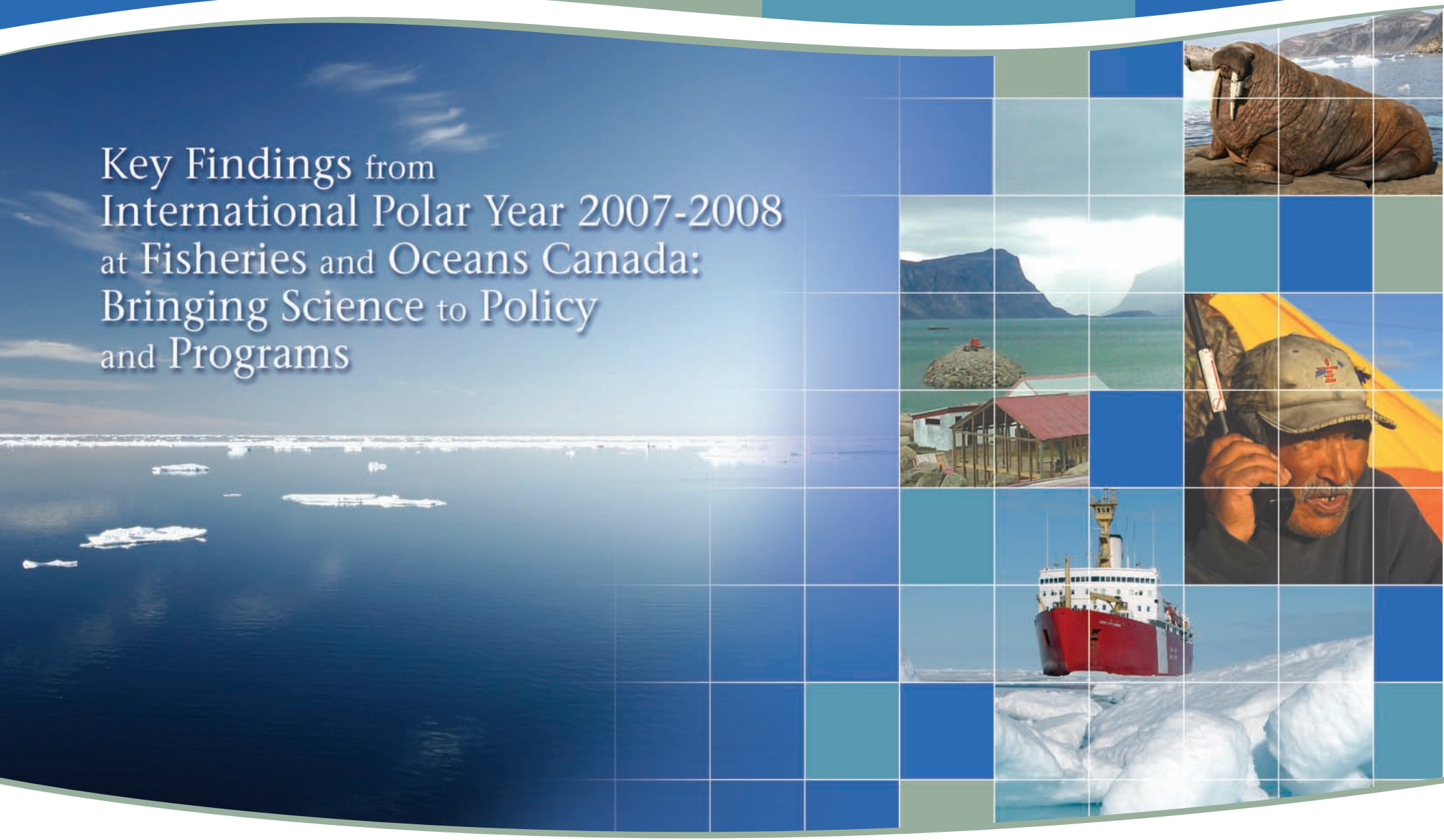
Fisheries and Oceans Canada
Pêches et Océans Canada

Ecosystems and Oceans Science
Sciences des écosystèmes et des océans

Key Findings from International Polar Year 2007-2008 at Fisheries and Oceans Canada: Bringing Science to Policy and Programs



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Photos on the cover, from top to bottom:
A walrus (*Odobenus rosmarus*) with a satellite tag on its tusk. Photo: DFO
Pangnirtung, Nunavut: A new small craft harbour for commercial fishing is under construction. Photo: DFO
Livee Qulualiq of Nunavut using a satellite phone during a search for bowhead whales (*Balaena mysticetus*). Photo: DFO
CCGS Louis S. St-Laurent awaits IPY researchers. Photo: © Luc Rainville, Applied Physics Laboratory, University of Washington, 2007.
Background image: The blue water, sky and horizon from the deck of the CCGS Louis S. St-Laurent. Photo: © Paul Galipeau, 2007.

We would like to acknowledge the many individuals in the Arctic science and policy communities who provided assistance to Fisheries and Oceans Canada on this report.

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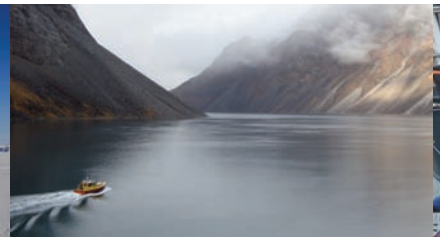



Science Comes to Cambridge Bay, Nunavut
Photo: Boyan Tracz - Arctic Research Foundation

In August 2010, Prime Minister Stephen Harper announced that the new Canadian High Arctic Research Station, an integral part of Canada's Northern Strategy, will be located in Cambridge Bay, Nunavut. The Canadian High Arctic Research Station will be a world-class, year-round, multidisciplinary facility exploring the cutting-edge of Arctic science and technology issues. It will create jobs, strengthen Canada's Arctic sovereignty, promote economic and social development and help protect and understand the northern environment, contributing to the overall quality of life for Northerners and all Canadians. Continuing the trend, in September 2011, the community welcomed a science research ship operated by the Arctic Research Foundation, named the "Martin Bergmann" (to whom this report is dedicated). The ship is overwintering in Cambridge Bay in preparation for its 2012 research mission in partnership with Parks Canada and other government departments.

Dedication

We are honoured to dedicate this work to the late Marty Bergmann, Director of the Polar Continental Shelf Program (PCSP) at Natural Resources Canada and, for many years, a public servant with Fisheries and Oceans Canada. Marty's contribution to Arctic science is inestimable, far exceeding any role he undertook. Working with the PCSP, Marty welcomed thousands of visiting scientists, students and media to Canada's Arctic during International Polar Year. His enthusiasm for the North was boundless. He was taken from the family, the work and the country he loved too soon and tragically, at age 55, on August 20, 2011 in a plane crash at Resolute Bay, Nunavut.

Marty Bergmann at the Polar Continental Shelf Program Office, Resolute Bay, Nunavut, July 2010.
Photo: Oksana Schimnowski

Strategic Overview

Canada is a polar nation, the second largest in the world, with the Arctic comprising approximately 40% of the country's 15 million square kilometre land mass and continental shelf.[1] The Canadian Arctic is facing unprecedented social, political, economic, environmental and cultural changes. Models indicate that the Arctic is among the most sensitive regions to environmental change and it is likely the Arctic will experience more rapid and severe climate change than any other region on Earth.[2]

Fisheries and Oceans Canada (DFO) has extensive regulatory and legislative roles and responsibilities in this vast region, for both marine and freshwater environments. In broad strokes, these include: fisheries, oceans and habitat management and conservation; mapping, charting and navigational aids; marine search and rescue; environmental disaster response; and protection of endangered species.

International Polar Year (IPY) — the fourth since the late 1800s — offered an opportunity for scientists from around the world to collaborate and advance scientific knowledge. This cross-sectoral and international collaboration has been a hallmark of all IPY projects; it is also vital to Canada's role and leadership in both scientific and diplomatic forums with the potential to affect the Canadian Arctic.

Of the 52 Canadian IPY Program projects, DFO principal investigators led or co-led seven of the largest projects and participated in an additional seven all within the climate change theme. DFO's IPY research highlights the interactive physical environmental processes in the Arctic, and provides insight on the linkages and sensitivities within this ecosystem. Evidence gathered through these projects is contributing significantly to our understanding of the Arctic Ocean: how rapidly it is changing, the vital role it plays in regulating global climate and, in turn, how global climate change is affecting our own vulnerable Arctic ecosystems.

