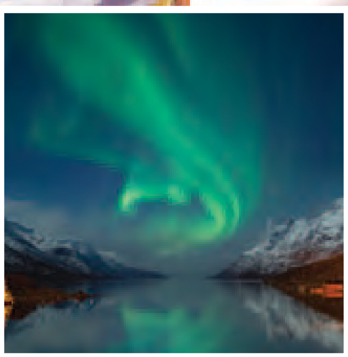
INTERNATIONAL POLAR YEAR CANADIAN SCIENCE REPORT:

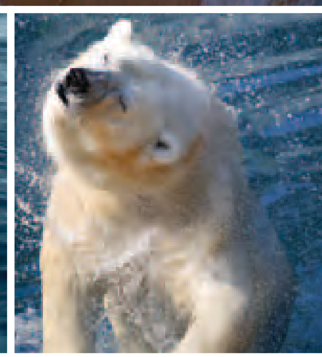
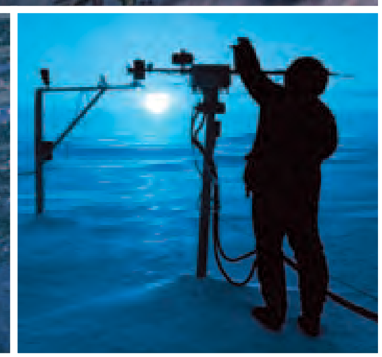
highlights

Canadian Polar Commission
Commission canadienne
des affaires polaires

2007·2008 IPY·API

Canada

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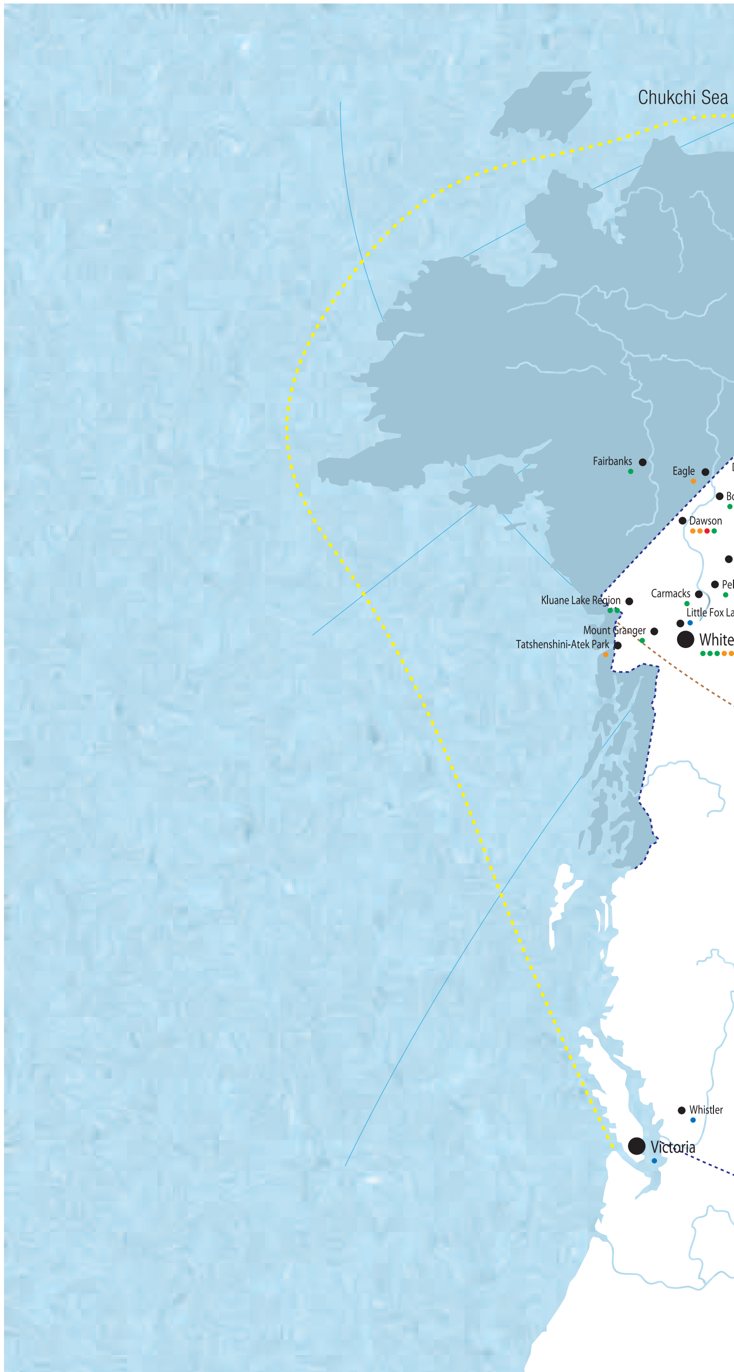

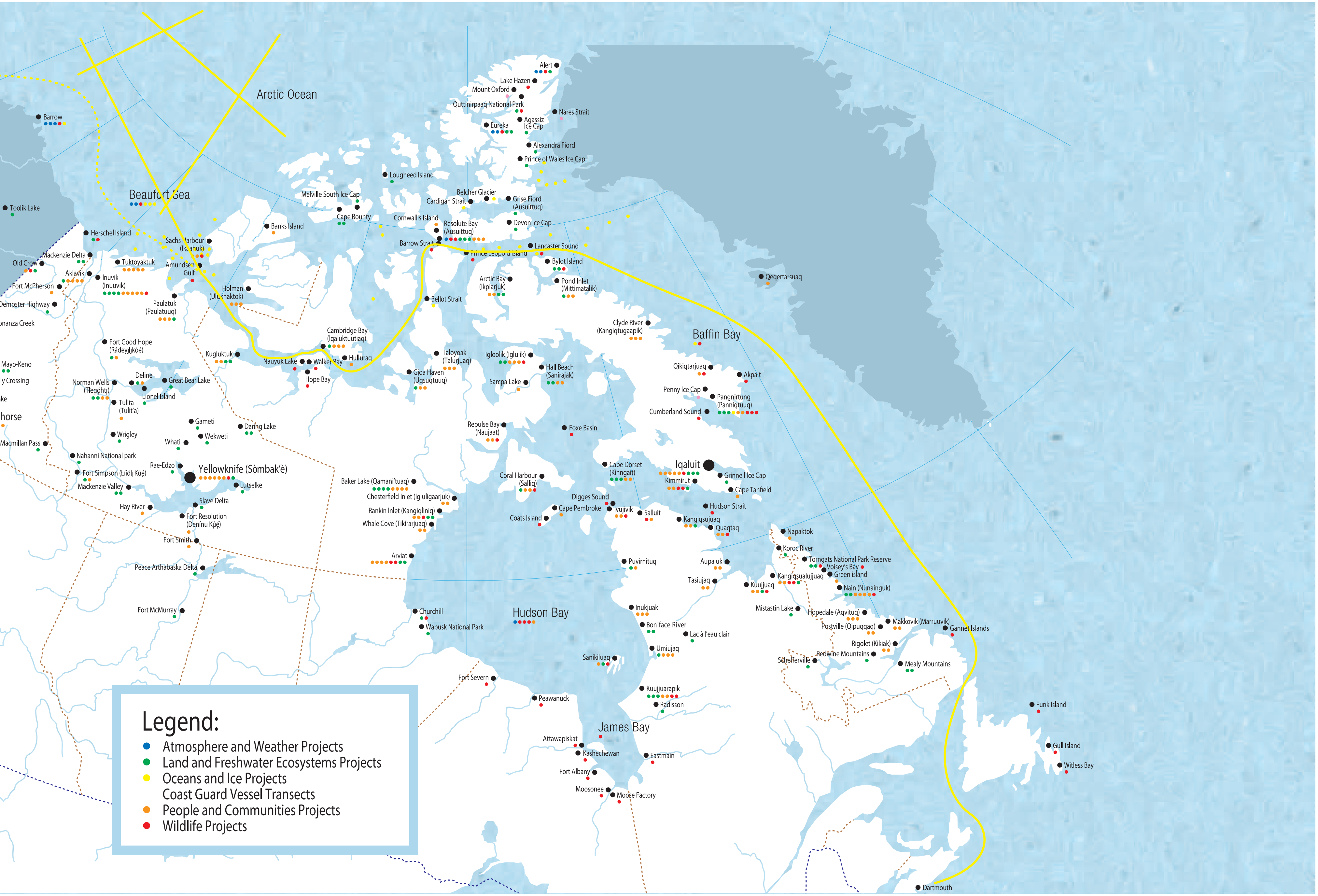

Arctic Ocean
Beaufort Sea
Baffin Bay
Hudson Bay
James Bay
Legend:
Atmosphere and Weather Projects
Land and Freshwater Ecosystems Projects
Oceans and Ice Projects
Coast Guard Vessel Transects
People and Communities Projects
Wildlife Projects
Alert
Lake Hazen
Mount Oxford
Quttinirpaaq National Park
Nares Strait
Agassiz Ice Cap
Eureka
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Prince of Wales Ice Cap
Lougheed Island
Belcher Glacier
Cardigan Strait
Grise Fiord (Ausuittuq)
Melville South Ice Cap
Cape Bounty
Cornwallis Island
Resolute Bay (Ausuittuq)
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Prince Leopold Island
Lancaster Sound
Bylot Island
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Qeqertarsuaq
Clyde River (Kangiqtugaapik)
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Banks Island
Herschel Island
Sachs Harbour (Ikaahuk)
Mackenzie Delta
Old Crow
Tuktoyaktuk
Amundsen Gulf
Aklavik
Inuvik (Inuuvik)
Fort McPherson
Dempster Highway
Holman (Ulukhaktok)
Paulatuk (Paulatuuq)
Cambridge Bay (Iqaluktuutiaq)
Fort Good Hope (Rádeyįlįkóé)
Kugluktuk
Nauyuk Lake
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Hall Beach (Sanirajak)
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Akpait
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Cumberland Sound
Mayo-Keno
Norman Wells (Tłegóhłı)
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Great Bear Lake
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Repulse Bay (Naujaat)
Foxe Basin
Macmillan Pass
Nahanni National park
Rae-Edzo
Yellowknife (Sǫmbak'è)
Fort Simpson (Łíídlįį Kų́ę́)
Mackenzie Valley
Lutselke
Slave Delta
Hay River
Fort Resolution (Deninu Kų́ę́)
Fort Smith
Baker Lake (Qamani'tuaq)
Chesterfield Inlet (Igluligaarjuk)
Rankin Inlet (Kangiqliniq)
Whale Cove (Tikirarjuaq)
Arviat
Coral Harbour (Salliq)
Cape Dorset (Kinngait)
Iqaluit
Kimmirut
Grinnell Ice Cap
Cape Tanfield
Digges Sound
Cape Pembroke
Ivujivik
Salluit
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Quaqtaq
Coats Island
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Torngats National Park Reserve
Voisey's Bay
Green island
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Nain (Nunainguk)
Puvirnituq
Aupaluk
Tasiujaq
Kuujjuaq
Peace Arthabaska Delta
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Churchill
Wapusk National Park
Inukjuak
Mistastin Lake
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Makkovik (Marruuvik)
Gannet Islands
Postville (Qipuqqaq)
Boniface River
Lac à l'eau clair
Umiujaq
Rigolet (Kikiak)
Redwine Mountains
Schefferville
Mealy Mountains
Sanikiluaq
Fort Severn
Kuujjuarapik
Radisson
Peawanuck
Funk Island
Attawapiskat
Kashechewan
Eastmain
Gull Island
Witless Bay
Fort Albany
Moosonee
Moose Factory
Dartmouth

Message from the Minister

Aboriginal Affairs and Northern Development

As Minister of Aboriginal Affairs and Northern Development, I am pleased to welcome the 2012 International Polar Year (IPY) "From Knowledge to Action" conference to Canada.

Our government's vision for Canada's North is clear — we must exercise our Arctic sovereignty, and pursue environmentally sustainable economic and social development in the North, while improving and devolving Northern governance. This is laid out in our government's Northern Strategy, which was announced by Prime Minister Harper in 2008, and has been a guiding set of principles for our government.

A major national and international achievement has been our involvement in the IPY program, which has led to a commitment for construction of a state-of-the-art High Arctic research station. We are proud to be hosting the third and final IPY Conference in April 2012, in Montreal, which will serve as an opportunity to highlight the latest polar research and discuss how this new knowledge can be used to advance programs and policies. I would like to acknowledge the Canadian Polar Commission's role in communicating Canada's polar research results at home and abroad since 1991. Their contributions have been instrumental in the success of IPY.

The theme of this final conference, "From Knowledge to Action", places a timely focus on our need to adapt to our changing world and prosper from the opportunities offered by the North. We will be bringing together a broad range of key players from around the world to share evidence-based knowledge, and discuss innovative ways of further incorporating the North into the world economy. Canada is proud to be hosting the final conference, which will build on the momentum of the 2010 conference in Oslo, and which will be a pivotal milestone in Northern relations, global decisions, policies and outcomes moving forward.

Canada's North is a fundamental part of our national identity and of the world's economic future. Our government continues to work with territorial and Aboriginal leaders, Northerners, and international partners to ensure that our North remains a prosperous and secure region within a strong and sovereign Canada. Through our Northern Strategy, we are working to unlock the resource potential of the North, and to ensure long-term, sustainable benefits for Northerners and for all of Canada.

The Honourable John Duncan

Message from the Chairperson
Canadian Polar Commission

The Canadian Polar Commission is pleased to have been a major proponent of International Polar Year 2007-2008 (IPY), and I would like to acknowledge my predecessors at the Commission for their contributions to Canada's resounding IPY success.

International Polar Year 2007-2008 represents the pinnacle of nearly 130 years of progress in Canadian polar research. Our country was only 15 years old when International Polar Year began in 1882-83. Some foreign scientists did research here, but few Canadians. The second IPY, in 1932-33, saw young Canadian atmospheric physicists launching research balloons and kites over Chesterfield Inlet, unaware that just a few years later, during IPY 1957-58 (International Geophysical Year), their expertise would enable them to help usher in the space age.

Fifty years later, International Polar Year 2007-2008 constituted a massive research effort with hundreds of Canadian scientists working closely with international colleagues — and, notably, with northern indigenous peoples and communities. Unlike earlier polar years, IPY 2007-2008 included major research activities related directly to the human dimension of the Arctic. This report offers you a glimpse of their discoveries, which will set the course of polar research and inform policy choices for decades.

