homarus americanus) distribution and drift in the vicinity of the Gulf of Maine offshore banks and their probable origins. Fish. Oceanogr. 14(2): 112-137.

Head, E.J.H., D. Brickman, and L.R. Harris. 2005. An exceptional haddock year-class and unusual environmental conditions on the Scotian Shelf in 1999. J. Plankton Res. 27: 597-602.

* Citation year is 2004; however, publication occurred only after publication of "Bedford Institute of Oceanography 2004 in Review".

Hellou, J., K. Cheeseman, M.J. Jouvenelle, and S. Robertson. 2005. Behavioural response of Corophium volutator relative to experimental conditions, physical and chemical disturbances. Environ. Toxicol. Chem. 24: 30613068.

Hellou, J., K. Haya, S. Steller, and L. Burridge. 2005. Presence and distribution of PAHs, PCBs and DDE in feed and sediments under salmon aquaculture cages in the Bay of Fundy, New Brunswick, Canada. Aquatic Conserv: Mar. Freshw. Ecosyst. 15: 349-365.

Jiang, J., Y. Lu, and W. Perrie. 2005. Estimating the energy flux from the wind to ocean inertial motions: The sensitivity to wind fields. Geophys. Res. Lett. 32. L15610, doi:10.1029/2005GL023289.

Johnson, B.T., J.D. Petty, J.N. Huckins, K. Lee, and J. Gauthier. 2004.* Hazard assessment of a simulated oil spill on intertidal areas of the St. Lawrence River with SPMD-TOX. Environ. Toxicol. 19: 329-335.

Karcher, M., R. Gerdes, F. Kauker, C. Köberle, and I. Yashayev. 2005. Arctic Ocean change heralds North Atlantic freshening. Geophys. Res. Lett. 32. L21606, doi:10.1029/2005GL023861.

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PRODUCTS 2005

FISHERIES AND OCEANS CANADA

Maritimes Region - Science Branch

CANADIAN HYDROGRAPHIC SERVICE

Tide Tables

Canadian tide and current tables. 2005. Vol. 1. Atlantic Coast and Bay of Fundy. Canadian Hydrographic Service, Fisheries and Oceans, 615 Booth Street, Ottawa, ON K1A 0E6, Canada.

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Canadian Hydrographic Service Charts – 2005:

Chart 4460.	Charlottetown Harbour. (New edition)
Chart 4820.	Cape Freels to/à Exploits Islands. (New chart)
Chart 4827.	Hare Bay to/à Fortune Head. (New chart)
Chart 4865.	Approaches to/Approches à Lewisporte and/et Loon Bay. (Limited new edition)
Chart 4920.	Plans Baie des Chaleurs / Chaleur Bay Côte sud / South Shore. (New edition)
Chart 5051.	Nunaksuk Island to/à Calf Cow and/et Bull Islands. (New edition)
Chart 5052.	Seniartlit Islands to/à Nain. (Limited new edition)
Chart 5055.	Cape Kiglapait to/à Khikkertarsoak North Island. (New chart)
Chart 5070.	Satosoak Island to/à Akuliakatak Peninsula. (New edition)