IPY early research results are directly relevant to all three DFO strategic outcomes[3] and will continue to contribute as further analysis and use is made of gathered data. Critical knowledge garnered through IPY research will support decision-making related to commercial fishery quotas and subsistence harvesting levels, as well as support other resource and habitat management decisions (both marine and freshwater). Results have already been used by Canadian trade negotiators in reaching a deal with China on seal products and are providing critical new data for predictive modelling, including severe weather scenarios, ecosystem sustainability, potential impacts of natural or man-made disasters and the effects of climate change. (Details of major results and findings of the DFO IPY projects are contained in Part II of this report.)

Scientific research and inquiry often leads to the early identification of emerging issues or critical insights into a changing world. This "early warning" is helpful from a policy perspective, as it provides an opportunity to reflect on current and planned policy, as well as upcoming legislative or regulatory changes, to assess relevance and applicability now and into the future.

[1] Hik, David S.; Kraft Sloan, Karen. "Putting the Canadian Polar House in Order." *Arctic* 57 (2), 2004. .

[2] Arctic Council and International Arctic Science Committee (IASC). "Arctic Climate Impact Assessment." New York: Cambridge University Press, 2005.

[3] DFO's three strategic outcomes are: Economically Prosperous Maritime Sectors and Fisheries; Sustainable Aquatic Ecosystems; and Safe and Secure Waters.

***Umiak 1*: Photo Courtesy of The Fednav Group.**

The Fednav Group operates *Umiak I*, a 31,500-tonne icebreaking bulk carrier that makes 12 voyages each year to move 360,000 tonnes of nickel concentrates from Vale NL Ltd.'s Voisey's Bay mine in northern Labrador for processing at Vale smelters in Sudbury, Ontario and Thompson, Manitoba, and eventually its nickel refinery in Long Harbour, NL. There is no bulk carrier more powerful, and it is capable of breaking ice one and a half metres thick at a speed of three knots. Ships like this are designed, built and equipped to resist ice loads, and to handle Arctic weather and operating conditions. Arctic shipping in Canada is governed by legislation, including the *Arctic Waters Pollution Prevention Act* and its regulations, the *Canada Shipping Act* 2001, the *Marine Liability Act*, and the *Marine Transportation Security Act*, among other legislation. Ship owners and operators must ensure that they comply with all applicable Acts and regulations, such as the carriage of nautical charts from the Canadian Hydrographic Service. Canadian construction standards for ice class ships are found in the Arctic Shipping Pollution Prevention Regulations.

The interconnectivity and sensitivity of the entire Arctic environment means that small observable changes in climate produce cascading effects with real costs — economic, social and environmental. A warming Arctic does bring potential access to additional species (shifting north as a result of water temperature rises). However, this same change may also bring new diseases to existing species, introduce alien invasive species and increase the number of predators, all of which can quickly and easily disrupt the Arctic food web and affect critical food sources for Northerners.

IPY modelling has revealed some surprises, including a future scenario in which current marine mammal populations in Hudson Bay will be replaced by temperate species as the climate continues to warm and sea ice is lost. Declines in seal abundance, for example, have already led to reductions in food sources for polar bears. At the same time, killer whales have now replaced humans as the top predator in Hudson Bay, leading to increased predation on traditional Inuit subsistence mammals. Further research will be essential given the potential impact on, for example, harvests and the potential implications for subsistence fishery resources available for local communities.

The potential use of the Northwest Passage as an international shipping route is a hotly debated topic as sea ice loss and thinning continue. Will it ever be economically viable? What are the risks, both human and environmental? What pressures will it place on DFO resources for icebreaking, search and rescue, and environmental response? More certain is the likelihood of increased resource exploration and development, and expanding ecotourism, both of which have potential in terms of economic development, but carry considerable environmental and disaster-response implications. IPY research results have strengthened the evidence base and are now validating and

improving modelling systems that support decision-making and related risk-based planning by providing not only new data for modelling, but also greater understanding of the integration and interaction between the critical environmental factors, namely ocean, ice, wave and atmospheric systems.

The vastness of the Arctic region, its remoteness and the limited time in which most research can take place challenge our ability to ensure sufficient scientific research and analysis to support evidence-based decision-making. This emerging area of national focus must be balanced against the ongoing needs in "southern" Canadian coasts and inland waters. Balance must also be struck between science that supports economic development in this "new" frontier and science that supports conservation and sustainability of the fragile environment.

Focused injections of funding to support Arctic research, such as this most recent International Polar Year, make a significant contribution to global understanding of the North and the effects of climate change in particular. That said, as the results of the research continue to contribute to our understanding of the Arctic, as data are incorporated into modelling systems and research results are correlated and shared across projects and across nations, decision-makers will still not have all the information and scientific advice they need: demand has already outpaced supply. Baseline data and early warnings become truly useful as subsequent research establishes trends with more certainty; suspicions about habitat changes, and stock shifts and numbers are confirmed or refuted; and evidence — much of which is dependent on monitoring and access to ships — becomes available that is solid enough on which to base decisions. There are some who look to the proposed Canadian High Arctic Research Station as a means to fill some of this knowledge need and, indeed, it is expected to help maintain a focus on Northern science. Nevertheless, DFO — and other federal departments — will need to consider what legacy will be built from IPY and how best to leverage the work done internationally, as well as domestically, to support a sustainable and economically prosperous Arctic.

Oliver Sound with *Heron* Launch (CHS). Photo: Canadian Hydrographic Service

The Canadian Hydrographic Service works hard to survey and chart key channels in Canada's Arctic. Among its tools is the CSL *Heron*, a launch for hydrographic and geophysical surveying. To help understand coastal erosion and storm impacts, among other studies undertaken during International Polar Year, the CSL Heron was used to collect sediment samples and to acquire multibeam sonar data from coastal areas. It is seen here in Oliver Sound in the high Arctic, near the north end of Baffin Island. The remote, uninhabited waterway is part of **Sirmilik National Park**, and the nearest community is Pond Inlet, population 1500.

1. Introduction

During each International Polar Year (IPY), scientists from around the world pool resources, knowledge and technologies to advance collaborative scientific and exploration programs in the Arctic and Antarctic. The IPY legacy dates back to 1882-83, 1932-33 and 1957-58.

The fourth such endeavour, held in 2007-09, differed greatly from its predecessors. This IPY featured more scientists, participating from more nations, than ever before. For the first time, investigations moved beyond simple discovery of polar regions in favour of directed scientific study to acquire in-depth knowledge of the physical, biological and chemical processes at work in polar regions and to understand and explain how a changing polar climate is predictive of, and even driving, change in the rest of the world.

The fourth IPY was held over two years, 2007-09 (IPY 2007-08), wherein the Government of Canada invested $156 million towards the largest global investment ever in Arctic science. Canadian scientists focused on two scientific Arctic priority themes climate change impacts and adaptation, and the health and well-being of Northern peoples.

DFO principal investigators led six large projects of the 52 IPY science projects funded under the Canadian program, all within the climate change theme:

Project	Principle Investigator
Canada's Three Oceans	**Eddy Carmack**
Canadian Arctic Through-flow Study	**Humfrey Melling**
Climate Variability and Change Effects on Chars in the Arctic	**Jim Reist**
Global Warming and Arctic Marine Mammals	**Steven Ferguson**
Impacts of Severe Arctic Storms and Change on Arctic Coastal Oceanographic Processes	**William Perrie**
Pan-Arctic Tagging of Beluga Whales	**Mike Hammill**

The Department's scientists also collaborated on many other IPY projects relevant to the Canadian Arctic, with partners from other government departments, universities and international organizations. For example, the Department played a substantial role in the largest IPY project in Canada: the Circumpolar Flaw Lead System Study, led by David Barber (University of Manitoba), with co-leads Gary Stern (Fisheries and Oceans Canada) and Jody Deming (University of Washington). Gary Stern led the Contaminant team and Steven Ferguson led the Marine Mammal and Sea Birds team.

The additional studies that this report highlights are:

- Arctic Freshwater Systems (DFO scientist Jim Reist)
- Arctic Surface Ocean—Lower Atmosphere Study (SOLAS) (chercheur du MPO : Michael Scarratt)
- The Carbon Cycle in the Canadian Arctic and Sub-Arctic Continental Margin (DFO scientist Robie Macdonald)
- Determining the Diet of the Greenland Shark in a Changing Arctic (DFO scientist Steven Campana)
- Engaging Communities in the Monitoring of Country Food Safety (DFO scientist Ole Nielsen)

Canada's interconnected system of oceans provides immeasurable benefits to Canadians, including jobs, food, natural resources, carbon sequestration, climate regulation and recreation. Growing evidence indicates that the Arctic Ocean is a strongly interacting system that is rapidly changing, which reinforces the need to learn more about how the Arctic system regulates climate and how climate change is affecting, and will further affect, Arctic ecosystems.