Much lies unseen behind research findings: the sometimes gruelling work, the day-to-day field challenges that build experience and understanding, the exhilaration of discovery; the new perspectives gained by northerners looking at their homeland through the lens of research, the new partnerships, networks and friendships; that pivotal moment when a student catches the polar research bug. These too are important results of IPY.

In the years between each IPY, major events, discoveries and innovations have rearranged the human world. We can expect more. This IPY has boosted our knowledge of the Arctic and Antarctic — Earth's least understood and fastest changing regions — and will help humanity negotiate the challenges, known and unknown, of the coming decades. Congratulations to all participants on their magnificent achievement.

Bernard W. Funston

About the Canadian Polar Commission

Established in 1991, the Canadian Polar Commission has responsibility for: monitoring, promoting and disseminating knowledge of the polar regions; contributing to public awareness of the importance of polar science to Canada; enhancing Canada's international profile as a circumpolar nation; and recommending polar science policy direction to government. In carrying out its mandate, the Commission hosts conferences and workshops, publishes information on subjects of relevance to polar research and works closely with other governmental and non-governmental agencies to promote and support Canadian study of the polar regions.

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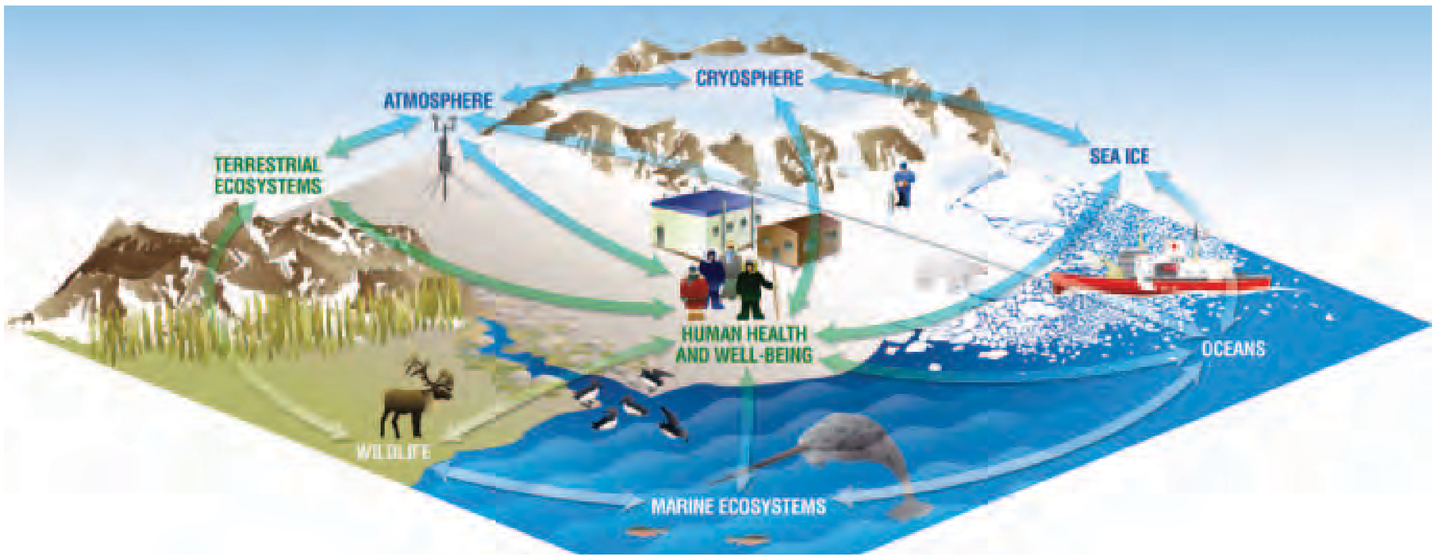
Introduction

Why IPY?



The Arctic and Antarctic are the fastest and among the most dramatically changing regions of the planet. Far-reaching global environmental issues — such as climate change, rising sea levels and the storage and release of carbon — all trace back to what is now happening in the polar regions. As barometers of environmental change and archives of what Earth was like in the past, the Arctic and Antarctic are hard to beat.

For good reason, there was a sense of urgency and purpose to the fourth International Polar Year (IPY). As the largest international scientific collaboration to study the polar regions, IPY brought together tens of thousands of researchers from more than 60 nations. Supported jointly by the World Meteorological Organization and the International Council for Science, IPY 2007-2008 consisted of more than 200 research projects in the biological, geophysical and social sciences. The projects involved archaeological excavations, surveys of the biodiversity of polar ecosystems, studies of ocean chemistry and analyses of how climate change will affect polar communities.

IPY 2007-2008 continued a 125-year-old tradition of international scientific collaboration. The first International Polar Year, held in 1882-1883, united various independent expeditions to the far reaches of the planet into an international effort to study meteorology, earth magnetism and the aurora. The theme of international cooperation prevailed in the second IPY in 1932-1933 and in the IPY-inspired International Geophysical Year (IGY) in 1957-1958, which set in motion the signing of the Antarctic Treaty to protect the continent from military activities. IPY 2007-2008 was timed to coincide with the 125th anniversary of the first IPY, the 75th anniversary of the second IPY and the 50th anniversary of IGY.

IPY 2007-2008 was a timely effort to understand how the effects of climate change in the Arctic and Antarctic would affect the rest of the planet. It set the stage for continued studies of the polar regions and offered a platform for early career scientists to launch their research. As part of its legacy, IPY continues to offer open-access data from its monitoring and research activities.

Canada played an important role in IPY. After all, nearly one-quarter of the Arctic falls within Canada's boundaries; more than half of our coastline is in the Arctic. Canada's IPY program took place between March 2007 and March 2009, allowing for two field campaigns of intensive activity by more than 1,750 researchers from government agencies, universities and northern communities.

The Government of Canada Program for IPY dedicated $150 million to support 45 research projects. In addition, the Natural Sciences and Engineering Research Council of Canada (NSERC) funded 11 IPY projects. Four of the projects received funding from both the Government of Canada Program and NSERC, bringing the total to 52 science projects.

Researchers in the field worked at more than 100 sites across Canada's North and aboard five Canadian Coast Guard icebreakers. They focused on two key areas: climate change impacts and adaptation, and the health and well-being of northern communities. Researchers were encouraged to use interdisciplinary approaches and to meld traditional knowledge and science.

Each Canadian research project was required to be relevant to the needs of northern communities, involve Northerners in planning and implementing the research and include an element of capacity building for students and communities. Indeed, unlike previous IPYs, IPY 2007-2008 included people from the circumpolar world in the planning and execution of research projects, a recognition that local populations in the circumpolar world now have more control over their lives through land claim settlements and self government.

The Canadian Polar Commission was instrumental in establishing Canada as a major player in IPY 2007-2008. It sought input from the polar research community and northern communities on how Canada should participate in IPY. The Polar Commission also established and supported the National IPY Committee and Secretariat to receive research proposals and oversee the projects.

These efforts will continue to bear fruit for Canadians in the North and South as the scientific results of Canada's IPY projects will inform policy, programs and practices and contribute to a better understanding of the state of the polar regions.

Sections

IPY by the Numbers

228 projects
were undertaken through IPY 2007-2008, with 170 dedicated to science and 57 to education and outreach

$156 million
of funding were provided by the Government of Canada and the Natural Sciences and Engineering Research Council of Canada for IPY 2007-2008

1,000
previously unknown marine species were discovered through IPY research. Of these, around 25 percent were found to be common to both polar regions

1,800
Northerners — and 215 students from Canada's North — contributed to IPY projects as researchers, technicians and field guides

8 science projects were led by Northerners

240
international researchers from 23 countries were involved in Canadian IPY projects

8 international IPY research networks were led by Canadians

9 delegates
attended the first International Polar Conference held in Germany in 1879 to plan the first International Polar Year

2,500 delegates
are expected to participate in the IPY conference From Knowledge to Action in Montreal in April 2012

Atmosphere

The case of the missing mercury and other polar mysteries

When spring arrives in the Arctic, mercury disappears from the atmosphere.

During springtime, something strange happens in the Arctic sky: the chemical element mercury disappears from the atmosphere, only to return when the sun falls below the horizon. Spring also happens to be the time of year when low-level ozone, a greenhouse gas, depletes. What do these events mean for the Arctic environment?

Canadian scientists on the IPY OASIS (Ocean-Atmosphere-Sea Ice-Snowpack) project set out to better understand the processes behind the seasonal disappearance of mercury and ozone. OASIS was one of several ambitious IPY atmosphere and weather projects that gathered year-round data and studied everything from the pollution pathways in the Arctic to the impact of severe Arctic storms on the upper ocean and coastal zones.

In the case of OASIS, there is an urgency to understand how and where mercury, a powerful neurotoxin, travels in the Arctic, whether in the atmosphere, on the snow pack or in the ocean. If it disappears in the spring, where does it go?

Key Findings

- Large-scale ozone and mercury depletion over the Arctic Ocean was confirmed.
- Global warming may cause pollutants embedded in the Arctic environment to be released, undermining efforts to reduce environmental and human exposure to toxic chemicals.
- Frost flowers — salty ice crystals that grow on newly-formed Arctic sea ice in cold, windless weather — influence chemical interactions between the ocean and the atmosphere.
- Much more deposited mercury appears to be retained over sea ice than over land-based snowpack.

OOTI and O-buoy

Thanks to earlier observations at Alert, Nunavut, the world's most northerly atmospheric observatory, scientists know that ozone and mercury disappear in the atmosphere with the arrival of the polar spring; subsequent research indicated that these events are related to chemical reactions with bromine that comes from sea salt. Bromine reacts differently with ozone and mercury. Bromine atoms destroy ozone molecules, but combine with mercury to create a different chemical state of mercury that readily deposits on snow and ice surfaces.

Many of the details of the chemical processes at play, however, are not well understood, and this was not helped by the scarcity of on-site measurements far out over the Arctic Ocean.

The OASIS team set out to determine whether these springtime events, already observed at inland snowpacks, differed on the sea ice and close to ice leads. To do that, they had to be resourceful. The scientists developed OOTI (Out on the Ice), a miniature atmospheric chemistry and physics laboratory, mounted on a sled for rapid deployment by snowmobile, and O-buoys, an ice-tethered buoy equipped with ozone and carbon dioxide gauges.

Processing the volumes of data collected, the scientists found that there is significantly more mercury in the atmosphere over the sea ice than is generally observed inland. Models estimating the contribution of mercury from the atmosphere to the Arctic Ocean and the Arctic as a whole may need to be reevaluated.

As for ozone, the scientists did observe springtime depletion over the Arctic Ocean, and in many instances there seemed to be a link with bromine levels. But the evidence was conflicting: ozone was not always destroyed in the presence of very high bromine levels. Scientists are also unsure whether or how these events may be linked to either high pressure systems or temperature.

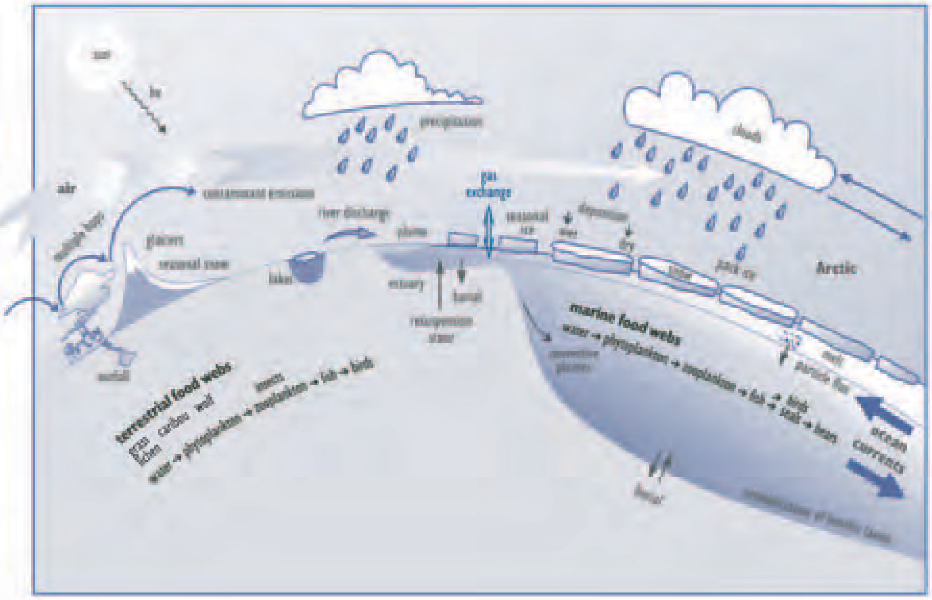
Another Canadian IPY project, Intercontinental Atmospheric Transport of Anthropogenic Pollutants to the Arctic (INCATPA), took a closer look at data relating to mercury depletion in the atmosphere that were collected at Alert between 1995 and 2007. INCAPTA scientists found that these events have been occurring earlier in the spring in recent years.

Scientists install a weather station on the Devon Ice Cap, Ellesmere Island.

Polluted air masses from the south take only a few days to reach the central Arctic.

At the PEARL research station, scientists took year-round measurements of the entire atmospheric column, from ocean surface to stratosphere.

Contaminant pathways to the Arctic.



Pathways of pollution

How might climate change affect the distribution of pollutants, such as polychlorinated biphenyls (PCBs), in the North?

The atmosphere is considered the primary and most rapid pathway of pollutants migrating to the Arctic. Polluted air masses can take only a few days to travel from source regions into the central Arctic region. Once deposited, toxic chemicals such as PCBs, organochlorine pesticides and mercury can be deposited onto the Arctic's surfaces and accumulate in wildlife, country foods and northern people, which may result in negative health impacts.

Scientists speculate that when the Arctic warms and sea ice retreats, previously deposited pollutants may be freed from snow, ice and soil back into the atmosphere. Mercury in meltwater may enter Arctic lakes and oceans where it can be converted to methylmercury and bioaccumulate through the food chain. Indeed, IPY researchers did detect this phenomenon over open water in Hudson Bay and the Beaufort Sea, where mercury re-circulated.

Trying to predict how pollution may track through the Arctic atmosphere in the future requires robust models that incorporate many factors. To a large degree, these models are being built with data harvested from the Polar Environment Atmospheric Research Laboratory (PEARL), located on Ellesmere Island at Eureka, Nunavut.