S57 ENCs (Electronic Navigation Charts) – 2005:*

CA576603.	Chart 4847.	Bay Roberts. (New edition)
CA176030.	Chart 4001.	Gulf of Maine to/à Strait of Belle Isle. (New edition)
CA276206.	Chart 4011.	Approaches to/à Bay of Fundy. (New edition)
CA376173.	Chart 4622.	Cape St. Mary's to Argentia Harbour and/et Jude Island. (New edition)
CA376355.	Chart 5134.	Approaches to Cartwright. (New edition)
CA476009.	Chart 4237.	Approaches to/Approches au Halifax Harbour. (New edition)
CA476063.	Chart 4277.	Great Bras D'Or, St. Andrews Channel and/et St. Anns Bay. (New edition)
CA476168.	Chart 4865.	Lewisporte and Approaches and/et Loon Bay. (New edition)
CA476190.	Chart 4653.	Bay of Islands. (New edition)
CA476215.	Chart 4728.	Epinette Point to Terrington Basin. (New edition)
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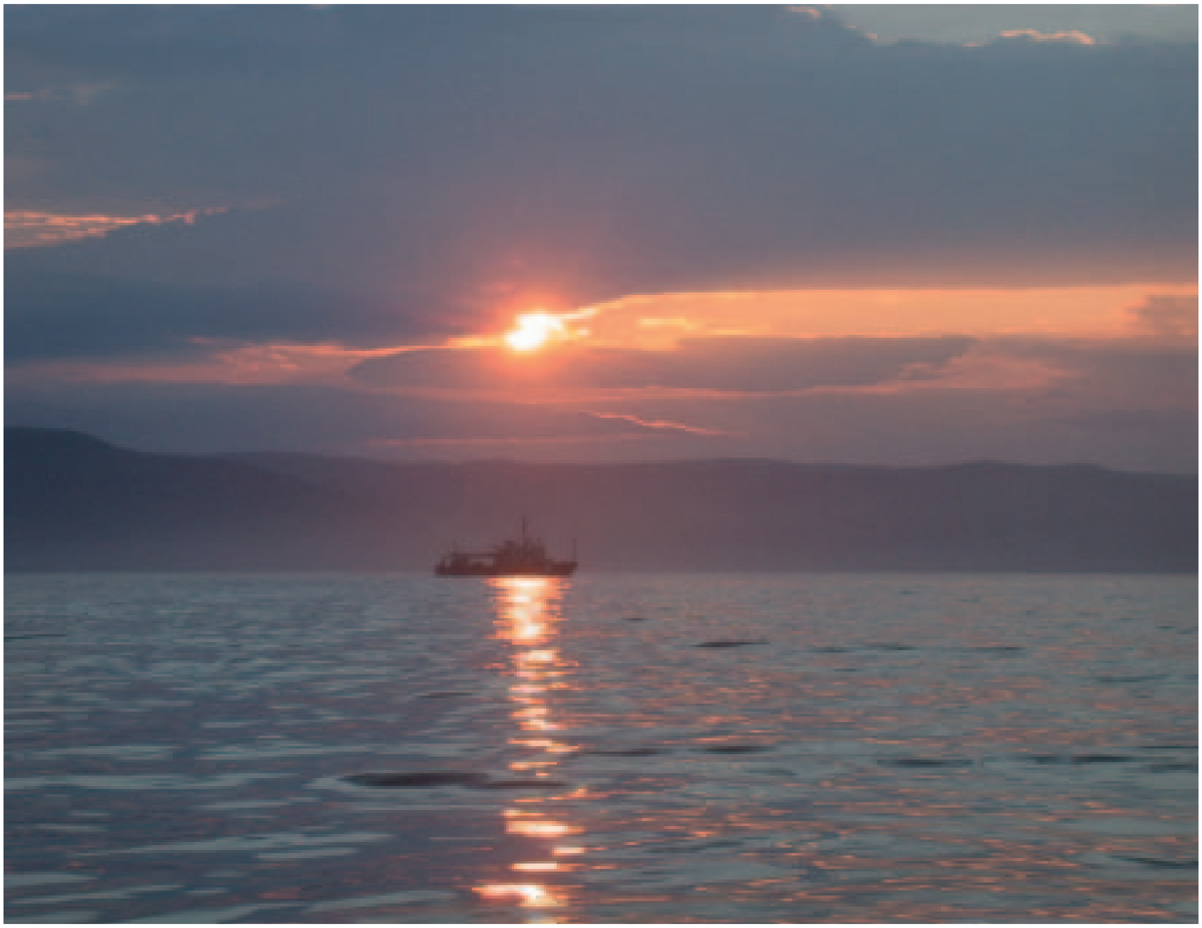
CA476285.	Chart 4306.	Canso Lock to St.Georges Bay/Écluse de Canso à St.Georges Bay. (New edition)
CA476300.	Chart 4617.	Red Island to Pinchgut Point. (New edition)
CA576001.	Chart 4201.	Halifax Harbour - Bedford Basin. (New edition)
CA576095.	Chart 4266.	Sydney Harbour. (New edition)
CA576114.	Chart 4848.	Long Pond. (New edition)
CA576118.	Chart 4848.	Holyrood (Marina). (New edition)
CA576121.	Chart 4847.	Bell Island. (New edition)
CA576123.	Chart 4847.	Foxtrap. (New edition)
CA576132.	Chart 4909.	Quai/Wharf Richibucto. (New edition)
CA576268.	Chart 4920.	Quai/Wharf Belledune. (New edition)
CA576282.	Chart 4306.	Canso Lock and Causeway. (New edition)
CA576283.	Chart 4306.	Point Tupper to/à Ship Point. (New edition)
CA576386.	Chart 4846.	St. John's Harbour. (New edition)

* Available from Nautical Data International Inc. (http://www.digitalocean.ca).



End of a good day's work - the CCGS Matthew *carrying out hydrographic survey operations in the mouth of Canada Bay, on the east side of the Great Northern Peninsula, Newfoundland and Labrador*

National Public Service Week 2005 Photo Contest award-winning photograph by Michael Lamplugh of the Canadian Hydrographic Service at BIO

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