Climate change will affect many aspects of DFO's mandate, including habitat and fisheries management, species at risk, small craft harbours, and maritime safety and security. Understanding and assessing the emerging risks and opportunities of projected impacts and preparing appropriately are now considered intrinsic to the work of the Department. Even while DFO works to mitigate the risks of climate change to marine ecosystems and physical infrastructure, it must also be poised to respond to opportunities such as those caused by regional shifts in fisheries productivity.

A Harbour Begins in Pangnirtung, Nunavut
Photo: DFO

New infrastructure for inshore commercial fishing is coming to the Arctic. In August 2009, Prime Minister Stephen Harper announced $17 million towards the construction of a new small craft harbour there to support fishing and marine links among Arctic communities. In addition to the harbour, the government will provide scientific research and resource management support for the development of a Nunavut fishery as a means of promoting local economic growth and the development of regional employment. The greatest potential for future economic development in the area is with the inshore turbot fishery. Nunavut's offshore fishery, based in the Davis Strait, is the Territory's most important commercial fishery.

CCGS *Louis S. St-Laurent* bearing its International Polar Year Insignia
Photo: © Gerd Braune, 2008

The flagship of Canada's Coast Guard fleet, the CCGS *Louis S. St. Laurent* was a key research platform during IPY. The ship is expected to be de-commissioned in 2017, when it will be replaced by **Canada's new polar-class icebreaker, the CCGS *John G. Diefenbaker***. The scientific capabilities and multi-purpose design of the new ship were directly and positively impacted by the chemical, physical and biological studies aboard Canadian icebreakers, CCGS *Louis S. St. Laurent*, *Amundsen*, and *Laurier* during IPY. The new CCGS *John G. Diefenbaker* is a centerpiece of **Canada's Northern Strategy**, which focuses on strengthening Canada's Arctic sovereignty, northern economic and social development, and protecting the North's environmental heritage. The new icebreaker will enable the Canadian Coast Guard to increase coverage in the Canadian Arctic and adjacent waters, operating during three seasons in the Arctic over a larger area and in more difficult ice conditions than is currently possible.

This report is a preliminary exploration of how scientific results emerging from International Polar Year projects led by Fisheries and Oceans Canada are relevant to the Department's mandate, its programs and policies. Due to the nature of research, results for many projects are just starting to emerge, with the bulk yet to be revealed. Nevertheless, specific contributions are already supporting key departmental policies and program management responsibilities, including: Adaptation to Climate Change, Integrated Fisheries Resource Management, Habitat Management, Integrated Ocean Management, Ocean Forecasting and International Affairs. Further, this report highlights emerging issues for the consideration of the Department in the development of future policies and priorities.

The report '*Key Findings from International Polar Year 2007-2008 at Fisheries and Oceans Canada: Executive Summary*', published by DFO in 2010, presents information on early key findings from IPY 2007-08.

The involvement of Fisheries and Oceans Canada in International Polar Year research was driven largely by the Department's mandate to manage marine resources in a changing Arctic. The Department's involvement provides insights into how climate is driven by the ocean-ice system in the Arctic, the major impacts of climate change on Arctic marine and freshwater systems, and how climate change is affecting the ecosystems and aquatic animals upon which Northern communities depend. This research is contributing to the foundation of knowledge required to make future decisions aimed at facilitating adaptation to the effects — positive and negative — of climate change on the Northern environment, economy and society.

In particular, DFO's IPY science is:

- informing the development of the new Canadian polar-class icebreaker, Canadian Coast Guard Ship CCGS *John G. Diefenbaker*, and in particular its scientific capabilities;
- contributing to setting commercial fishery quotas and levels of subsistence harvesting via scientific assessments and understanding of the status and health of fish, invertebrates and marine mammals, and their aquatic ecosystems;
- informing the review, assessment and monitoring of activities for habitat management and the environmental assessment process by adding to the body of scientific knowledge;
- supporting oceans management and resource users by helping to build a more solid baseline of physical, chemical and biological information;
- contributing to overall departmental goals relating to sustainability and biodiversity conservation; and
- contributing to the establishment of and enhancing relationships with national and international partners, as well as providing data for international initiatives.

DFO's involvement with IPY not only yielded crucial scientific data and information, it also allowed DFO scientists to create new relationships with Northern communities and peoples, and strengthen existing ones. Helping to establish community-based monitoring programs and identify opportunities to integrate traditional knowledge are powerful examples of the benefits that can be leveraged from investments in collaborative science projects in the North.

The special funding for IPY data collection has ended. DFO scientists, however, will continue to benefit from IPY as they conduct analyses and incorporate findings into complementary ongoing research initiatives, such as the Climate Change Science Initiative. This initiative is DFO's national research initiative focused on understanding the role of oceans in regional climates, assessing the impacts of climate change on ecosystems, and investigating emerging issues that affect ecosystem health, such as ocean acidification and emerging infectious diseases. Although the Climate Change Science Initiative and other science programs (e.g., DFO's Emerging Fisheries initiative and the Beaufort Regional Environmental Assessment) partially fill the void left by the end of IPY funding, two huge gaps remain: research on Arctic freshwater species, ecosystems and processes, and the effects of change on wildlife habitats, both of which need a well-designed monitoring program.

While there are additional IPY research findings relevant to the Department, the scope of this report encompasses only those projects directly involving DFO scientists. You can find more information on Canadian International Polar Year research projects on the Government of Canada IPY website.

2. Linking International Polar Year Science to Policy and Programs

2.1 CONNECTING SCIENCE TO POLICY AND PROGRAM MANAGEMENT

Science is an integral support to decision-making across all of DFO's program and policy areas. Scientific data, products, research and advice are used, for example, to develop Integrated Ocean Management Plans, Marine Protected Area Networks, Integrated Fisheries Management Plans, Conservation and Harvesting Plans, and Species at Risk Assessments and Recovery Plans. DFO science also informs habitat management decisions and compliance and enforcement activities, and provides expert advice to other government departments.

DFO science, including IPY science, connects to policy and program management through several governance mechanisms, such as the Department's strategic outcome committees in which science advice and evidence is considered within a holistic framework. On a more tactical level, regular, formal and informal, interactions between Science managers and scientists in the regions and in DFO management sectors provide guidance and direction on policy, program and research needs.

The long-standing annual workshop between Science and Fisheries Management in DFO's Central and Arctic Region is an example of one of the principal methods for bringing together science and program management. Workshop participants are divided into teams, each focusing on a particular fish stock, and scientists and managers present research/management needs in relation to these stocks. This exercise identifies the research needed to complete stock assessments, and it results in a schedule for completing the research over a five-year period. The same approach was adopted in 2010 to bring together Science and Habitat Management, Science and Oceans Management, and Science and Species at Risk. These workshops allow managers and scientists to work together to identify the research needed to produce the required scientific information for furthering management objectives.

Canada's comprehensive land claims agreements established Northern co-management boards to address environmental stewardship and wildlife harvesting. The Department's Science program is integral to the work of these boards and through such collaboration science is integrated with traditional knowledge from wildlife stakeholders such as local fishers, trappers and hunters. Not only does DFO Science deliver science knowledge and advice to co-management boards and land claims groups, it also modifies regional and, ultimately, national policy and program delivery in response to Board concerns. The emerging fisheries priority in the eastern Arctic is a prime example: DFO scientists meet periodically with the wildlife management boards to discuss board issues and to present the latest scientific results and, in addition, they conduct research for the wildlife management boards in response to their needs.