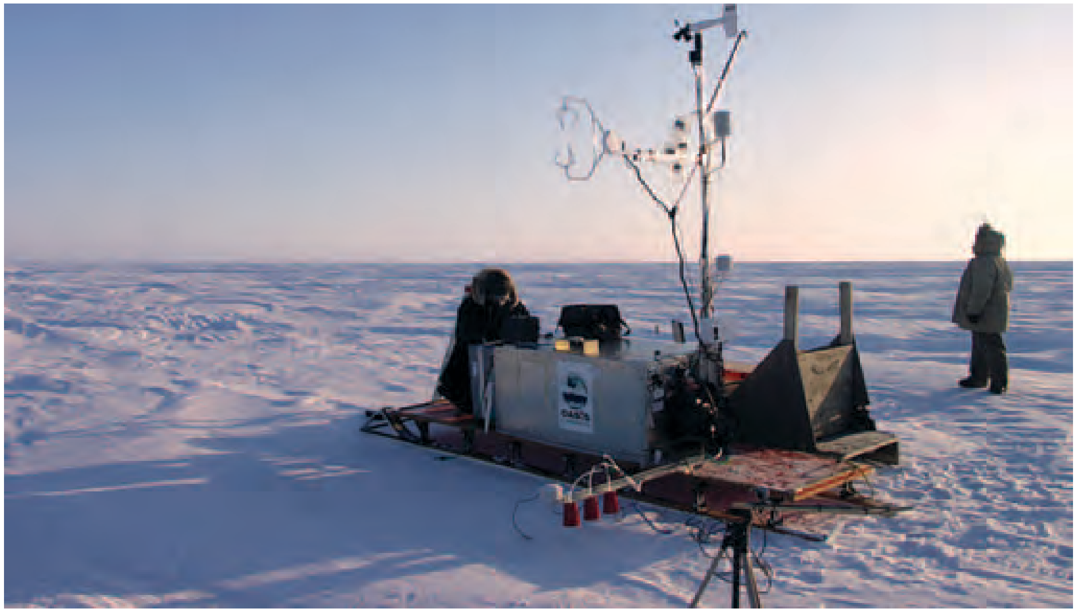
PEARL is considered a "whole atmosphere" laboratory. At PEARL, scientists can take year-round measurements of the entire atmospheric column from ocean surface to stratosphere, probing its physical states and composition, including the presence of ozone and related gases.

At PEARL, IPY scientists tracked the spread of smoke and pollution from the lower part of the atmosphere to the upper part, where particles can affect weather and climate. This is important because, at present, there is only a generic understanding of the sources and nature of the complex patterns that develop when aerosols are transported into

18 research stations in Canada's North received $5 million in IPY funding to improve equipment and facilities and to provide training.

the Arctic.

During IPY, detection of plumes over PEARL originating from fires at more southern latitudes proved the case. Scientists, for example, tracked a pan-Arctic smoke plume as it travelled from south-east Russia to Eureka in about five days. Sophisticated sensing instruments captured the plume as it passed over Eureka at altitudes of between 5 and 9 kilometres and were able to establish that it consisted of Russian smoke particles.



Developed during IPY, OOTI is a miniature atmospheric chemistry and physics laboratory, mounted on a sled for rapid deployment by snowmobile.

What's Next?

From long-term atmospheric monitoring data, scientists have observed the impacts of climate change on the environmental fate of toxic chemicals such as mercury in the Arctic. But climate change occurs on decades-long time scales, while models relating to toxic chemicals in the atmosphere are typically based on fewer than 20 years of information. To understand how climate change will affect the transport and behaviour of pollutants in the environment, measurements must be continued to establish trends spanning similar time scales as climate change observations.

Future research will also try to tease out the connections between an increase in storm activity across the Arctic and changing sea ice conditions and sea surface temperatures. Knowing more about storm activity will help researchers build realistic models of possible impacts along the Beaufort and related archipelago coasts.

And the OOTI and O-buoy technologies, developed during IPY, will be refined in the coming years to operate autonomously for even longer periods. They promise to become important tools for tomorrow's Arctic scientists.

Canadian IPY Research in this Area

"OASIS-CANADA: Understanding Ozone and Mercury in the Air Over the Arctic Ocean"; Project leaders: Ralf Staebler and Jan Bottenheim, University of Toronto

"INCATPA: Intercontinental Atmospheric Transport of Anthropogenic Pollutants to the Arctic"; Project leader: Hayley Hung, Environment Canada

"The PEARL near the Pole—Atmospheric Research in the High Arctic"; Project leader: James Drummond, University of Toronto

"Impacts of Severe Arctic Storms and Climate Change on Coastal Areas"; Project leader: William Perrie, Fisheries and Oceans Canada

"Ocean Production of Trace Gases in the Arctic and their Impact on Climate," Project leader: Maurice Levasseur, Université Laval

"Arctic Weather and Environmental Prediction Initiative"; Project leader: Ayrton Zadra, Environment Canada

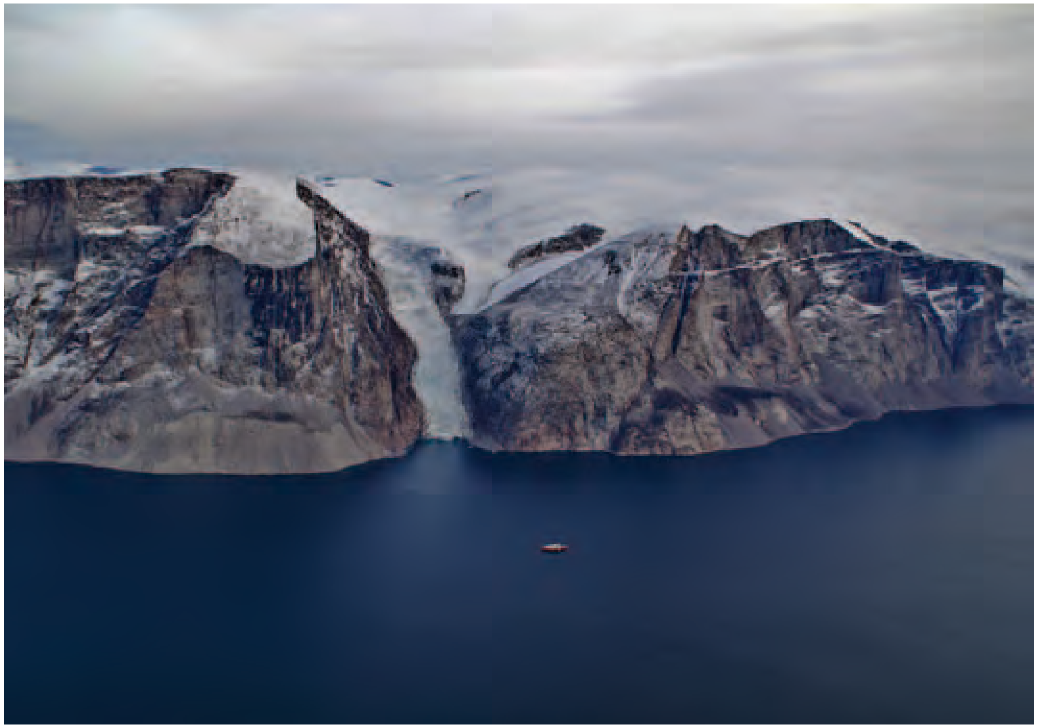
"The Circumpolar Flaw Lead System Study"; Project leader: David Barber, University of Manitoba

"Structure and Evolution of the Polar Atmosphere"; Project leader: Theodore Shepherd, University of Toronto

"Understanding the Dehydration-greenhouse Feedback Process in the Arctic"; Project leader: Jean-Pierre Blanchet, Université du Québec à Montréal

Ocean

Tracking the drivers of the Arctic Ocean



Land meets sea in dramatic fashion at Gibbs Fiord on Baffin Island.

Canada's Arctic Ocean is a key element in the global climate system, but its characteristics are most strongly influenced by its interaction with adjacent areas of the Pacific and Atlantic oceans. These patterns of circulation are complex. High mountains along the eastern side of the Pacific trap evaporated water in the region, raising sea level 80 centimetres above the North Atlantic and 40 centimetres above the Beaufort Sea. These swollen seas flow "downhill": north through the Bering Strait, out into the Arctic over saltier Atlantic water moving across from the Eurasian side, east across Canada's Arctic shelf to Baffin Bay and out into the Labrador Sea.

Arctic currents are restricted by the Canadian Arctic Archipelago to a few specific pathways. Canada's IPY researchers made the first comprehensive observations of this interchange of water in the Ocean Currents of Arctic Canada (CATs) study, which mapped water volume, current speed and the effects of wind through channels in the Eastern Arctic. CATs determined that the fast-moving streams do not take up the width of the ocean straits but are surprisingly narrow — about 10

Key Findings

- Many of the recent changes in the properties and circulation of Canadian Arctic waters are linked to changes in wind patterns and strength.
- Cores of sediment reveal that climate fluctuations in the Canadian Arctic since the last ice age have been asymmetric: warm intervals with less ice in the west occurred simultaneously with cool intervals and more ice in the east, and vice versa.
- Freshwater accumulation in the Canada Basin increased during the last decade, reducing the supply of nutrients to plankton in the sun-penetrated upper ocean.
- The acidity of Canadian Arctic waters is increasing due to absorption of carbon dioxide and lowering of salinity. High acidity now hinders some species' use of calcium carbonate to form protective shells.
- Arctic storms generate hazardous winds, waves and surges when sea ice is far from shore. From the opposite perspective, wide ice-free expanses of warm water promote storm development. Both aspects are consequences of summertime ice retreat from Arctic coastlines.

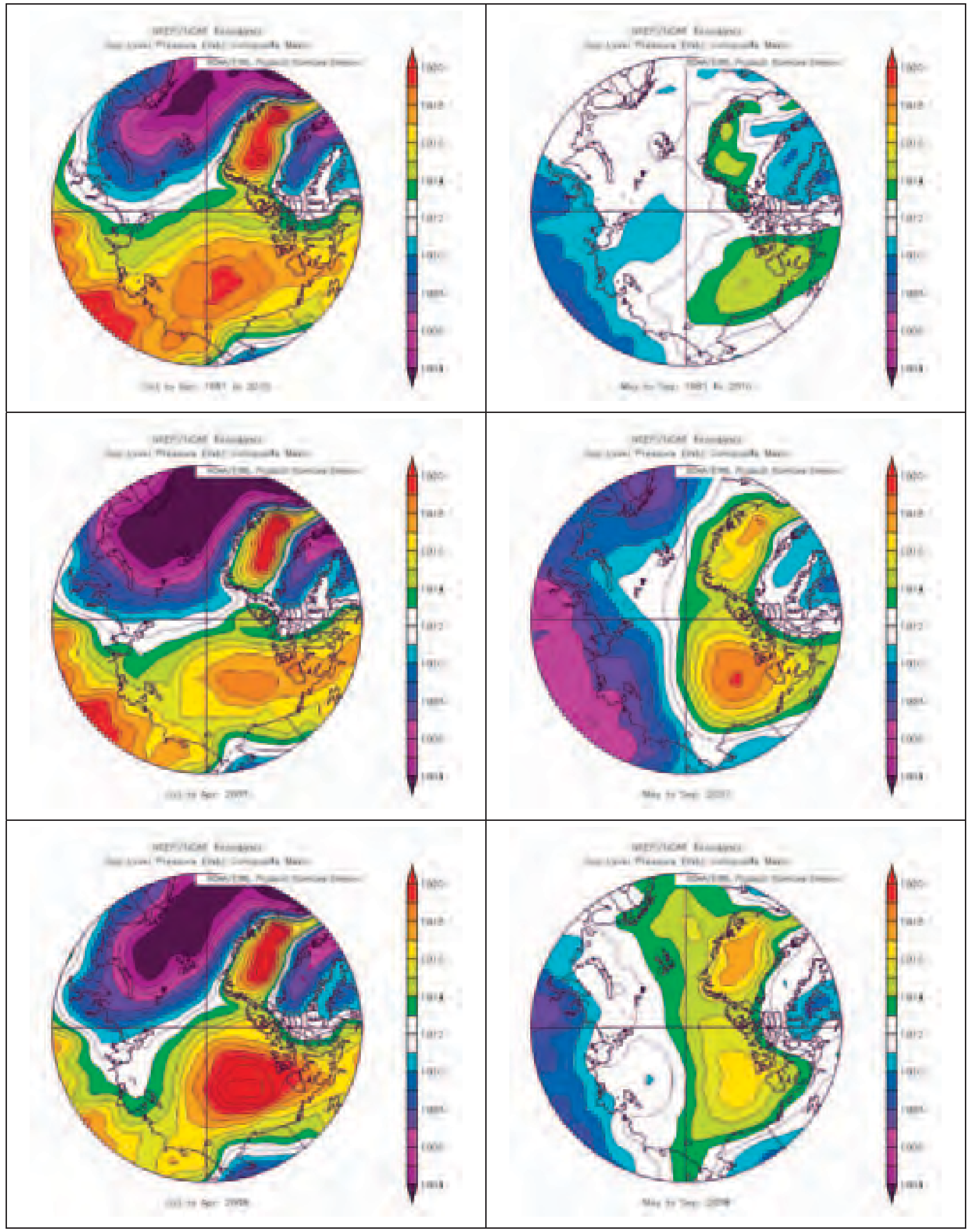
> Canada's three oceans are interconnected dynamically, chemically and biologically.

kilometres wide — and are often at the mercy of strong winds that blow through the passages. As opposed to drift ice, landfast ice tends to impede the movement of ocean currents due to friction and the sheltering effects of the wind.

Message in a gyre

In the Southern Hemisphere where Antarctica is the core, only the atmosphere can carry environmental influences rapidly to the highest latitudes. In the Arctic, the ocean also has a say in what gets transported. Arctic ice, the ocean and ecosystems interact relatively strongly with the Pacific and Atlantic oceans via both air flow and currents. The Canada's Three Oceans (C3O) project, a two-year study involving two icebreakers and 200 researchers, examined these interactions. It looked at how the influx of freshwater from sources such as the Pacific, sea ice melt and massive Arctic rivers is stored and how marine ecosystems are affected.

The best example of such a freshwater "storage reservoir" is the Beaufort Gyre, a vast, anti-cyclonic



Studies during IPY revealed the fingerprint of a changing atmosphere on a changing ocean. These maps show surface air pressure during winter (left) and summer (right). Wind circulates clockwise around high pressure, and its speed increases as the spacing of colours decreases. The panels show conditions during the two IPY years, 2006-07 (middle pair) and 2007-08 (bottom pair), and averaged over the last 30 years (top pair).

Left: CCGS Henry Larsen, support vessel for IPY ocean projects, navigates Alex Fiord.

Right: Doppler sonars, used for underwater measurements, are stored on deck.