Another primary method linking science to policy utilizes the peer-review process and publication of scientific results through the Canadian Science Advisory Secretariat (CSAS), which coordinates the peer review of scientific issues for DFO. CSAS develops integrated overviews of issues in fish stock dynamics, habitat, species at risk, ocean ecology and use of living aquatic resources, and to quickly identify

emerging issues. Publications are posted on DFO's website. CSAS research documents related to IPY research include:

- Ferguson, S.H. and B.G. Young. 2011. *Aerial survey estimates of hauled-out Ringed Seal (Pusa hispida) density in western Hudson Bay, June 2009 and 2010*.
- Hammill, M. and V. Lesage. 2009. *Seasonal movements and abundance of beluga in northern Quebec (Nunavik) based on weekly sightings information*. Research Document – 2009/010.
- Loseto, L. et al. 2010. *Information in Support of Indicator Selection for Monitoring the Tarium Niryutait Marine Protected Area (TNMPA)*. Research Document – 2010/094.
- Reist, J. and C.D. Sawatzky. 2010. *Diversity and Distribution of Chars, Genus Salvelinus, in Northwestern North America in the Context of Northern Dolly Varden (Salvelinus malma malma (Walbaum 1792))*. Research Document – 2010/014.
- Stern, G. 2009. *Contaminants in Canadian Arctic Bowhead whales*. Research Document - 2009/028.

Additional methods to link science with program and policy areas include DFO's Central and Arctic Region's senior-level coordinating committee (*Science, Oceans, Habitat and Species at Risk, and Fisheries and Aquaculture Management Coordinating Committee*). This committee provides a forum to discuss operational issues and coordinate the Science program to address short, medium and long-term science priorities for Fisheries and Aquaculture Management as well as Oceans, Habitat, and Species at Risk. It is composed of three Regional Directors and the CSAS Coordinator. Science, including IPY science, is brought to bear on these discussions and priority-setting exercises.

2.2 EMERGING ISSUES

Research funded under the aegis of International Polar Year revealed new information about how the ocean-ice system in the Arctic drives climate, the major impacts of climate change on the Arctic and, specifically, how climate change affects Arctic ecosystems and aquatic animals, and how the people who depend on them are trying to adapt. This research points to some surprising and significant findings that will be important for DFO to consider and further explore in order to support its new priorities for the North. In addition, continued monitoring and analysis of the pace (and effects) of climate change will be essential and will require systematic, regularized data collection.

New research findings of particular note are presented below.

Climate change adaptation

IPY research indicates that the frozen environment — including sea ice, freshwater ice, glaciers, ice sheets, permafrost and snow — is the Arctic's number one attribute. Variations in sea ice have dramatic effects on the ocean environment and on the ecosystems that thrive within it. The characteristics of the Arctic Ocean, its ice cover and its atmosphere are determined by ever-varying interactions that involve both positive and negative feedbacks[4]. This is a strongly interacting system, with some

[4] A positive feedback occurs when a perturbation to a system leads to change in that system, which in turn amplifies the perturbation; a negative feedback occurs when a perturbation leads to change in the system that in turn opposes or reduces the perturbation.

physical interaction processes better understood than others. For the Department to respond appropriately to changing Arctic conditions, researchers need to continue collecting data on a systematic basis and conducting additional research to understand climate change better. Over time, the regular and repeated acquisition of data will assist the Department to distinguish natural variability from pervasive change, and thus determine what management actions and policies to put in place.

A warming Arctic, and habitat changes in particular, will put the fauna that inhabit the North under increasing stress. Animals and fish unable to deal with these new realities will be less fit and therefore more likely to succumb to the diseases already present. A warming Arctic will also bring new species of fish and other animals into the North — and they will bring their diseases as well. The introduction of these new diseases could have a significant impact on animals with no immunity or previous exposure. Maintaining existing community-based monitoring programs for hunter-harvested fish and marine mammals will be essential to detect these problems in a timely fashion.

Increased shipping/maritime activity [5]

Larger and more sustained areas of open water in the North will allow greater shipping activity, along with noise, disturbance, icebreaking and the potential for collisions with wildlife. Increased shipping and maritime activity will provide economic benefits to Canadians, but will also increase risk of environmental impacts, such as black carbon air pollution, oil spills and invasive species introductions. DFO will need to increase its focus on risk assessment and environmental monitoring in the North to be prepared for and responsive to these risks. IPY results indicate that the Department will require improved modelling systems to predict future physical and biological scenarios (such as a fully integrated ocean-ice-wave-atmosphere model system for improved physical predictions).

Potential for expanding Northern fisheries and markets

Knowledge about the region's biodiversity, including understanding key processes such as trophic interactions[6], population ecology and the supporting physical and chemical environment, are vital for establishing new, and/or maintaining existing, sustainable fisheries.

Warming climates may adversely or positively affect fish and the food-web structure in the Arctic. In many ecosystems, warming climates will very likely increase production and result in species shifts to the benefit of fisheries. Climate change will, however, also allow for colonization[7] by sub-Arctic species since ocean warming may shift fish and marine mammal populations further north. For example, IPY research has shown that killer whales are replacing humans as the apex predators in Hudson Bay, which appears to be affecting prey-predator relationships, and may have implications for harvest allocations and subsistence hunting.

[5] Safe navigation for ships is a means to prevent accidents and will require improved nautical charts in most areas of the Arctic. While considered vital to economic development as well as safety, security and sovereignty in the Arctic, further discussion of this issue is beyond the parameters of IPY research.

[6] Trophic interactions are the feeding (predator-prey) interactions between species in the food web.

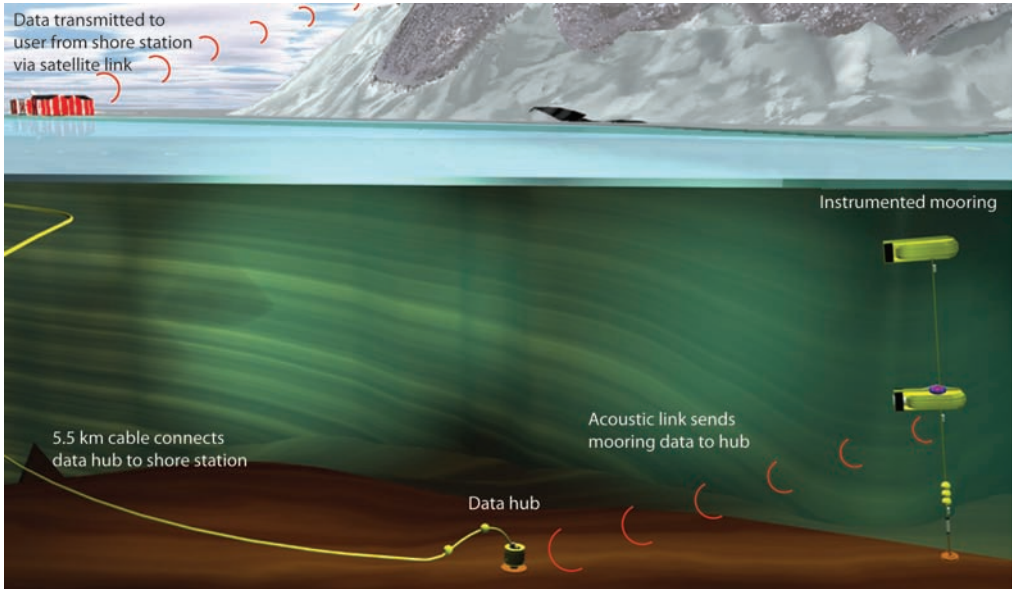
[7] Colonizers are organisms that enter an area and become naturalized through their own biological capacity; one factor in such colonization may be climate change effects on the underlying ecosystem.

Finally, the expected increase in human activity will introduce invasive species[8] into Arctic waters. The baseline monitoring carried out as part of the IPY projects on fish, freshwater habitats and ecosystems, etc. (all of which are DFO's responsibility in the Territories) will be used to inform an ecosystem-based approach to understanding aquatic species and their responses to climate change. Continued research is required to better understand the relationships of sea ice, primary and secondary production, fish, marine mammals and the carbon cycle, as well as the effects of contaminants on ecosystems and biota.

International interests in Arctic Ocean management/regulation

The international community is active in the creation of intergovernmental agreements that affect the Arctic and is benefiting from international science undertaken as part of International Polar Year. For example, the 2011 NUUK Declaration of the Arctic Council was notably informed by IPY science[9], and shifting ecosystems observed by IPY scientists under a changing Arctic climate will bring new considerations for the management of internationally shared stocks.

Canada itself is placing increased emphasis on the Arctic through its Northern Strategy and Arctic Foreign Policy and considerable interdepartmental, intersectoral and international research and collaboration. DFO collaborates with other Arctic nations both bilaterally and multilaterally through organizations such as the Arctic Council and the Intergovernmental Panel on Climate Change, and contributes its scientific research results and knowledge to many international initiatives. These include the Arctic Monitoring and



Real Time Arctic Ocean/Sea-Ice Observatory

Researchers from Fisheries and Oceans Canada developed and installed a prototype underwater Arctic Ocean observatory in the Northwest Passage at Barrow Strait. Strategically located at the eastern end of the principal transportation gateway through the Canadian high Arctic, and just upstream of the highly productive Lancaster Sound ecosystem, real time data from this location will be valuable for ice/ocean forecast modeling of the region. In addition to serving in the interest of Arctic marine transport and responsible resource development, these data may also serve as a predictive tool. This is possible because of the good understanding of the links between water properties, ice cover and biological productivity in the area, derived from the analyses of 13 years of instrumented mooring data just to the east. The combination of real time data and knowledge from long term monitoring provides a methodology for predicting the evolution of the ice cover as well as seasonal zooplankton productivity.

8 Invasive species are organisms that are transported to new environments by proximate human vectors, become naturalized in their new environment and prove to be pests (e.g., ballast water or hull fouling).

9 http://www.arctic-council.org/index.php/en/about/documents/category/5-declarations

Assessment Programme, Protection of the Arctic Marine Environment Working Group, and Conservation of Arctic Flora and Fauna working groups of the Arctic Council. As IPY project results continue to emerge, they will be incorporated in such key policy-relevant reports as the recently released Snow, Water, Ice and Permafrost in the Arctic report; the Arctic Biodiversity Assessment; assessments of the status, trends and effects of various contaminants, including mercury and persistent organic pollutants; the Arctic Ocean Review; and the Arctic marine and freshwater biodiversity monitoring initiatives.

Development of Arctic commodities

Natural resource development in the Arctic is a priority for the Canadian government. As such, there will be increased activity in offshore oil and gas development and mining over the next several decades. In addition, expanding the fishery is the focus of significant federal investment, as evidenced by small craft harbour development at Pangnirtung and emerging fisheries in the eastern Arctic. IPY results underscore that additional baseline and monitoring data are required in key marine and freshwater areas for accurate and comprehensive environmental assessments to ensure development does not lead to significant adverse environmental impacts.

Specialized Northern technology and infrastructure

Research in the North requires specialized technology; the Department strives to advance both the technology and cost-effectiveness of its monitoring and research operations, whether through analyzing satellite data; deriving physical and biological data from satellite-tagged fish and marine mammals, and from scientific buoys; or through the use of autonomous and tethered submersibles.

Scientists working from ships play a vital role in our understanding of the North and in many cases are the only means by which marine research can be undertaken. This requires vessels capable and available to serve as platforms for fisheries, biodiversity and habitat research, stock assessment, oceanographic research and hydrographic surveys. Icebreakers will continue to be essential for Arctic marine research and, for that reason, science capabilities are being integrated into the new CCGS *John G. Diefenbaker*, which is planned for launch in 2017.

2.3 CASE STUDIES

This section presents five case studies that explore in more detail how International Polar Year projects are contributing to DFO policy and program objectives in the areas of:

- Integrated Fisheries Resource Management
- Habitat Management
- Integrated Oceans Management
- Oceans Forecasting
- International Affairs

2.3.1 Integrated Fisheries Resource Management

Activity Overview

The role of Integrated Fisheries Resource Management is to deliver policies, programs and plans under the *Fisheries Act*, the *Species at Risk Act* and related regulations in consultation with Aboriginal groups, provinces and industry to manage, protect and conserve fisheries resources. This includes preparation of Integrated Fisheries

Management Plans and Conservation and Harvesting Plans, Rebuilding Plans, Recovery Strategies and Action Plans. The program, informed by the scientific assessment of the status of fish, invertebrate and marine mammals, works to provide Canadians with a sustainable fishery resource to support an economically viable and diverse industry. The Department's 2009 Sustainable Fisheries Framework provides the foundation of an ecosystem-based and precautionary approach to fisheries management in Canada.

Fisheries Management in the Central and Arctic Region conducts programs to conserve and manage fishery resources for sustainable use in Nunavut, the Northwest Territories and the North Slope of the Yukon. In areas where land claims are settled, fisheries are co-managed with legislated co-management boards. Activities include: Integrated Fisheries Management Planning, Conservation, Education and Enforcement.

Contribution of IPY Science to Integrated Fisheries Resource Management

IPY projects provide information for better informed and effective fisheries management under changing Arctic conditions. The research lends new insight into the distribution, health and trophic interactions of Arctic fish and marine mammals, as well as the current and potential future oceanic conditions that support marine life.

Global Warming and Arctic Marine Mammals research is providing valuable knowledge about marine ecosystem change in the Arctic and the drivers of change. This project examined various aspects of Arctic marine mammal (seals, whales and polar bears) ecology to try to determine the impacts of global warming on their abundance and distribution. Several areas of Arctic marine mammal health were also studied, including diet, infectious diseases, contaminants and stress. Researchers used satellite tracking, analysis of tissue samples collected by local hunters, and genetics and population modelling to understand how these animal populations may respond to environmental change. Findings point to some surprising discoveries and anticipated changes. Modelling results describe a future scenario in which current marine mammal populations in Hudson Bay will be replaced by temperate species as the climate continues to warm and sea ice is lost. Results include changes in primary productivity and the development of new trophic linkages with the introduction of new competitors, predators and infectious disease.

For example, ringed seal research results indicate an overall decline in seal abundance. Trophic consequences of reduced seal abundance include less food for polar bears, a shift in fish forage species from Arctic cod to sand lance to capelin, and a reduction in overall Inuit subsistence fishery resources.

Findings also reveal a Hudson Bay marine ecosystem that is shifting under a changing climate from a polar bear-seal system with Inuit hunters at the apex to one with killer whales at the apex. This change in apex predators has management and conservation significance, since expanding killer whale distribution and increased predation of traditional subsistence mammals — bowhead, narwhal and beluga — may affect harvests, thereby eroding traditional Inuit subsistence culture. Results of this research will help Inuit communities adapt to changes in marine mammal distribution and abundance.

Global Warming and Arctic Marine Mammals ecosystem modelling results also provided information where no information was previously available on Hudson Bay fish species composition and biomass. Results

may be used to assess fish resource biomass and the possibility of new/expanded future fisheries in Hudson Bay-Hudson Strait.

Pan-Arctic Tagging of Beluga Whales research provides a baseline understanding of important traditionally harvested species, informing the development of DFO's Conservation and Harvesting Plans. For this IPY project, DFO scientists tracked beluga whales using satellite telemetry combined with traditional knowledge and observations of local people. Evidence shows that there are distinct stocks of beluga in Hudson Bay, and possibly in James Bay, which will help inform conservation management approaches, especially with regard to the eastern Hudson Bay and Ungava Bay beluga stocks that are classified as 'Endangered' by the Committee on the Status of Endangered Wildlife in Canada. As well, summer movements and the timing of beluga whale fall migration appear to be linked to water temperature, and changes in ice formation and water temperature may alter migration patterns and affect hunting opportunities for Nunavik Inuit.

Climate Variability and Change Effects on Chars in the Arctic (hereafter referred to as `Climate Change Effects on Chars') research is creating a clearer picture of Arctic char life history, diversity and habitat linkages, informing fisheries management work. The baseline monitoring carried out as part of this IPY project will be used to inform an ecosystem-based approach to understanding char and its responses to climate change. Researchers investigated char life history and diversity to provide biological context, and developed community-based monitoring programs in Sachs Harbour, Kuujjuaq and Nain to assess and monitor char biodiversity. Arctic char and related fishes of the genus *Salvelinus* support significant Northern subsistence, recreational and commercial fisheries, and thus contribute to economies, and social and cultural elements of Northern life. Chars are also key indicators of the health of the northern aquatic ecosystems, which are at significant risk from increased climate variability and change. While climate change is anticipated to have both positive and negative impacts on chars, researchers anticipate that climate change will lead to significant shifts in the nature of diversity over the shorter term and an overall decline in populations and diversity over the longer term. Understanding the effects of climate change on the various char species is critical to ensuring the sustainability of these fishes, their continued sustainability as food sources, and the vitality of northern freshwater and nearshore coastal ecosystems.

Led by Environment Canada, with contributions from DFO scientists and other researchers, the **Arctic Freshwater Systems** project assessed the hydrology and ecology of northern freshwater ecosystems, including a range of Canadian Arctic lake, riverine and delta freshwater systems. The results of the study have helped develop a unique database that includes information on aquatic organisms to support and inform an effective freshwater fisheries management program. This IPY project has strong linkages to both the Climate Change Effects on Chars project and the Impacts of Severe Arctic Storms and Climate Change on Arctic Oceanographic Processes project.