(clockwise-swirling) ocean current west of the Arctic Archipelago. Beneath a mixture of ice-melt, precipitation and river water are layers of Pacific and Atlantic inflow of increasing salinity. Canadian IPY researchers documented a higher accumulation of freshwater in the gyre during the last decade, with a peak in freshwater storage during 2008, IPY's second year of study.

This finding has ecological implications, as freshwater floats over saltier ocean water and tends not to mix, thus preventing the transport of important plankton-feeding nutrients to the ocean's surface.

Shell-bearing plankton and other marine organisms that rely on calcium carbonate concentrations to form shells are at further risk due to the increasing acidification of the Arctic Ocean. One-third of the carbon dioxide emissions produced by humankind have been absorbed by oceans and converted into carbonic acid. Northern oceans are at the greatest risk, for two reasons: cold water dissolves gas more efficiently and more acidic sea ice is melting into the water at a faster rate during the summers. Findings from IPY studies point to damage to calcifying organisms and, by extension, all Arctic marine ecosystems.

Taking the long view of the carbon cycle

Described by Canadian IPY researchers as a "harbinger of change" in the Arctic Ocean, the Atlantic inflow has warmed by as much as 0.5 degree Celsius in the last decade. Warmer layers of summer water have also penetrated from the Pacific side.

One consequence of warming temperatures is that Arctic storms seem to be growing in intensity if not frequency. Just as currents and northern ocean coasts are adversely impacted by these storms, Canadian researchers found that the intensity of storms are influenced by expanses of open water, such as those that appear during summer and early autumn. Summer ice retreat in the northwest, from expanses of the Chukchi Sea and the Alaskan coast, opens long tracts of water. Northwest storm winds generate larger and more energetic waves and violent surges that can flood and erode the Canadian Beaufort shoreline and affect coastal communities.

Climate predictions for the Arctic can be made in relation to only a few decades of observations, and records of marine systems are shortest of all. To develop a long-range picture, Canadian IPY scientists studied ocean sediment samples to produce a new picture of the life-supporting carbon cycle, climate

> Canadian IPY projects were undertaken in Nunavut (29), the Northwest Territories (21), Nunavik (16), Yukon (14) and Newfoundland and Labrador (11).

variation and sea ice cover that has occurred over the last several thousand years. Their research has shown that a cooling period began in the east of Canada some 6,000 years ago, while Arctic seas to the west were warmer, producing much less ice cover than in modern times. This synopsis of the past is a valuable tool, especially for linking changes in climate to marine environments and modern human influences.

Knowledge of the ocean's physical and chemical environment is fundamental to ecosystem-based ocean management. The basic properties of the ocean (ice cover, temperature, salinity, density structure, dissolved oxygen, nutrients, iron) and the processes that maintain these properties (freezing, thawing, transports, inflows, outflows, mixing, energy balance) are key determinants of the life existing within it. Variation in the Arctic marine ecosystem is clearly linked to variations in the physical and geo-chemical characteristics of the ocean. There is no consensus yet, however, on whether pan-Arctic marine production will increase or decrease with reduced ice cover.

Models developed during IPY will make it easier to forecast storm surges and shoreline erosion, benefitting northern coastal communities such as Salluit.

What's Next?

Canadian IPY projects developed predictive computer models to accurately reproduce the dynamic exchange of water and ice across the Canadian Arctic, and to forecast storm surges and potential flooding and shoreline erosion in the region. These models will provide important information to at-risk coastal communities, and can be adapted by weather forecasters and those planning search and rescue missions.

Scientists say it is crucial that the comprehensive approach adopted during IPY be sustained to better detect signs of progressive change in the Arctic Ocean environment that can vary dramatically from year to year.

Canadian IPY Research in this Area

"C3O: Canada's Three Oceans"; Project leader: Eddy Carmack, Fisheries and Oceans Canada

"Ocean Currents of Arctic Canada"; Project leader: Humfrey Melling, Fisheries and Oceans Canada

"Investigation of the Effect of Climate Change on Nutrient and Carbon Cycles in the Arctic Ocean"; Project leader: Roger Francoise, University of British Columbia

"Impacts of Severe Arctic Storms and Climate Change on Coastal Areas"; Project leader: William Perrie, Fisheries and Oceans Canada

"The Circumpolar Flaw Lead System Study"; Project leader: David Barber, University of Manitoba

"Ocean Production of Trace Gases in the Arctic and their Impact on Climate"; Project leader: Maurice Levasseur, Université Laval

"The Carbon Cycle in the Canadian Arctic and Sub-Arctic Continental Margin"; Project leader: Charles Gobeil, Université du Québec

Sea Ice

The Arctic sea icescape is blowing in the wind

Sea ice is an engine of change in the Arctic.

As predicted 30 years ago, the Arctic is experiencing the strongest signs of global warming, but at a much faster rate than was forecast. Satellite data confirm that the area of ocean covered by ice in the circumpolar region has been shrinking since the late 1970s. It declined a remarkable 65 percent in 2007 and again in 2011.

What happens to sea ice is of major concern, since it is an engine of change. Sea ice plays a central role in how the Arctic marine system responds to, and affects, climate change; it regulates the exchange of heat, moisture and gas among the ocean, ice and atmosphere. It also controls the distribution and timing of light to nutrient-rich waters in the upper levels of the ocean. And dramatic loss of sea ice cover significantly affects the balance between incoming and outgoing solar radiation. That is because sea ice typically reflects up to 50 percent of sunlight, up to 90 percent if snow-covered, whereas the dark surface of the ocean absorbs 90 percent of sunlight.

The Canadian IPY program provided scientists with an unprecedented

Key Findings

- In the Amundsen Gulf, at the western end of the Northwest Passage, open water persists longer than normal and winter sea ice is thinner and more mobile.
- Cyclones play an important role in sea ice growth and decay. They delay the formation of new ice, reduce the growth of multi-year ice and break up multi-year ice in the late summer.
- Conditions associated with climate change could bring nutrient-rich waters from deep in the Pacific Ocean to nutrient-poor surface waters along the Arctic coast, affecting local food webs.
- The ice edges bordering flaw leads — regions of open water between pack ice and land-fast ice — are areas of high biological productivity.
- The Beaufort sea ice gyre (rotating ocean currents) used to rotate clockwise throughout most of the year but now reverses directions regularly. This contributes to a reduction in sea ice thickness and extent.

access to the Arctic. The Circumpolar Flaw Lead Study (CFL), based in the southern Beaufort Sea, marked the first time a fully outfitted research icebreaker overwintered in the Arctic, allowing scientists to study the evolution of sea ice, from formation to decay. It also allowed the year-round observation of many age classes of sea ice, leading to significant improvements in the ability to detect the geophysical (such as salinity, brine volume, thickness) and thermodynamic (such as surface temperature and profile) states of sea ice.

The scientists confirmed that cyclones (and anticyclones in the winter) play an important role in the dynamics and evolution of sea ice. These weather phenomena, characterized by powerful inward spiraling winds, gain energy over the open water between pack ice and land-fast ice, and tend to steer along the interface between open water and sea ice. While cyclones in the Arctic Basin do not seem to be occurring more frequently, they are becoming more intense. Cyclones generate waves that move the ice pack, and they may help trigger larger than usual storm swells. Scientists with the CFL study noted that even the thickest ice floes, weakened by warm summer temperatures, are susceptible to fracturing from these swells.

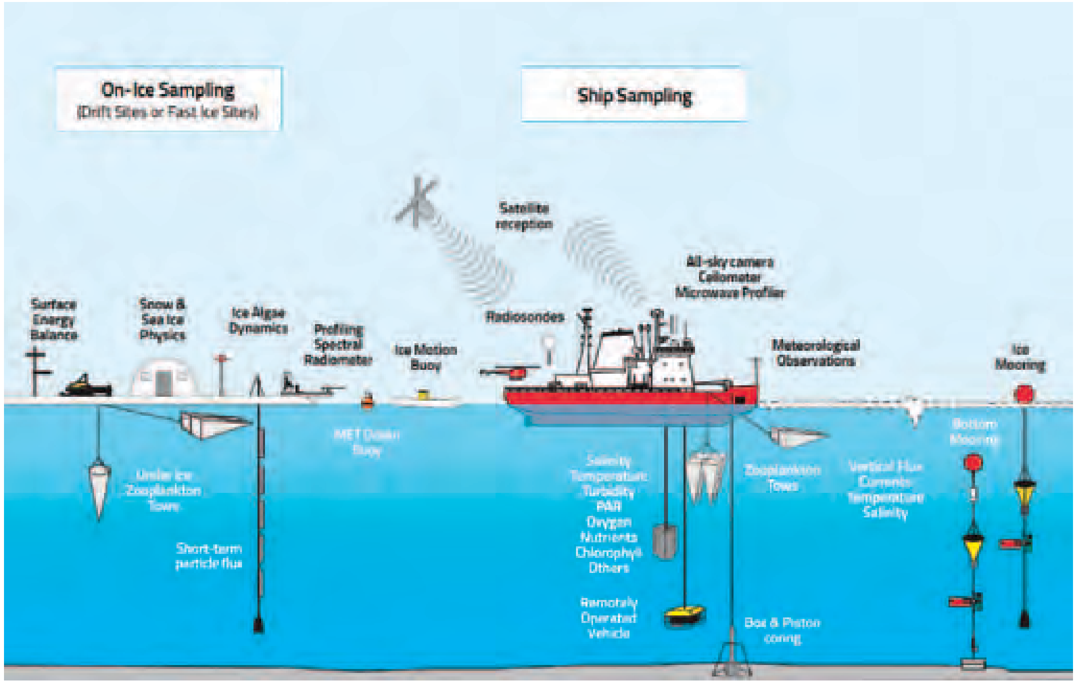
Storehouse of pollutants and carbon

Canada's IPY researchers also analyzed weekly ice charts from 1960 to 2008, seeking trends and variability in summer sea ice. They found that ice cover had decreased the most in Hudson Bay, approximately 11 percent per decade. In Baffin Bay, it disappeared at a rate of 8.9 percent per decade; in the Beaufort Sea, 5.2 percent; and in the Canadian Arctic Archipelago, 2.9 percent.

Researchers uncovered evidence that the increasing surface-air temperatures in the Arctic will continue to reduce summer sea ice and facilitate navigation through the Canadian North in the near future. Once largely inaccessible to freighters, the Northwest Passage has been seasonally ice-free since 2007. Due to warm spring temperatures and increased loss of multi-year ice, the Passage experienced a record reduction in sea ice in August 2010. This has important implications for seasonal shipping and Canadian Arctic sovereignty.

CCGS Amundsen was the first research icebreaker to overwinter in the Arctic.

An increasingly fragile sea ice cover, associated with the loss of multi-year ice, is accelerating change in the Arctic.



CCGS Amundsen's facilities and sophisticated equipment make it a versatile research platform for oceanographers, geologists, terrestrial ecologists and epidemiologists.

The implications for global climate change are significant as well. A recent scientific review, for example, reinforced the idea that the waters of high-latitude continental shelves are generally undersaturated in carbon dioxide relative to the atmosphere. That would suggest that the Arctic acts as a carbon sink, storing atmospheric carbon dioxide. IPY researchers caution, however, that not enough is known about the processes associated with sea ice that may or may not affect the uptake of carbon dioxide.

Scientists do know, however, that polar regions are particularly susceptible to the effects of chemical contaminants. As if traveling on a conveyor belt, contaminates from lower latitudes are transported through ocean and atmospheric currents into the Arctic, where they enter the food chain. During IPY, several studies looked at the linkages between sea ice and the transport of contaminants. In one, augered boreholes in the ice were studied to tease out the relationship between organochlorine pesticides such as HCH (hexachlorocyclohexane) and the physical and thermodynamic characteristics of sea ice. The scientists determined that levels of HCH in the brine exceeded the under-ice water concentrations by a factor of three, suggesting that the brine ecosystem has been, and continues to be, the most exposed to HCHs.

New rules for northern residents

In addition to their scientific observations, IPY-CFL researchers turned to the people of the Arctic to tap their traditional knowledge and observations of sea ice. Inuvialuit (Inuit living in the western Canadian Arctic) in Paulatuk, Sachs Harbour and Ulukhaktok, in the Northwest Territories, were asked to document their knowledge of the sea ice.

The most common observation reported by interviewees from all communities was the presence of less sea ice and more open water. In particular, there are larger and increased areas of open water throughout the winter that would, in previous years, typically remain frozen. Open water is being found closer to shore as well. Community members from Sachs Harbour noted that freeze-up occurs about one month later than it did 20 to 30 years ago. They also told IPY researchers that it was no longer safe to travel far out into Amundsen Gulf on the sea ice.

An increasing amount of rubble ice, rough ice and open water is the new reality for residents across Canada's Arctic. They will be forced to change well-established travel routes or abandon travel on the ice altogether.

The first International Polar Year took place from 1882 to 1883, and was the first series of coordinated international expeditions to the polar regions ever undertaken.

Seemingly working in a lily-pad world, scientists collect samples of sea ice.

What's Next?

The findings from the IPY sea ice studies will keep scientists and policy makers across Canada very busy. The results can be incorporated in modeling studies that monitor sea ice circulation, and be used to assess the impact of an increasingly mobile ice cover on the presence of nutrients and pollutants in the Beaufort Sea region. This may have implications for non-renewable and renewable resource development, navigation and Arctic sovereignty.

And what will the reduction of existing sea ice and ice thickness mean to northern coastal communities? An increase in storm surges can speed up coastal erosion, thereby affecting fishing and harvesting activities. Changes in when seasonal sea ice freezes and breaks up will impact the safety and efficiency of transportation by residents and hunters. Northern communities will need to identify adaptation strategies.

Canadian IPY Research in this Area

"The Circumpolar Flaw Lead System Study"; Project leader: David Barber, University of Manitoba

"Ocean Production of Trace Gases in the Arctic and their Impact on Climate"; Project leader: Maurice Levasseur, Université Laval

"The Carbon Cycle in the Canadian Arctic and Sub-Arctic Continental Margin"; Project leader: Charles Gobeil, Université du Québec

"Impacts of Severe Arctic Storms and Climate Change on Coastal Areas"; Project leader: William Perrie, Fisheries and Oceans Canada

"Investigation of the Effect of Climate Change on Nutrient and Carbon Cycles in the Arctic Ocean"; Project leader: Roger Francoise, University of British Columbia

"Ocean Currents of Arctic Canada"; Project leader: Humfrey Melling, Fisheries and Oceans Canada

"C3O: Canada's Three Oceans"; Project leader: Eddy Carmack, Fisheries and Oceans Canada

"Natural Climate Variability and Forcings in Canadian Arctic and Arctic Oceans"; Project leader: André Rochon, Université du Québec å Rimouski

Cryosphere

What happens when permafrost loses its frost?