Lastly, results from the **Canada's Three Oceans** study predict that ocean warming may draw colonizers from the North Pacific into western Arctic waters, with implications for the rest of the ecosystem/food web and for fisheries management. For example, while Pacific salmon have always existed in the western Arctic, their northward excursions and overwintering are expected to occur more frequently in a warmer Arctic and in an Arctic that is less constrained by physical and ecological barriers to their movement and survival. It has also recently been found that the ecologically pivotal Arctic cod aggregate in the warm, deep

Atlantic water of the Beaufort Sea, exactly where industry wants to develop oil. If Arctic cod and regional ecosystems are affected by climate change and offshore development, there will almost certainly be implications for subsistence harvesting and management of fish and marine mammals in the western Arctic, necessitating adaptation at the community level. Research findings also suggest that the changing characteristics of Arctic marine waters had a negative impact on Atlantic cod off the coast of Labrador during the 1990s. More hard data are required to confirm this, but such information is vital to the assessment of fish stocks and the development of Integrated Fisheries Management Plans.

2.3.2 Habitat Management

Activity Overview

Given its responsibilities under the *Fisheries Act*, the Species at *Risk Act* and the *Canadian Environmental Assessment Act*, DFO is a major federal regulator involved in development projects occurring in or around fresh and marine fish-bearing waters across Canada. The DFO Habitat Management Program contributes to DFO's mandate to conserve and protect fish habitat and sustain valuable fisheries resources. In the context of government-wide initiatives for sustainable development and smart regulations, the Habitat program helps Canadians manage the impacts of non-fishery activities on fish habitat using scientific knowledge and understanding to: develop regulations and policies; provide formal advice and direction; engage with individuals, organizations and other levels of government; and manage compliance. The Habitat Management Program includes: the review, assessment and monitoring of activities in and around water to ensure compliance with the *Fisheries Act*; environmental assessments of proposed projects prior to making regulatory decisions under the *Fisheries Act*; and the provision of expert advice to ensure compliance with the *Fisheries Act*; and the development and implementation of training, information management, outreach, and reporting products and services that support both *Fisheries Act* referrals and environmental assessment activities.

Contribution of IPY Science to Habitat Management

IPY research findings have added to the body of scientific knowledge on northern freshwater and aquatic ecosystems and will serve to inform the review, assessment and monitoring of activities under the *Fisheries Act* referral process and to inform environmental assessments.

The **Global Warming and Arctic Marine Mammals, Pan-Arctic Tagging of Beluga Whales and Climate Change Effects on Chars** projects provide new insights into the distribution, habitat and biodiversity of economically and culturally important marine mammals and fish species. These insights will contribute to habitat management program activities to assess development proposals in the North. For example, new information on the migration routes and distribution of marine mammals informs stewardship strategies in areas with increasing year-round shipping traffic (e.g., Foxe Basin and Hudson Strait).

The IPY project **Impacts of Severe Arctic Storms and Climate Change on Arctic Coastal Oceanographic Processes** Processes (hereafter referred to as 'Impacts of Severe Arctic Storms') is providing valuable information about the potential impact of storms on coastal communities and on offshore resource development activities, which will contribute to the development of climate change adaptation strategies and recommendations relevant to coastal communities. This project investigated the effects of intense storms and severe weather on oceanographic processes in the southern Beaufort Sea and the western Canadian Arctic. Researchers used computer model simulations to

explore the influence of atmospheric circulation patterns, mixing of fresh and salt waters, and expanses of open water on the severity of Arctic storms. Research indicates that large expanses of open water can lead to bigger waves and storms that have more of an impact on fragile coastlines.

The IPY multi-disciplinary **Arctic Freshwater Systems** project helped to assess the hydrology and ecology of northern freshwater ecosystems. This research is improving our understanding of the impacts of climate change on fish habitat and freshwater ecosystems, providing relevant information for inland fisheries important to indigenous peoples. DFO scientist Jim Reist's research under this project focused on documenting distributions, life history and habitat utilization by freshwater and anadromous fish species in the Northwest Territories — information that is critical for assessing the effects of humans on fish habitat. Additional research in which Jim Reist was involved investigated the effects of 'slumping' on tundra lakes. Shoreline slumping occurs when the underlying permafrost thaws and substantive amounts of sediments, organic materials and nutrients enter the lakes. Slumps affect water chemistry and alter levels of productivity in these lakes, as well as levels of fished aquatic species such as lake trout and northern pike.

2.3.3 Integrated Oceans Management

Activity Overview

Fisheries and Oceans Canada has the responsibility under the *Oceans Act* to "…lead and facilitate the development and implementation of plans for the integrated management of all activities or measures in or affecting estuaries, coastal waters and marine waters...". As one of the central principles underlying implementation of Canada's Oceans Strategy, Integrated Oceans Management is a comprehensive approach to planning and managing human activities. Integrated Oceans Management is a collaborative, open process that brings together organizations active in a particular area of the ocean. These players develop Integrated Oceans Management Plans that incorporate social, economic and environmental considerations within decision-making to minimize conflict and to provide a framework for sustainable use.

Integrated Oceans Management provides federal and provincial government authorities, Aboriginal organizations, industry and Canadians with a science-based process that focuses on the development of marine conservation tools (e.g., Marine Protected Areas) and decision-support mechanisms (e.g., Risk Analysis). These products create a strong foundation for ocean management and enhance our regulatory decision-making capabilities.

Scientific products such as the delineation of Ecologically and Biologically Significant Areas (EBSAs) and Ecologically Significant Species and Community Properties (ESSCPs) are some of the important decision-making tools. They are used to bring attention to an area that has particularly high ecological or biological significance and facilitate greater-than-usual risk aversion when managing activities. Ecologically and Biologically Significant Areas are also used to identify potential Marine Protected Areas and are the basis for developing a National Network of Marine Protected Areas across the Arctic.

Contribution of IPY Science to Integrated Oceans Management

IPY science helps build a solid baseline of information for ocean management. Oceanographic and biological data will be an important part of scientific assessments, tool development, and ongoing management related to Marine Protected Area Networks and the development of Integrated Ocean Management Plans and associated

tools (e.g., to inform the proposed Marine Protected Area in Darnley Bay near Paulatuk). In addition to understanding the changing Arctic environment, this new information will allow us to understand the social and cultural impacts associated with climate change and will contribute to climate change adaptation strategies.

Global Warming and Arctic Marine Mammals, Pan-Arctic Tagging of Beluga Whales and Climate Change Effects on Chars research findings provide important information on the distribution, diversity, habitat and trophic interactions of fish and marine mammals — information necessary to inform the Integrated Ocean Management process and to assist in Marine Protected Area Network planning. For example, Global Warming and Arctic Marine Mammals results provided information necessary to identify Foxe Basin as an Ecologically and Biologically Significant Area. Migratory chars use coastal marine habitat during the summer open-water season, confirming the biological significance of such areas.

The **Pan-Arctic Tagging of Beluga Whales** project showed that eastern Hudson Bay beluga make extensive use of offshore areas near the Belcher Islands. This contrasts sharply with the behaviour of beluga whales in western Hudson Bay, which spend the summer very close to shore.

Similarly, the IPY project **Determining the Diet of the Greenland Shark in a Changing Arctic** is providing new information on the distribution of Greenland sharks, which will help inform scientific assessments and future planning processes. The Greenland shark is one of the largest species of shark and one of only two shark species that regularly inhabit the Arctic seas. DFO research scientist Steven Campana is working in collaboration with researchers at the University of Windsor to satellite tag Greenland sharks in the eastern Arctic to monitor their movements, and to record water depth and temperature. Early results show that sharks migrate more than 1,000 kilometres and dive to depths of up to one kilometre, indicating that they are much more mobile than was previously thought.

Through the IPY project **Polar Ecosystems in Transition: An Interdisciplinary Case Study of the Effects of Climate Change on Polar Bears (*Ursus maritimus*)**, DFO scientists collaborated with scientists from universities, other government departments and U.S. colleagues to investigate the effects of climate change on temporal trends in contaminant accumulation, foraging ecology and human use of polar bears. This project provides a better understanding of the top-down effects of polar bear predation on seals and fish-trophic linkages. DFO's participation in the project was focused on the movements, haul-out and foraging behaviour of ringed seals in greater Hudson Bay. The results provide important information on the Hudson Bay and Foxe Basin ringed seal stocks, which will assist in the decision-making needed to maintain biodiversity in the face of changing environmental conditions.

The fundamental element of ecosystem-based ocean management is knowledge of the ocean's physical and chemical environment. The basic properties of seawater (temperature, salinity, dissolved oxygen, nutrients and density structure) and the processes that maintain these properties (inflows, outflows, phase changes, mixing and energy balance) support the life within it. During the IPY, the **Canadian Arctic Through-flow Study** established, for the first time, an ocean properties observing system that spanned the Canadian Arctic — from north Greenland to the Beaufort Sea. This study has provided fundamental

information on Canadian Arctic through-flow, a critical link in the global freshwater cycle. Canadian Arctic through-flow carries to the Atlantic most of the freshwater delivered to the Arctic via rivers, rain and snow. It also delivers abundant nutrients essential to the marine life of the productive ecosystems of the Canadian east coast, both Arctic and temperate. New knowledge of the physical environment that is emerging from the Canadian Arctic Through-flow Study, and new tools for ice-ocean instrumentation, ice-ocean modelling and monitoring of a zooplankton biomass index have a strong potential impact on ecosystem-based ocean management.

Environmental assessment, regulatory decisions and ocean management in the Arctic, and particularly the Beaufort Sea, are concerned with estimates for extremes in waves, winds, ice and currents. The **Impacts of Severe Arctic Storms** project provides models that can generate statistics for present and future extremes in environmental variables, with explicit consideration for present warming Arctic and retreating sea ice conditions. The **Canada's Three Oceans** study acquired year-round observations of ocean surface conditions in the Beaufort Sea, providing data on waves, storm surges, sea ice and currents for validation of these forecast models. This information is suitable for offshore oil and gas stakeholders, and is of concern for Northern community members.

The **Carbon Cycle in the Canadian Arctic and Sub-Arctic Continental Margin** project uses sediment records from several Arctic margins to provide important information for understanding organic carbon and assessing baseline (pre-development, pre-change) conditions. For example, baseline information about how organic carbon is fed to benthic (at the bottom) or pelagic (within the water) systems allows scientists to assess where the most productive systems are and how climate change will potentially affect them. The early results demonstrate that there are strong regional contrasts in sediment processes and sources (e.g., land versus marine and in the overall chemical composition of the sediments). For example, the examination of manganese in sediment cores helps to determine how organic matter metabolizes using oxygen. In the absence of oxygen in the sediments, manganese becomes soluble; thus, it can be re-precipitated as it encounters dissolved oxygen. Therefore, changes in future climate such as increasing sea level, melting permafrost and coastal erosion may alter the preservation and remineralization of these elements.

IPY results provide valuable insights into the changing climate so that marine conservation tools and decision support tools are developed with the best available science, and the decisions we make today can be successfully measured tomorrow.

2.3.4 Ocean Forecasting

Activity Overview

As a maritime nation bordered by three oceans and with an extensive network of inland waters, Canada has a vested interest in understanding ocean processes to enable the prediction of ocean conditions and sea state, as well as their influence on other earth systems such as global climate. This is accomplished through research and the long-term monitoring of key ocean parameters (e.g., temperature, sea level, nutrients, tides, salinity, etc.) via: space-based, aerial and autonomous vehicles; vessel-based observations; and the management of data to ensure their integrity and accessibility. These data provide the foundation for ocean prediction products, services and information used to inform safe navigation, emergency preparedness (e.g., tsunami warnings, storm surges), adaptation to climatic change, search and rescue, the mitigation of oil spills, and at-sea operations such

as offshore oil and gas. Users of this information include the Canadian Coast Guard, other federal government departments and agencies (e.g., Environment Canada, Department of National Defence, Transport Canada, Public Safety Canada), various maritime industries (e.g., commercial shipping, offshore oil and gas, fishing industry), the Canadian and international marine science community, and interested Canadians.

Contribution of IPY Science to Ocean Forecasting

Several of the IPY projects directly contribute to furthering our understanding of ocean processes, especially by contributing to ocean models. The Canadian Arctic Through-flow Study and Canada's Three Oceans projects, both led by DFO research scientists, are excellent examples of this contribution. The Circumpolar Flaw Lead System Study, Impacts of Severe Arctic Storms, Carbon Cycle in the Canadian Arctic and Sub-Arctic Continental Margin, and Canadian Arctic Surface Ocean – Lower Atmosphere Study also help us make sense of current Arctic conditions and potential impacts of climate change.

The **Canadian Arctic Through-flow Study** has had a strong impact on the development of improved regional marine forecasts for the Arctic and will support future marine ecosystem forecasts. The Canadian Arctic Through-flow Study measured the flow of freshwater, sea water and sea ice passing from the Arctic to the Labrador Sea through the Canadian Arctic Archipelago. As a component of the international Arctic/Sub-Arctic Ocean Fluxes project, the project team installed recording instruments in four ocean gateways between the Arctic and the Atlantic for the two years of the IPY to monitor ocean currents, salinity, temperature, and ice drift and thickness. In addition to new ice and weather observations, the study sponsored the development and use of models in a variety of contexts, such as regional ocean circulation. These models are in line to become the ice-ocean components of the Canadian Meteorological Service's regional weather forecast model and the Canadian Ice Service's ice-forecast model. Such developments will provide improved forecasts of weather and ice conditions for Arctic communities and industrial activities. The models will have the capability to facilitate Arctic search and rescue and oil-slick tracking. In addition, the physical ice-ocean model will become the driver for biological production models being developed within DFO, government institutions and Canadian universities.

The waters from the Pacific flow through the Arctic Ocean and out to the Atlantic, representing a great continuum of water moving around our country. Understanding the role of the interconnected oceans in regulating climate as well as the changes that are taking place is fundamental to understanding climate change. In partnership with the Joint Ocean Ice Study, the Canada's Three Oceans team collected a substantial amount of physical, chemical and biological data along a 15,000 kilometre stretch of water from the surface to the seabed. IPY funding provided a unique opportunity to create a focused program of data collection to create a proper baseline for assessing change in the Arctic. To carry out the research, team members boarded two Canadian Coast Guard icebreakers over the course of their missions. Canada's Three Oceans lead researcher Eddy Carmack recently submitted two publications (Carmack et al. 2010; Carmack and McLaughlin 2011) that describe the current understanding of the physical, chemical and biological linkages of the three oceans. The measures of ongoing change are:

- redistribution of oceanic boundaries and habitat
- hypoxia (i.e., areas of low oxygen)

- ocean warming and sea ice melting
- increased acidification
- altered food web dynamics and biogeography

In the Circumpolar Flaw Lead System Study project, for which DFO scientist Gary Stern was a co-lead and worked in partnership with ArcticNet, findings have provided valuable knowledge about climate processes within the changing flaw lead system of the Beaufort Sea. Research data will be used to produce an ecosystem model to forecast changes in sea ice, since this will affect the overall Arctic aquatic ecosystem. The Circumpolar Flaw Lead project examined the importance of climate processes in changing the nature of a flaw lead system[10] and the effect of these changes on the marine ecosystem, contaminant transport, carbon fluxes and greenhouse gases. Ten science teams focused on different components, such as physical oceanography, sea ice, food webs and contaminants. Sampling was done throughout a full annual cycle, which allowed comparison of seasonal variability within the flaw lead. Researchers have produced a publication on the changes of the perennial pack ice in the southern Beaufort Sea during the summer of 2009. Results indicate that sea ice is decaying faster than anticipated.

In addition to the strong ties with the IPY Arctic Freshwater Systems: Hydrology and Ecology project led by Environment Canada, the **Impacts of Severe Arctic Storms** strongly complements Canada's Three Oceans research. One focus of the Impacts of Severe Arctic Storms project was to model sea ice and the behaviour of sea ice on different time scales.

A model was used to estimate currents, including coastal interactions with the Mackenzie River plume. This approach can be further developed as a basis to study interactions between the coastal shelf and the shoreline for studies of future oil spill trajectories. The **Canada's Three Oceans** project collected oceanographic data in the Beaufort Sea that were used to validate the forecasting models. Information from this project will contribute to the development of climate change adaptation strategies relevant to coastal communities, and will contribute to development assessments for offshore resource development and future port/onshore infrastructure.