As the climate warms, a Baffin Island glacier is in retreat.

From ice cores to satellite images, studies show that the Arctic is losing the very features that make the region so distinctive. The snow, ice shelves, glaciers and permafrost of the North are all wilting in the face of climate change.

There is no mistaking it: the Arctic is warming. In the past 20 years, the average annual temperatures in the frozen ground of the High Arctic have risen by nearly 1°C every decade. Less snow now covers the ground in spring and early summer; since 1967, snow cover in June has dropped by nearly half. Yukon glaciers are shrinking because of longer, warmer summers. Entire ice shelves — floating platforms of ice that can be up to 50 metres thick — have disappeared off the coast of Ellesmere Island.

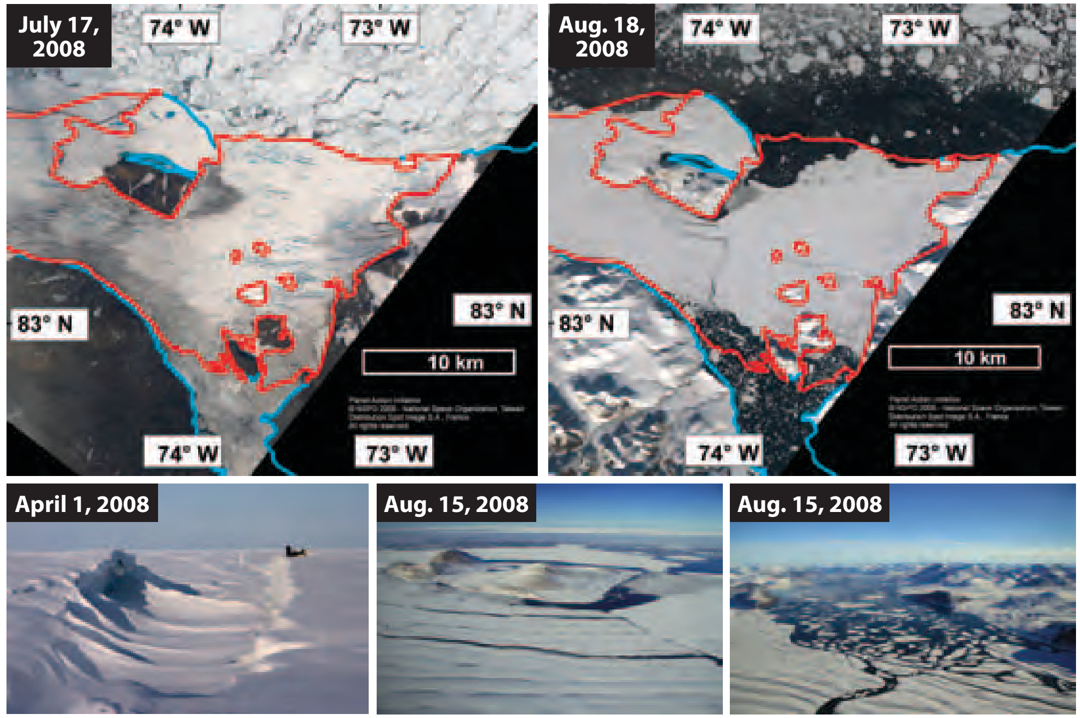
Canadian IPY research focused on creating a current snapshot of the cryosphere in order to understand past changes and as a baseline for tracking future changes. One of the main components of the Arctic ecosystem, the cryosphere consists of any frozen surface, including sea and freshwater ice, glaciers, ice sheets, snow and permafrost. In terms of total mass and heat capacity,

Key Findings

- For the Arctic cryosphere (areas of snow, ice and frozen ground), the IPY period marked an acceleration of trends that began in previous decades: warming permafrost, reduction in snow cover extent and duration, reduction in summer sea ice extent, increased mass loss from glaciers and thinning and break-up of the remaining Canadian ice shelves.
- Arctic snow cover is gradually decreasing because snow is melting earlier in the spring. Since 1967, June snow cover extent across the Arctic has dropped by 46 percent.
- Permafrost has warmed across northern Canada with mean annual ground temperature increasing by up to 0.2°C per decade since the mid-1980s in the Mackenzie Valley, 0.8°C per decade since the early 1970s across the western Arctic and about 1°C per decade since the 1990s in the eastern and High Arctic.
- Model simulations predict earlier dates for ice and snow melt in the spring and later dates for ice formation in the fall.

the cryosphere is the second biggest driver of global climate conditions after the world's oceans.

The state of the cryosphere affects ocean circulation, freshwater systems and wildlife. For instance, surface and subsurface hydrology can be affected as the upper layer of permafrost — soil or rock that remains frozen the entire year — thaws in response to warming. Melting glaciers contribute to a global rise in sea levels that threaten coastal areas and islands around the world. Many Arctic organisms have adapted to living in or on snow and ice. Seals and polar bears, for example, rely on sea ice for breeding, feeding and migrating. Freshwater ice affects the growth of algae, the basis of the aquatic food web.



During IPY, researchers tracked the disintegration of the Ward Hunt Ice Shelf. At top, satellite images show the extent of loss in one month (original ice shelf outlined in red). At bottom (left to right), a large crack is discovered during spring; aerial view of the front of the disintegrating ice shelf; the rear of the ice shelf breaking up.

From boreholes to satellites

Changes to the cryosphere can reinforce themselves. Consider the case of snow and ice. Both reflect sunlight, so when rising surface air temperatures lead to less snow and ice cover, the Arctic surface absorbs more heat. This causes more snow and ice to melt, leading to further absorption of sunlight, and the cycle continues.

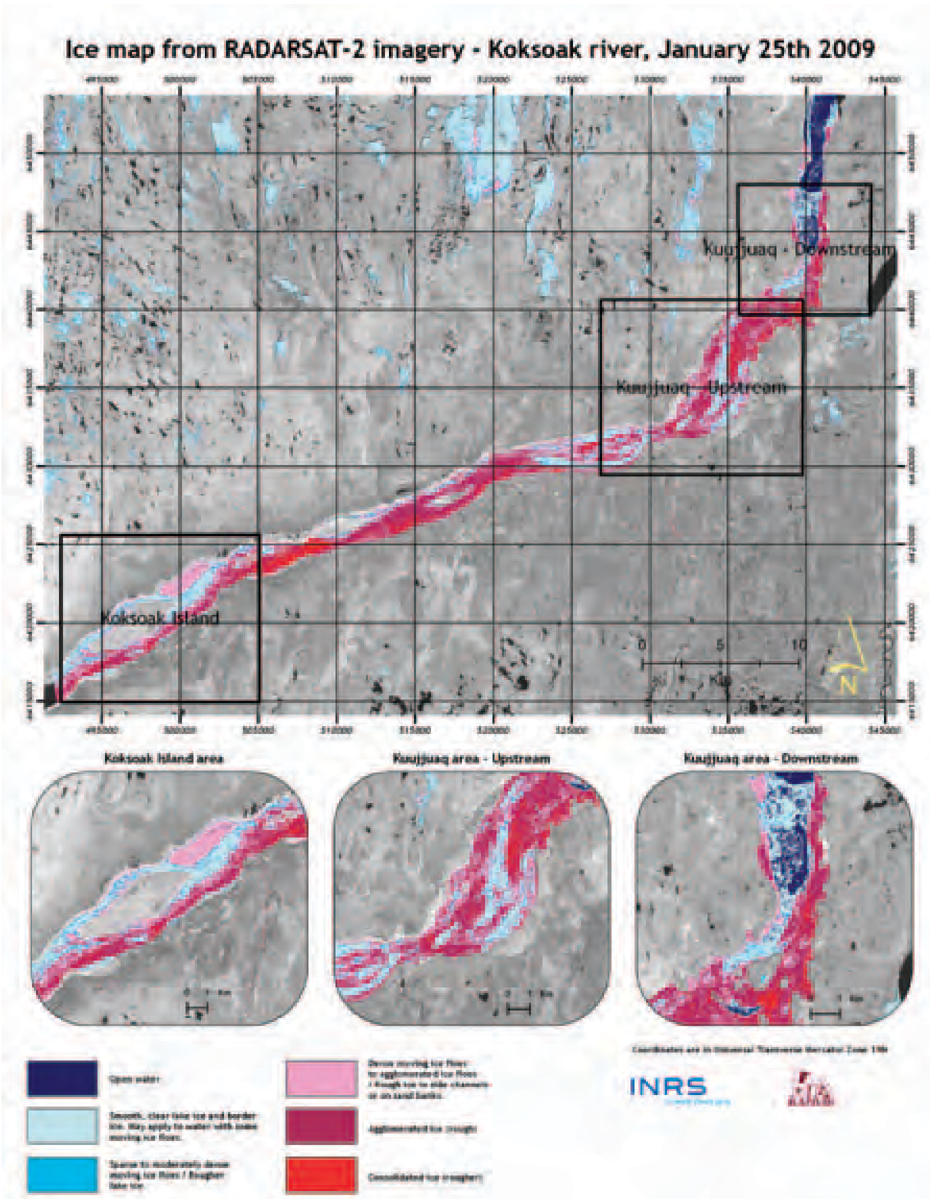
To monitor changes in the cryosphere, Canada's IPY researchers took a multifaceted approach. They combined field studies with satellite remote sensing, established monitoring sites on the ground and utilized models to predict future changes.

Studying the cryosphere requires many different monitoring methods. Permafrost, for instance, is best examined at ground level, as changes in ground temperature are difficult to estimate from satellite imagery. Government and university researchers and northern communities established new permafrost monitoring sites throughout the Canadian Arctic. At each site, boreholes were drilled 20 metres deep on average, and temperature cables connected to data loggers were installed to record ground temperature at various depths. Currently, permafrost temperature is measured at about 170 boreholes.

Another IPY project analyzed ice cores, long vertical samples of ice that contain evidence of a variable climate in the Arctic over thousands of years. Ice cores help researchers gain insight into past climate phenomena, including times when the Arctic was warmer than today.

For many scientists, the work was an endurance test. In a 2007 study, a team of Canadian and U.S. researchers traversed 4,200 kilometres across the Arctic via snowmobile to measure snow cover within a region that had never been previously sampled.

Northern communities are leveraging insights gleaned from IPY research.



Ice maps were created every seven to 10 days using data from the RADARSAT satellite to support safe river-based transportation by residents of Kuujjuaq. Open water is shown in blue; rough ice in shades of red.

Rangers to the rescue

Canadian Rangers, reservists from the North who train with the Canadian Forces, partnered with scientists to access some of the most remote regions in the Arctic. Experts from Nunavut, Yukon and Northwest Territories, who also contributed their observations and traditional knowledge, incorporated field work into their annual patrols. Their work included using ground penetrating radar to measure Ellesmere Island ice shelves, which have experienced a dramatic change in ice area and volume over the past decade.

Several projects were initiated to meet the information needs identified by northerners. In Nunavik (the Arctic region of Quebec), river ice mapping activities were conducted in consultation and collaboration with the community of Kuujjuaq. During the two-year project, ice maps were created every seven to 10 days using data from the Canadian Earth observation satellite RADARSAT to support safe river-based transportation by members of the community. Coastal communities in the Canadian Arctic received weekly maps of the boundary between sea ice and open water based on satellite imagery. This information assisted northern communities in adapting to changes in ice conditions.

Adaptation is now the watchword for northern communities. The challenges vary. Permafrost, for instance, is often the foundation on which infrastructure in the Arctic is built. Northern communities rely on frozen ground, rivers, lakes and sea ice to travel and hunt. With less predictable snow and ice cover every year, such activities become more dangerous.

There are also implications for natural resource development as ice roads provide essential access to exploration sites and allow the re-supply of mineral and hydrocarbon production sites. Mines in the Northwest Territories that depend on ice roads will be faced with shorter operating periods to transport supplies to mine sites in the winter. Offshore oil and gas developments may experience significant threats from collisions with ice islands released from the ice shelves of Ellesmere Island.

> Canadian IPY projects took place at more than 100 study sites across Canada's North and from aboard five Canadian Coast Guard icebreakers.

Scientists take soil samples to learn more about permafrost.

What's Next?

Results generated from the body of research on the cryosphere conducted during IPY will be used in the coming years to track changes in snow and ice features across the Arctic. Data gathered at monitoring sites, models of temperature change over time and satellite imagery are being made available to policy makers and planners, as well as to community groups for whom development, infrastructure and community life are closely linked with the state of the cryosphere.

Sustained efforts to comprehensively observe all elements of the cryosphere are necessary to understand the response to a changing global climate system, understand how these changes will affect terrestrial, aquatic and marine ecosystems, and reduce the vulnerability of northern residents and northern development to climate-induced uncertainty.

Canadian IPY Research in this Area

"Variability and Change in the Canadian Cryosphere"; Project leader: Anne Walker, Environment Canada

"Environmental Change in the High Arctic from Snow and Ice Cores"; Project leader: Jocelyne Bourgeois, Natural Resources Canada

"Measuring the Impact of Climate Change on Landscape and Water Systems in the High Arctic"; Project leader: Scott Lamoureux, Queen's University

"Permafrost Conditions and Climate Change"; Project leader: Antoni Lewkowicz, University of Ottawa

"Dynamic Response of Arctic Glaciers to Global Warming"; Project leader: Martin Sharp, University of Alberta

Marine Ecosystems

Untangling a web of riches and woe

Beluga whales congregate in Arctic waters.

The Arctic is home to 24 of the world's 125 marine mammal species. Many of these species — polar bears, narwhals, belugas and seals among them — live in the Arctic year-round and are icons of the harsh polar environment. In the face of frigid temperatures, the perpetual darkness of the polar night and the continuous daylight of midnight sun, they have adapted how they hunt, migrate and reproduce.

This marine ecosystem also underpins the traditional way of life for communities in the Canadian North. Many communities engage in subsistence hunting for nutrition, hides and furs and tools.