The **Carbon Cycle in the Canadian Arctic and Sub-Arctic Continental Margin** project gathered carbon cycling data to address knowledge gaps in the Arctic margin sediments (e.g., those found in Davis Strait, Baffin Bay, the Canadian Arctic Archipelago, and the Beaufort, Chukchi and Bering Seas). Led by researchers at the Université du Québec, with involvement of DFO senior research scientist Robie Macdonald, this IPY project involved the collection of sediment cores for analysis of trace elements (e.g., iron, sulphur) and organic biomarkers (e.g., terrestrial plant products). The research is helping to determine the Arctic Ocean's role in the carbon cycle, baselines against which future changes (e.g., those caused by development or climate change) will be measured, and what future system changes will be caused by alterations to the carbon cycle. It is also examining biogeochemical cycles that have consequences for the productivity of the Arctic shelves.

The Canadian Arctic Surface Ocean – Lower Atmosphere Study looked at how the biologically produced trace gases nitrous oxide (a "warming" greenhouse gas) and dimethylsulfide (a "cooling" gas) may be affected

[10] A 'flaw lead' is an area of persistently open water between land-fast ice and pack ice during winter.

by changes in sea ice and ocean circulation. Oceanic processes control dimethylsulfide production and thus play an important role in the formation of dimethylsulfide-derived atmospheric aerosols that enhance cloud formation and scatter sunlight. Ecosystem models show how a warmer Arctic may increase the emission of dimethylsulfide, which may then offset warming through this negative feedback. In the case of nitrous oxide, the Arctic presently appears to be a small source, though it may increase in importance with a warming climate.

2.3.5 International Affairs

Activity Overview

Through engagement with international partners, DFO's International Affairs program:

- promotes and protects the interests of Canadians by ensuring their access to fish resources that are managed internationally;
- promotes and influences sustainable regional fisheries management and healthy global marine ecosystems; and
- contributes to a stable international trade regime for Canadian fish and seafood products.

The program uses a coordinated and proactive approach that reflects domestic positions and interests, including the Government of Canada's international priorities, leading to broad and constructive relationships with international partners. This approach is grounded in the Department's scientific expertise and best management practices. Many Canadians directly benefit from internationally managed fish stocks, and the Canadian seafood sector as a whole heavily relies on international trade. As Canada also shares three oceans, effective relations and collaboration with international, regional and domestic partners are essential to addressing fisheries and ecosystem challenges, and to advancing international standards, agreements and management decisions that reflect Canadian approaches.

As identified in DFO's International Science Strategy, DFO Science plays a key role in achieving the program outcomes of DFO's international agenda by providing the foundation for improved science-based decisions and policies, and by producing navigational safety products and emergency advice.

Contribution of IPY Science to International Affairs

IPY projects contribute to establishing and enhancing relationships with national and international partners, as well as providing data for international initiatives.

Results from five IPY projects (**Global Warming and Marine Mammals, Canada's Three Oceans, Climate Change Effects on Chars, Arctic Freshwater Systems and Polar Ecosystems in Transition**) are contributing to several Arctic Council initiatives. Initiatives by the Conservation of Arctic Flora and Fauna working group include the Circumpolar Biodiversity Monitoring Program and the Arctic Biodiversity Assessment. The Circumpolar Biodiversity Monitoring Program is the cornerstone program of the Arctic Council's Conservation of Arctic Flora and Fauna working group. Similarly, principal investigators and results from these IPY projects also contributed to the Arctic Monitoring and Assessment Programme working group assessments on the cryosphere (i.e., Snow, Water, Ice and Permafrost in the Arctic – SWIPA) and mercury (to be produced in 2012). Additionally, ocean acidification data from Canada's Three Oceans, the **Canadian Arctic Through-flow Study and the Circumpolar Flaw Lead System Study** is being used by the Arctic

Council's Arctic Monitoring and Assessment Programme in an ongoing assessment of Arctic Ocean acidification. Results from the **Climate Change Effects on Chars** project also contribute to the annual Arctic Report Card (ecosystems section), which provides a regular international perspective on the "state of the Arctic."

Research findings from the **Canadian Arctic Through-flow Study and the Circumpolar Flaw Lead System Study** are contributing to sea ice and ocean statistics that are used by international climate modellers to forecast climate, for example, under the Arctic Ocean Model Intercomparison Project. The Arctic Ocean Model Intercomparison Project has contributed to the development and assessment of Arctic models used to prepare scenarios for the fourth report of the Intergovernmental Panel on Climate Change.

The IPY research is also helping to contribute to the international trade of Canadian fish and seafood products. Results from the IPY project **Engaging Communities in the Monitoring of Zoonoses for Country Food Safety Concerns in Canada** have potential links to the opening of new commercial fisheries in the North and the export of other Northern products, including seal and shellfish. The focus of this research (led by the Nunavik Research Centre of the Makivik Corporation, with DFO collaboration) is to test fish and marine mammals for parasites in order to determine potential impacts of food-borne diseases on both host animals and people, as well as to train local people in wildlife sampling and diagnosis of the diseases of interest. Results were recently used by Canadian negotiators to inform Chinese officials that Canadian seal products are safe and fit for human consumption, which was important information to enable trade of Canadian products.

Global Warming and Marine Mammals results indicate potential management implications of increasing killer whale predation on the internationally shared eastern Canada-western Greenland bowhead population. Both Greenland and Canada harvest bowhead whales from the same population. Stock assessment models developed by the Joint Commission on Narwhal and Beluga and North Atlantic Marine Mammal Commission do not currently take into account natural killer whale predation, and results indicate that the predation rate may be increasing as sea ice is lost.

Many of the IPY projects involve collaboration with international researchers and governments. For example, the **Canadian Arctic Through-flow Study** has established a network of researchers from universities and research institutes in the U.S. (e.g., Oregon State University, University of Delaware), the U.K. (University of Oxford, University of Southampton), Scotland (Scottish Association for Marine Science), Denmark (Technical University of Denmark) and China (Ocean University).

Likewise, the **Climate Change Effects on Chars** project and complementary DFO char research has led to strong linkages with academic and government institutions in Norway with the 'cross-fertilization' of graduate students, with Russian collaborators on chars from eastern Siberia, with U.S. researchers investigating genetic diversity in transboundary chars, and with Swedish, Icelandic and Finnish collaborators on international assessments. This collaboration leads to innovative science and new understanding, including of the mechanisms by which diversity in chars is created and maintained, the functional role of that diversity in high latitude ecosystems, and how climate change may shift the diversity. This understanding enhances adaptation options for the future sustainability and management of chars throughout the Arctic.

3. Conclusion

This report demonstrates the substantial value of DFO's involvement in IPY as a means to contribute to departmental policies and program management priorities, including Integrated Fisheries Resource Management, Habitat Management, Integrated Ocean Management, Ocean Forecasting and International Affairs. Early IPY results are also drawing attention to new and unexpected changes occurring in Arctic ecosystems, with implications for harvesting, resource and habitat management, and climate change adaptation, among other policy priorities. IPY science has advanced our scientific knowledge and understanding of the major changes taking place in Canada's Arctic, as well as our state of knowledge on northern ecosystems. Specifically, IPY research has provided us with a proper baseline of physical, chemical and biological parameters for assessing change in the Arctic. This information will provide fertile ground for real improvements in ocean management capability over the next decade, provided that staff and resources are applied to the undertaking and that observations continue to be collected to detect changes from the baseline status. Going forward, DFO needs to build on this work to improve our understanding of the Arctic Ocean's physical environment, processes and ecosystems in order to analyze trends, refine models and predictions, and contribute to departmental management and decision-making under changing Arctic conditions.

Focus on Climate Change Adaptation Broadens
Photo: DFO

Building on its successes under the "Climate Change" theme during IPY and its Climate Change Science Initiative, Fisheries and Oceans Canada's focus has become broader, and is focused on assessing the risk and vulnerabilities from climate change to develop adaptation strategies for Canadian aquatic ecosystems. On November 8, 2011, the Honourable Peter Kent, Minister of the Environment announced "that the Government of Canada will spend $148.8 million over the next five years to help our country adapt to climate change". Acknowledging Canada's status of a maritime nation, $16.5 million will be used by the Department of Fisheries and Oceans to implement a risk-based program, focused on DFO's mandated areas of responsibility, and designed to advance its knowledge and understanding of climate change risks, impacts and opportunities. The program will provide an avenue for the Department to mainstream climate adaptation science into its decisions. In this way, Canadians can be confident that the Government of Canada acknowledges and is responding to the challenges surrounding climate change in Canada's expansive aquatic resource.