What do we know about this ecosystem? We know that beneath the Arctic ice, in the open water between land and sea ice and along the edges of the ice shelves, the marine environment is shaped by sunlight, water temperature, the flow of nutrients and atmospheric phenomena. Less known is the diversity of species below the ice, particularly at the level of microorganisms, or the impact of reduced sea ice will have on the food web. IPY studies conducted by Canadian researchers are providing

Key Findings

- In many ways, arctic marine biodiversity is comparable to that found in Pacific and Atlantic ecosystems. But with rising temperatures in the Arctic, subarctic species are shifting their habitats northward, threatening to disrupt the Arctic food web.
- The Arctic marine food web is more active during winter periods than previously thought.
- Reduced sea ice cover in the Arctic is expected to lead to increased primary production from phytoplankton in open water.
- Greater primary production will support more biomass at upper levels in the food chain, benefitting local communities that practise subsistence hunting. But with the polar night limiting primary production for half of the year, the ecosystem likely will not support large-scale commercial fisheries.

a clearer picture of what happens beneath the sea ice, and how that ultimately affects what is visible on the Arctic surface.

The mighty producers of the marine world

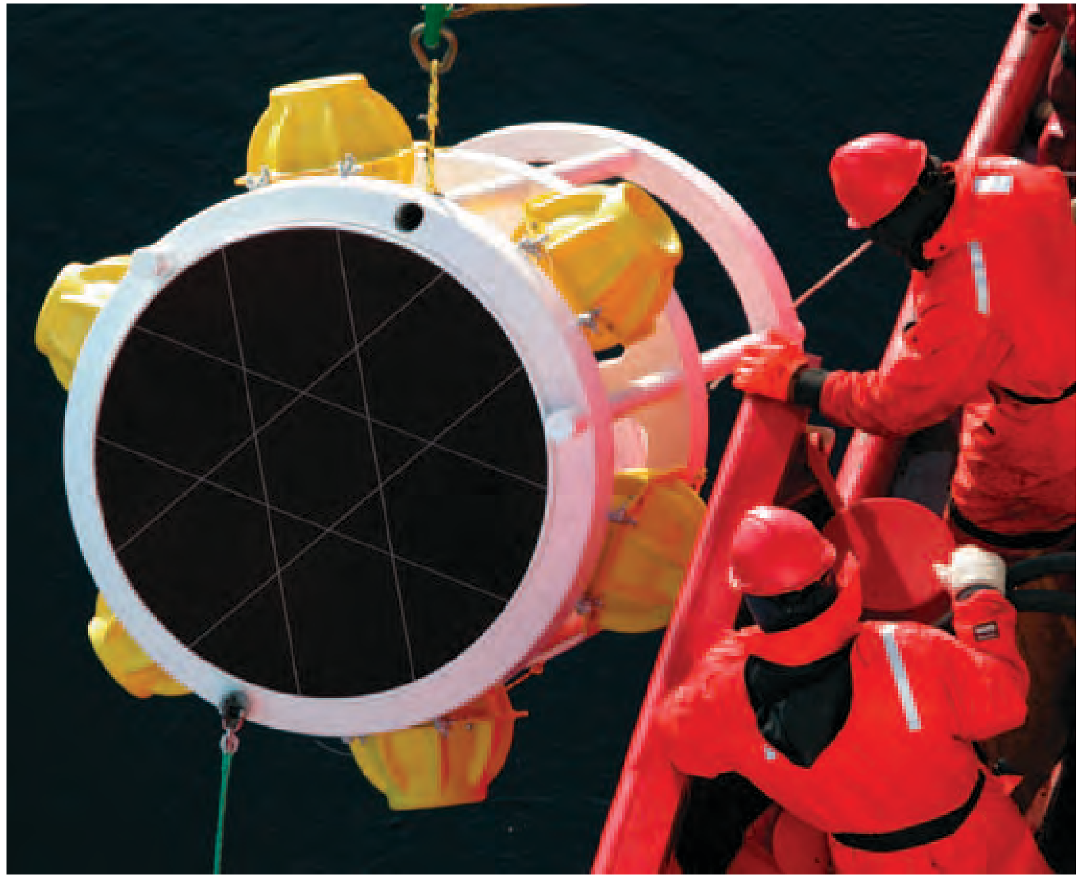
Life on land is almost entirely dependent on the ability of microorganisms and plants to clean the air and convert chemical compounds into organic forms that other species can use. So, too, is the Arctic food web built on the activity of primary producers. They consist of ice algae and phytoplankton, microorganisms that use sunlight to produce organic carbon that other organisms rely on for energy. Zooplankton consumes phytoplankton, while fish feed on zooplankton. They, in turn, are prey to larger organisms such as marine mammals and birds.

This is a simple example of one chain within the Arctic marine food web, which is far from linear. For example, large marine mammals such as killer whales may feed on seals, while baleen whales that lack teeth feed on huge quantities of plankton. Whether directly or indirectly, though, marine mammals rely on the energy that is passed up from phytoplankton at the base to zooplankton and fish.

Ecologists speak of the efficiency of a food web to describe how much energy is transferred when one level of the food chain consumes a lower level. Efficiency depends largely on the quality of nutrients available in each level and the proportion of which gets passed on to the level above.

To determine efficiency in various points throughout the Arctic, IPY researchers monitored primary productivity in regions near the ice edge, areas that are thought to model future conditions of reduced sea ice cover. In a new twist for Arctic science, remote sensing technology was used to measure primary productivity at the surface of the ice-free ocean. Since this satellite-based technology cannot detect productivity a few metres below the surface, IPY projects such as Canada's Three Oceans (C3O) and the Circumpolar Flaw Lead Study took more comprehensive measurements to detect food web activity in various parts of the Canadian Arctic.

C3O, for example, involved two Canadian Coast Guard icebreakers crossing a total of 15,000 kilometres over two Arctic summers to assess links between the Arctic, subarctic Pacific and subarctic Atlantic oceans. In covering such a great distance and mooring measuring devices at core locations, researchers were able to compare ocean chemistry, physics and biology across space and over a period of several seasons.



Scientists deploy a sediment trap as part of research into marine ecological processes.

From below, untangling a food web

Ice algae and phytoplankton require light and nutrients to survive and thrive. They get what they need thanks to a highly dynamic ecosystem. Nutrients produced in deep ocean waters rise to the surface, where light is more available, through

Microorganisms such as amphipods play an important role at the base of the Arctic food web.

The Arctic marine food web is far richer in species and more active in periods of ice cover than originally thought.

a process known as upwelling. Upwelling is largely controlled by wind currents. With reduced sea ice cover, winds will drive more upwelling events in some areas and lead to more primary production at the surface.

But that's where the benefits may end. IPY studies show, for example, that more primary production at the surface may only benefit species living near the surface. The extra energy generated by more phytoplankton may not end up efficiently cycled to the deeper ocean.

In parts of the Arctic marine ecosystem where there is no upwelling, there is a weaker exchange of nutrients with deep waters. This usually occurs when warmer, less salty, water rises to the surface while colder and saltier water sinks, and when the difference is extreme enough to prevent much mixing in nutrients. Reduced sea ice cover, the reality in tomorrow's Arctic, will only speed up this process. This is good news for phytoplankton and algae as well as zooplankton that are expected to displace the larger species currently transferring energy to higher levels. But such a shift to smaller primary producers will mean changes in the diet of species higher up on the food chain.

The IPY studies do paint an impressive picture of adaptation among microorganisms such as phytoplankton and zooplankton. Most notably, researchers found that the food web is much more active during periods of ice cover than previously thought. This suggests microorganisms so vital for primary production are highly adaptable to changing conditions in their environment.

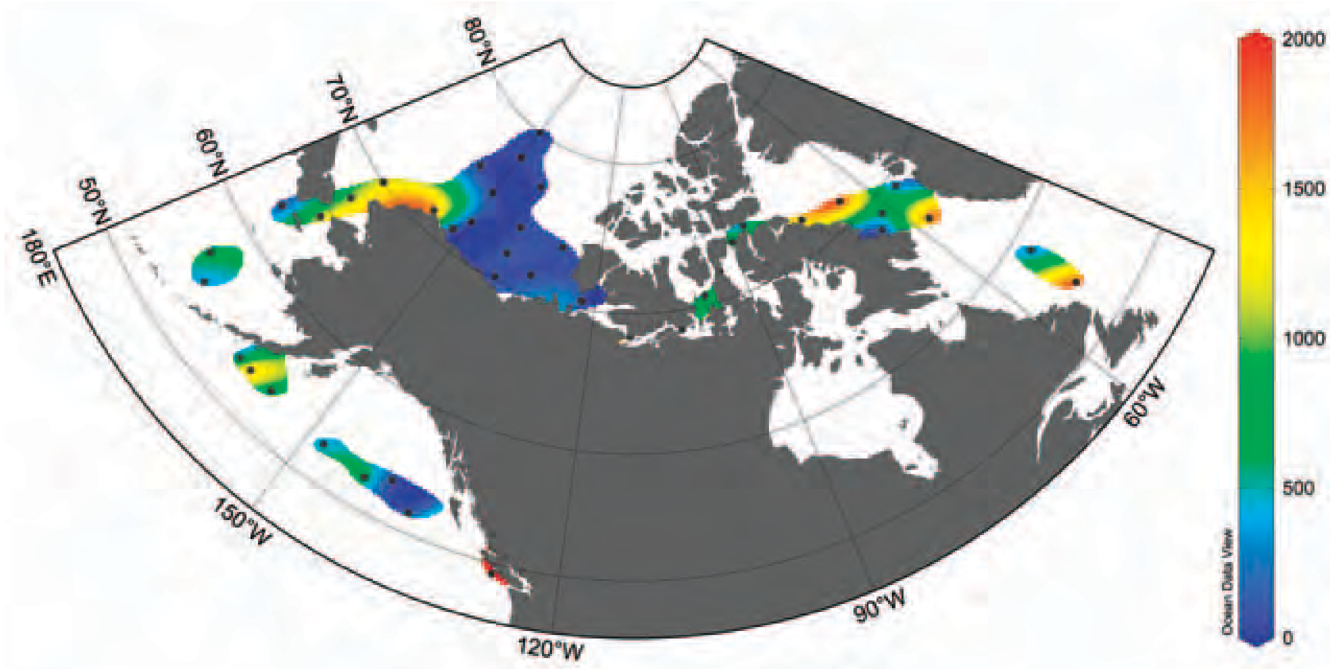
From above, monitoring changes in the marine world

Many of the IPY studies relating to the marine ecosystem focused on understanding the dynamics below sea ice. One project, Global Warming and

More than 4 million people live above the Arctic Circle in the eight circumpolar countries. These communities face dramatic changes in their environment and natural resources.

Arctic Marine Mammals, took a top-down approach in examining how climate change affects marine mammal distribution and abundance.

Scientists collaborated with northern subsistence hunters in the communities of Arviat, Sanikiluaq, Repulse Bay/Naujaat, Igloolik and Pangnirtung to collect samples. They also set up community monitoring systems so that northerners could be involved in observing changes in the behaviour and numbers of top predators. Data from this project were combined with findings from other researchers, including one group studying whether or not killer whales in the Arctic — a growing presence — may prey on or compete with narwhals, belugas and bowhead whales. While no findings are yet available, monitoring programs are in place to observe future changes in the top levels of the Arctic marine food chain.



Large-scale, pan-arctic distribution of primary productivity, gathered during the IPY Canada's Three Oceans project. Dots represent sampling stations.

What's Next?

IPY studies by Canadian researchers collected a baseline of data on factors such as oxygen concentration, salinity and water chemistry that will be essential information for future reference as changes in sea ice cover are monitored.

One element of the marine ecosystem that the Circumpolar Flaw Lead System project looked at was the exchange of nutrients between surface waters and the deep ocean, where light is unavailable and primary production is limited. While researchers have identified some regions where the exchange of nutrients is efficient, more studies are needed to confirm their findings.

Future studies will also examine higher levels of the food chain. Some will monitor the effects of climate change on the habitat and feeding grounds of bowhead whales to determine the extent of environmental change and human activities the whales can tolerate. They will also monitor the impact of killer whales, which are expected to compete with other animals, such as polar bears, that have no natural predators of their own.

Canadian IPY Research in this Area

"Canada's Three Oceans"; Project leader: Eddy Carmack, Fisheries and Oceans Canada

"Global Warming and Arctic Marine Mammals"; Project leader: Steve Ferguson, Fisheries and Oceans Canada

"The Circumpolar Flaw Lead System Study"; Project leader: David Barber, University of Manitoba

"Investigation of the Effect of Climate Change on Nutrient and Carbon Cycles in the Arctic Ocean"; Project leader: Roger Francois, University of British Columbia

"How Seabirds Can Help Detect Ecosystem Change in the Arctic"; Project leader: William Montevecchi, Memorial University

"Climate Variability and Change Effects on Chars in the Arctic"; Project leader: James Reist, Fisheries and Oceans Canada

"Determining the Diet of the Greenland Shark in a Changing Arctic"; Project leader: Aaron Fisk, University of Windsor

Terrestrial Ecosystems

The tundra is growing up before our eyes

Open tundra vegetation colonizes a dune complex.

Key Findings

- Arctic tundra vegetation in Canada has changed visibly over the past 10 to 30 years, with a general increase in plant cover, especially shrubs.
- For the foreseeable future, all types of tundra will store more carbon than they will release, although there are strong differences between the High Arctic and Low Arctic.
- According to models, polar desert tundra ecosystems will show the greatest response to warming, releasing more greenhouse gasses than previously thought.
- In some places, the alpine tree line has filled in and become more dense over the past 25 years

Canada has the greatest variety of tundra ecosystems of all polar nations, not surprising considering tundra makes up one-quarter of the country's land mass. Near the tree line, the forest-tundra begins the transition from boreal forest to land dominated by permafrost. This zone gives way to low arctic tundra, where dwarf birch, willows and sedges show modest growth alongside mosses and lichen. In the High Arctic, polar deserts feature hardscrabble vegetation such as saxifrage that clings to the south faces of boulders. Within each of the tundra zones is yet more variability, largely dictated by topography and the availability of moisture.

Our knowledge of these ecosystems, however, remains patchy. To fill in the gaps, a series of Canadian IPY-funded science projects looked at how climate and other factors are affecting northern terrestrial ecosystems. The timing was right: since 1970, temperatures in the tundra region have risen by 1° C per decade, among the highest rate of warming on Earth. Researchers examined soil, vegetation, the dynamics of the tree line and the carbon cycle. They pieced together a picture of environmental change from multiple perspectives, from up close at individual plots to sky-high satellite-based observations.

Advanced climate modeling, fieldwork and observations of long-time northern residents all point to two crucial observations with far-reaching implications: the permafrost is melting, raising concerns about the release of greenhouse gases into the atmosphere; and the Arctic is greening, posing challenges and opportunities to northern communities and wildlife.

Carbon sink or source?

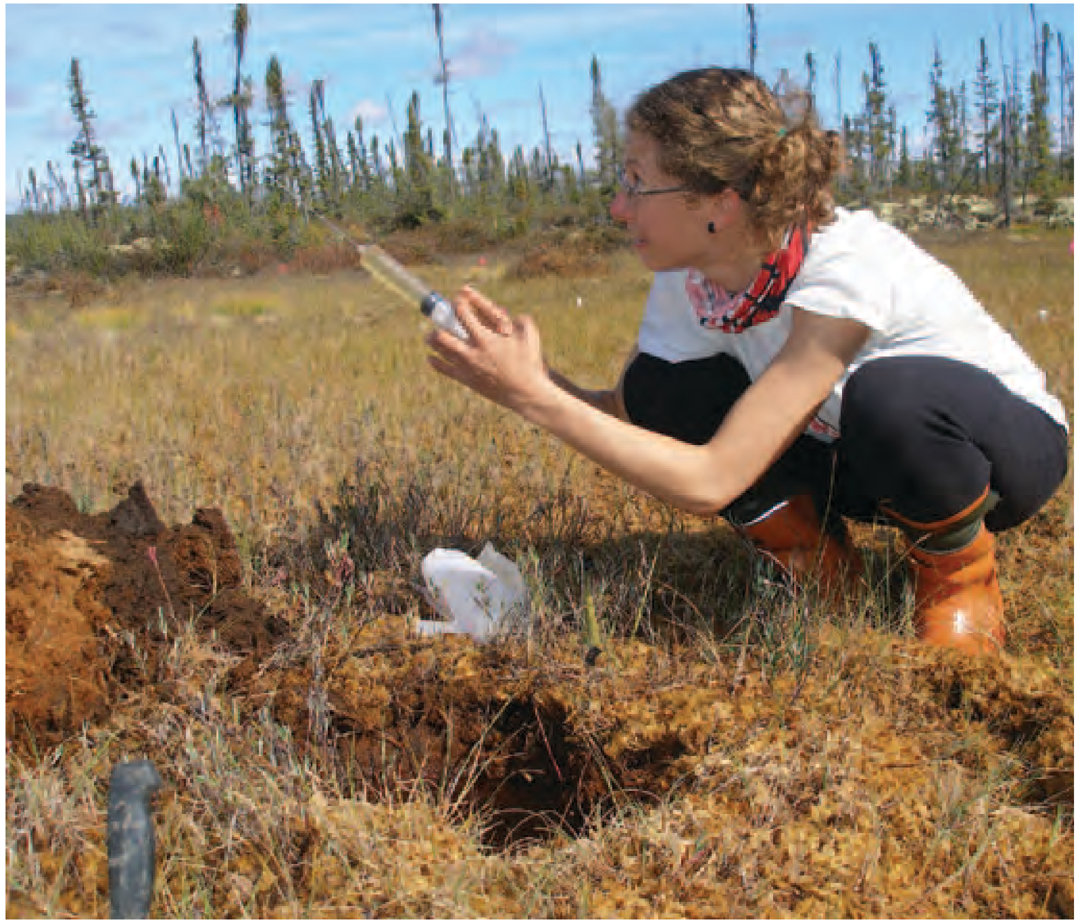
The state of permafrost is of global importance. This permanently frozen soil layer contains billions of tonnes of plant and animal matter — carbon — that has remained trapped for up to tens of thousands of years.

One of the findings coming out of IPY is that almost half of all soil-based carbon is locked in permafrost. What will happen as the active layer of permafrost thaws? In some cases, the permafrost will sink and become a marsh, while other areas will see increased drainage and dry out. But the larger concern is that carbon stores will be released into the atmosphere as carbon dioxide, a heat-trapping chemical that plays a role in speeding up global warming. Models built by Canadian IPY-funded researchers suggest that methane and nitrous oxide, two other greenhouse gases, may be released as well.

Another Canadian IPY project examined the carbon cycle from a small scale. These researchers investigated the relationships among mycorrhizal fungi (substances that have a beneficial symbiotic association with plants), soil microbes and tundra plants and explored how these relationships will change in a warming climate. They found that mycorrhizal fungi are critical drivers of Arctic ecosystem change: as climate warms, tundra shrubs increasingly partner with mycorrhizal fungi that specialize in the breakdown of the complex organic carbon stored in tundra soils. The evidence from this study suggests that warming will lead to the decomposition of carbon stores in the Arctic tundra.

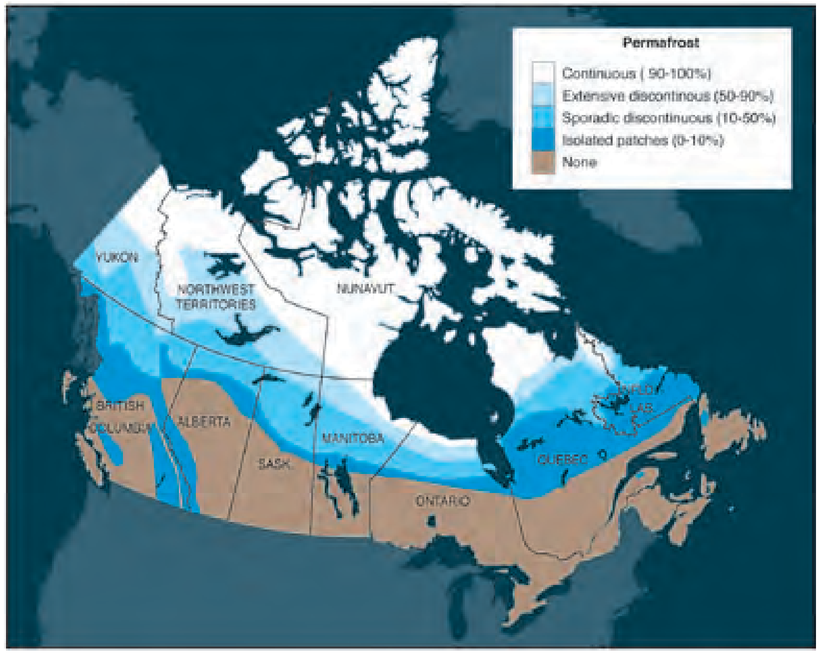
The impact of growing greenhouse gas emissions from permafrost may be mitigated by another undeniable trend: the classic low-growth tundra is now growing up. That was one of the key findings of a Canadian IPY project, Climate Change Impacts on Canadian Arctic Tundra (CiCAT), the first comprehensive assessment of the Canadian tundra. CiCAT researchers studied satellite images of vegetation cover, linked on-the-ground measurements with climate data and collected observations from northerners.

From this work, they found an increasing "green signal" at the forest-tundra boundary: shrubs are growing taller and vegetation is shifting to more



A researcher sends a squirt of water skyward as she collects samples for a study on tundra.

The tundra, in all its many forms, makes up a quarter of Canada's land mass.



Right: Ground ice causes the soil to heave.

deciduous and evergreen shrub cover. Models developed during IPY indicate that as the tundra greens and the tree line moves north, the polar desert areas of the High Arctic will start to show greater plant cover. With vegetation spreading in the Arctic, the increased plant life would act as a carbon sink, taking in carbon as the plants grow.

The "carbon sink or carbon source" debate is complex. To test out theories on how the tundra will react to warming, IPY researchers gathered data at the Tundra Ecosystem Research Station at Daring Lake, located on low-shrub tundra 300 kilometres northeast of Yellowknife, Northwest Territories. They studied carbon cycle in soils, nutrient uptake by plants and the active layer depths of permafrost. With the information gathered, they built an ecosystem model that tried to anticipate how the tundra would react to certain environmental changes. While the work is ongoing, the Daring Lake model suggests that the greening signal will continue: photosynthesis and shrub cover will contribute to greater uptake of carbon dioxide and put carbon back into soils.

Mixed message on the tree line

Another sign of Arctic warming can be seen at the tree line, which marks the limit of forests and the beginning of Arctic tundra. About 40 percent of Canada's land mass is above the tree line. An IPY project recorded changes and mechanisms of change in tree and shrub distribution in relation to climate, focusing in particular on growth rings and tree size. The researchers found a large variation in tree line response to warming: in some places, the alpine tree line has filled in and has become denser over the past 25 years.

In the Old Crow Flats of northern Yukon, changes in the terrestrial ecosystem are impossible to ignore. Homeland to the Vuntut Gwitch'in First Nation, Old Crow is a vast 5,600 square kilometre wetland. An IPY project led by Vuntut Gwitch'in First Nation combined scientific methods and traditional knowledge to investigate the area's past climates and present-day hydrology, permafrost, plants, wildlife and food security.

Observations by Old Crow elders and others living in the region were telling. Shrub growth has exploded, they reported, with some traditional trails now overgrown. With changes in climate and vegetation, some wildlife are expanding their range: moose can be seen along the North Slope, right up to the Arctic Ocean. Birds and insects never seen in the region are starting to appear. To capture more of these observations in the years ahead, the IPY project at Old Crow has established a system of community monitoring of the region's land- and water-based ecosystems, a legacy that will continue to bear fruit.

Similarly in the Eastern Arctic, the ground has been prepared for ongoing community monitoring of the environment. During IPY, CiCAT researchers set up programs with elders and high school students in a number of communities in Nunavik, the Inuit region in northern Quebec. They interviewed elders about traditional and local knowledge of commonly harvested berries: where berries were picked in the past and where they are picked today. The CiCAT researchers also met students and taught them how to conduct basic science fieldwork. The students were then invited to monitor berry harvesting and environmental variables such as vegetation and snow profiles. The students also had the chance to interview elders themselves about berry production. In the fall of 2012, the initiative will become part of the school curriculum in Nunavik high schools.

As part of an IPY project initiative, a Nunavik elder shares her knowledge of wildlife and berry harvesting with high school students.

What's Next?

Research during IPY illustrated the need to build a more sophisticated understanding of permafrost ecosystems. What will be the fate of the active layer of permafrost in a warming Arctic? What are the differences between ice-rich permafrost — which are responsible for unique landforms such as pingos — and simply cold rock?

Ecosystem models for the tundra, such as the one built from Daring Lake observations, need to be further developed and replicated at additional locations. Given the various environmental and social issues arising from a warming planet, scientists are anxious to better understand what the carbon cycle in permafrost and the greening of the Arctic will mean for the ecology of the Arctic

Canadian IPY Research in this Area

"Climate Change Impacts on Canadian Arctic Tundra"; Project leader: Greg Henry, University of British Columbia

"Yeendoo Nanh Nakhweenjit K'atr'ahanahtyaa: Environmental Change and Traditional Use in the Old Crow Flats"; Project leader: Shel Graupe, Vuntut Gwitch'in First Nation

"Impacts of a Changing Arctic Tree Line"; Project leader: Karen Harper, Dalhousie University

"Carbon, Microbial and Plant Community Dynamics in Low-Arctic Tundra"; Project leader: Suzanne Simard, University of British Columbia

"Changing Forests and Peatlands along the Mackenzie Valley"; Project leader: Jagtar Bhatti, Natural Resources Canada

"Measuring the Impact of Climate Change on Landscape and Water Systems in the High Arctic"; Project leader: Scott Lamoureux, Queen's University

"Climate and Alpine Tundra Ecosystems in Southwest Yukon"; Project leader: David Hik, University of Alberta

"Arctic Freshwater Systems"; Project leader: Frederick Wrona, Environment Canada

"Polar Research Observatories for Biodiversity and the Environment"; Project leader: Paul Herbert, University of Guelph

"Microbial Biodiversity of High Arctic Ecosystems"; Project leader: Warwick Vincent, Université Laval

Wildlife

What do population swings say about the future of caribou?

Canada is home to half of the world's migratory tundra caribou herds, and many of these herds have recently experienced declines.

Scientists estimate that, since the 1990s, the Arctic has lost 30 percent of its population abundance among vertebrates — freshwater and marine fish, marine birds and marine and terrestrial mammals. IPY-funded researchers worked hard to fill in key information gaps and tease out the reasons why some Arctic species are declining while others are holding their own or flourishing.

During the IPY years, caribou received considerable attention. This is hardly surprising: Canada is home to half the world's migratory tundra caribou herds, and many of these herds have experienced recent declines, likely part of a natural cycle.

Caribou herds were monitored in various ways: herds in the northwest were counted from photographs of animals gathering after the calving season. Herds in the northeast were counted when cows returned to their traditional calving grounds. According to researchers, caribou herd numbers increased between the 1970s and 1990s and then declined in the first decade of the twenty-first century. Based on recent figures, herds seem to be recovering. Yet the statistics vary dramatically from

Key Findings

- Scientists estimate the Arctic has lost 30 percent of its vertebrate population abundance since the 1990s.
- Caribou herds across the circumpolar world are experiencing unprecedented global challenges from climate change and industrial development. Because of the unique environment in which each herd has evolved, some will be affected more than others.
- It is estimated that one in 10 thick-billed murres has ingested plastic garbage, the first time plastic pollution in Canadian Arctic seabirds has been observed.
- Tundra predators such as snowy owls and arctic foxes can travel over very large areas —including over terrestrial and marine habitats — during a typical year. For small mammals on the tundra, winter habitat quality is strongly influenced by snow depth, with depths exceeding 60 centimetres being ideal habitat.

one herd to the next, meaning data from multiple herds are required to provide an overall picture of caribou population size.

Pinpointing the causes of decline is tricky because caribou population cycles occur over a period of 50 years or longer. Such long time frames make it difficult to determine whether or not a change in caribou populations is part of the natural cycling process, as well as the extent to which factors such as habitat destruction play a role. For scientists and conservation groups, long-term studies that monitor caribou populations provide a baseline of information that can be used as a reference when tracking rising and falling numbers.

Tethered high above the ocean, a researcher collects samples from a murre colony.

Arctic mammals, fish and birds: latest trends

In several projects, IPY researchers examined the results of wildlife monitoring studies conducted over the past 30 years of Arctic warming. The Global Warming and Arctic Marine Mammal project, for example, was an IPY-funded venture that established monitoring programs in northern communities with a focus on top predators. Species such as killer whales that have no natural predators have a top-down effect on the ecosystem. An abundant population of killer whales, noted by both Inuit hunters and confirmed by IPY researchers, spells trouble for the whales they prey on. If bowhead, beluga and narwhal populations drop because of predation, their prey thrive. Researchers have set up a database that keeps track of killer whale sightings and includes geographic information system data. The database is supplemented with information gathered from interviews with elders and hunters living in 11 Nunavut communities.

Similarly, the Polar Ecosystems in Transition project established community-based monitoring programs to study polar bears, focusing on their predator-prey relationship with ringed and bearded seals. The project integrated data from a 20-year survey of polar bears, in which researchers captured bears, tagged their ears and tattooed the insides of their upper lips for identification and

One in 10 thick-billed murres was found to have ingested plastic debris.

Beluga whales ply the open waters near Devon Island.

Left: Researchers take a blood sample from a tranquilized polar bear.

Right: Snowy owl.

then returned to count them every year. Added to the mix were aerial surveys of seals and detailed studies of their tissue and organs harvested from the catch of subsistence hunters.

Marine birds, especially thick-billed murres that breed in large colonies on cliffs, link terrestrial and marine ecosystems — murres nest on land but feed on fish. Over the course of several decades, researchers monitored nesting sites of thick-billed murres in two colonies. Their observations yielded information on the relationship between the timing of Arctic sea ice spring breakup and the start of the nesting period for seabirds. And they provided insight into the health of fish species, from Arctic cod to capelin, by examining the birds' diets. Recent IPY-funded studies have also examined plastic pollution in thick-billed murres; they found one in 10 birds have ingested a piece of plastic debris.

Some projects integrated climate change explicitly in their observations. Climate Variability and Change: Effects on Char in the Arctic, for example, examined how arctic char, a species that is important to Inuit culture and can be found throughout the North, is an important link in the Arctic food web. Arctic char can be studied to monitor contaminant levels in the ecosystem. Its life history is also closely tied to water temperature; char cannot lay eggs in water that is too warm.

For arctic char and other wildlife, the size of the population tends to grow and drop, or cycle, in fairly predictable ways. As a rule, population numbers or density cycles more at higher latitudes and in less productive systems — that is, less cyclicity in the tropics and more in the Arctic tundra. In a new finding, IPY researchers noted that, while terrestrial cycles of Arctic vertebrates were common and consistent, the same could not be said of marine vertebrates. For these species, cycles varied widely:

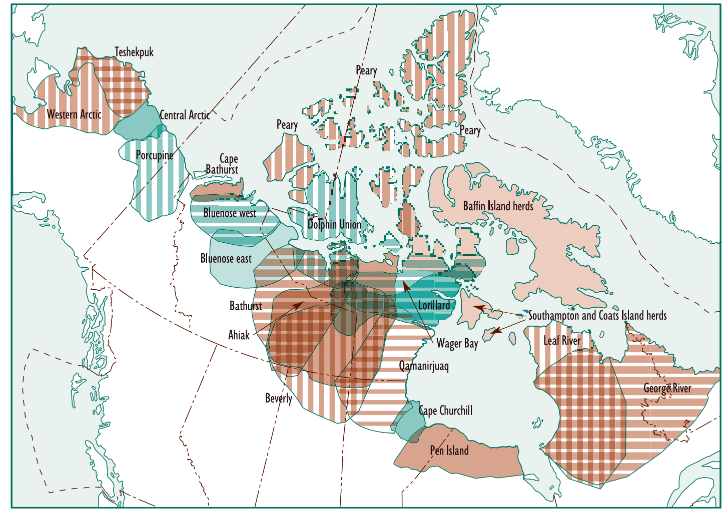
For IPY projects, Canada's North is defined as the land- and ocean-based territory north of the southern limit of discontinuous permafrost from northern B.C. to Labrador.

among some species, for example, the pattern of cycles came and went over time. Future research will aim to build on this insight.

Long-term relationships

To better understand how population sizes are changing, scientists require data that cover long time frames. Short-term studies, generally under four years, examine the biological factors that determine population dynamics, such as predation, disease and food availability, whereas long-term studies can also incorporate climate. Spatial scale is also a key factor: local studies fail to take into account various elements in an ecosystem as well as the connections between terrestrial and marine ecosystems.

Taking the long view is an important step in assessing the impact of climate change on northern biodiversity, especially for species whose populations are in decline as well as for populations new to the Arctic. As the climate warms, tundra habitat is slowly being replaced by subarctic vegetation, making some portions of the North more habitable for southern species. Scientists working in Sirmilik National Park in the northeast Arctic, for example, studied the encroachment of the red fox on the traditional habitat of the arctic fox. Similarly, killer whales are becoming more abundant in Arctic waters.



Main caribou herds in Canada

What's Next?

Climate change will have cascading effects on the Arctic ecosystem, which is why researchers recommend greater integration of monitoring projects. This includes combining data from studies of animals from various levels in the food web. Compiling circumpolar data would provide a global perspective on how climate change affects biodiversity in the Arctic.

Researchers also argue for expanding existing long-term wildlife surveys to better understand population history of key species. Case in point: scientists have yet to link many species population models with information on climate change or pollution. To make the most of these biological time trends, researchers say, Canada needs to develop the capacity to archive, retrieve and exchange long-term data so that the information can be tapped by future generations of scientists.

Canadian IPY Research in this Area

"Global Warming and Marine Mammals (GWAMM)"; Project leader: Steve Ferguson, Fisheries and Oceans Canada

"Polar Ecosystems in Transition: An Interdisciplinary Investigation into the Impacts of Climate Change on Polar Bears"; Project leader: Elizabeth Peacock, Government of Nunavut

"How Seabirds Can Help Detect Ecosystem Change in the Arctic"; Project leader: William Montevecchi, Memorial University

"Climate Variability and Change Effects on Chars in the Arctic"; Project leader: James Reist, Fisheries and Oceans Canada

"Monitoring the Impacts of Global Change on Caribou and Wild Reindeer and their Link to Human Communities"; Project leader: Don Russell, Yukon College

"Environmental Change and Traditional Use in the Old Crow Flats in Northern Canada"; Project leader: Shel Graupe, Vuntut Gwitch'in First Nation

"Arctic Peoples, Culture, Resilience and Caribou"; Project leader: Cindy Dickson, Council of Yukon First Nations

"Pan-Arctic Tagging of Beluga Whales"; Project leader: Mike Hammill, Fisheries and Oceans Canada

"Determining the Diet of the Greenland Shark in a Changing Arctic"; Project leader: Aaron Fisk, University of Windsor

"The Circumpolar Flaw Lead System Study"; Project leader: David Barber, University of Manitoba

"The Impact of Climate Change on Tundra Wildlife"; Project leader: Gilles Gauthier, Université Laval

Community Well-being

Learning from the past, planning for the future

In the Old Crow Flats, in the Yukon, researchers studied the impact of climate change on the traditional life of the Vuntut Gwitch'in First Nation.

Key Findings

- Arctic peoples have had to adapt to environmental change in the distant past, according to oral histories and archaeological studies.
- Melting permafrost, reduced sea ice cover and unpredictable weather patterns due to climate change affect the use of traditional knowledge for hunting and traveling.
- Climate change and increased industrial activity in the North are creating more favourable conditions for diseases, invasive species and contaminants to spread in the food web.
- Communities with strong support for local organizations and government are more resilient in the face of climate change.

Previous International Polar Years focused almost exclusively on the physical sciences. IPY 2007-2008 was the first to include studies that examined how environmental changes in the Arctic region affect the health and well-being of those who live there. Canada's IPY projects in this area covered plenty of ground. Historical studies looked at previous periods of climate change and how northern communities adapted; other studies probed how climate change currently affects northern communities. And tools were developed to help northerners adapt to climate change in the years ahead.

An old story

Archaeological studies have shown that communities in the Arctic have plenty of experience with climate change. One IPY project traced the influence of environment and resources on the migration of the early Inuit, known as the Thule, from the western Arctic to the east due to shifts in bowhead whale migrations. Scientists attribute the rise in whale populations and migration shift to reduced sea ice cover during a warming period between 1000 to 1300 CE.

Researchers studied archaeological sites that revealed how early Inuit lived near Cambridge Bay and Hall Beach in Nunavut, Inukjuak in Nunavik (northern Quebec) and Nain in Nunatsiavut (northern Labrador). As these sites are further explored, they will provide insight into the resilience of Inuit communities in the face of past climate change events.

Some changes in the Arctic landscape offer possibilities for more local archaeological studies. Researchers from the Prince of Wales Heritage

> Melting ice patches provide clues to how Arctic peoples adapted to climate change.

Researchers with an IPY archaeological study carefully look for artifacts at a coastal site. Such sites offer clues to how Inuit adapted to climate change.

Centre, in Yellowknife, NWT, studied ice patches — accumulations of snow, which, until recently, remained frozen year-round. Rising temperatures in the Arctic are causing some of the ice patches in the Mackenzie Mountains to melt, uncovering artifacts preserved for thousands of years. As a result, archaeologists are able to reconstruct past migration and hunting patterns in the Northwest Territories.

Ice patches are indicators of past hunting practices because of their importance to caribou. For centuries, hunters have watched for caribou at ice patches, where animals seek relief from mosquitoes and heat. As a result, ice patches have become repositories of arrows, spear tools, dart shafts and snares. They also contain fossilized caribou dung from which biologists have extracted DNA, offering a picture of past migration patterns. The dung was also analyzed for traces of plants, pollen, insect remains and even parasites — clues that help biologists reconstruct past ecosystems. In all, the IPY project researchers examined eight ice patches and extracted artifacts dating back nearly 5,000 years. The study also identified ice patches for future study.

Building the capacity to adapt

Two Canadian IPY projects, Community Adaptation and Vulnerability in Arctic Regions (CAVIAR) and Arctic Peoples: Culture, Resilience and Caribou (ACRC), looked at how climate change will affect the social conditions of communities in the Arctic.

CAVIAR took a bottom-up approach by allowing local communities in eight Arctic countries, including Canada, to define the focus of the study. CAVIAR also integrated traditional knowledge along with scientific methods to measure the vulnerability of communities to changing social and environmental conditions, and to determine how they can adapt.

CAVIAR found that climate change poses both risks and opportunities to northern communities related to natural resource extraction, economic activities and health. The degree of vulnerability varies within and between Arctic communities. Those whose organizations and governments have widespread support were best able to adapt to climate change.

ACRC, a joint project between the Arctic Athabaskan Council, Gwich'in Council International, Dene Nation, Inuit Tapiriit Kanatami and the Canadian office of the Inuit Circumpolar Council, investigated community responses to fluctuations in the availability of barren ground caribou. In the past decade, it is estimated that barren ground caribou populations, a resource vital to the livelihood and health of northerners, have declined by up to 85 percent in some herds.

The study was conducted in 16 communities across the Canadian Arctic. Researchers ran workshops and studied oral histories to learn from caribou hunters, community leaders, resource managers, elders, adults and youth about their adaptive strategies to cycles in caribou populations. They found that many communities cope by relying on a variety of foods from diverse ecosystems, strong social networks and knowledge of past episodes of caribou scarcity.

The Inuit Sea Ice Use and Occupancy Project examined the role of another key resource, sea ice, in the well-being of northern communities. Changes in the composition, thickness and extent of the frozen surface affect people whose traveling and hunting traditions are closely tied to the frozen ocean. The Canadian IPY-funded program contributed to the international Sea Ice Knowledge and Use (SIKU) project and developed an online, interactive atlas on sea ice. Yet another tool that emerged from this project is an affordable global positioning device that can be easily mounted on snow machines and sleds to track travel over sea ice.

Treating waste with wetlands

Improving sewage treatment is crucial to the well-being of northern communities. Sewage treatment in much of the North is not fully developed to withstand extreme cold, which can become a public health concern. One disease-causing parasite, *Toxoplasma gondii*, thrives in sewage.

To date, most wastewater treatment systems in the North have been modeled after those used in the South, but they can be too technologically complex for the Arctic environment. IPY-funded research studied the potential of using engineered wetlands, where natural biological, physical and

Left: Caribou seek relief from mosquitoes and heat at an ice patch. Such patches are repositories of hunting artifacts.

Top right: The community of Pond Inlet.

Bottom right: Arctic char drying in Bathurst Inlet.

Far right: An oil platform in the Beaufort Sea.

chemical processes clean the wastewater before it flows into the ocean.

The research was conducted largely in the Kivalliq Region of Nunavut, west of Hudson Bay, where researchers evaluated current wastewater treatment facilities. A pilot wetland site in the community of Baker Lake was found to function effectively both in harsh winter weather and the summer months. Further testing is needed to determine whether it is the most viable option for wastewater treatment in Arctic communities.

What's Next?

The Inuit Sea Ice Use and Occupancy Project's SIKU atlas is meant to be a "living" resource. In addition to preserving cultural knowledge of sea ice use, the atlas is intended to grow as understanding of changing sea ice conditions develops. Researchers hope to incorporate SIKU in the Nunavut school curriculum so that children and young people can learn more about Inuit knowledge of sea ice.

Canadian IPY Research in this Area

"Dynamic Inuit Societies in Arctic History"; Project leader: Max Friesen, University of Toronto

"Inuit History: Climatic Change and Historical Connections in Arctic Canada"; Project leader: Patricia Sutherland, Canadian Museum of Civilization

"Northwest Territories Ice Patch Study"; Project leader: Thomas Andrews, Prince of Wales Northern Heritage Centre

"Communities in the Changing Arctic"; Project leader: Barry Smit, University of Guelph

"Arctic Peoples, Culture, Resilience and Caribou"; Project leader: Cindy Dickson, Council of Yukon First Nations

"Environmental Change and Traditional Use in the Old Crow Flats in Northern Canada"; Project leader: Shel Graupe, Vuntut Gwitch'in First Nation

"Traditional Knowledge and Climate Change in Tr'ondëk Hwëch'in Traditional Territory"; Project leader: Allie Winton, Trondek Hwech'en

"Kwäday Dän Ts'inchi Discovery: Expanding our Understanding through Linked Scientific and Community Studies Project"; Project leader: Sheila Greer, Champagne and Aishihik First Nations

"Inuit Sea Ice Use and Occupancy Project"; Project leader: Claudio Aporta, Carleton University

"Constructed Wetlands for Treatment of Wastewater in Arctic Communities"; Project leader: Brent Wootton, Fleming College

"The Impacts of Oil and Gas Activity on Peoples in the Arctic"; Project leader: Dawn Bazely, York University

"Engaging Communities in the Monitoring of Country Food Safety"; Project leader: Manon Simard, Makivik Corporation

"Monitoring the Impacts of Global Change on Caribou and Wild Reindeer and their Link to Human Communities"; Project leader: Don Russell, Yukon College

"Impacts of a Changing Arctic Tree Line"; Project leader: Karen Harper, Dalhousie University

Human Health

Lifestyle changes take their toll on Inuit

An inuk hunter surveys pack ice. For Inuit, country food is healthier than store-bought food.

The Inuit's traditional diet, based on liberal amounts of fish and marine mammal meat, is rich in omega-3 fatty acids that help ward off chronic illnesses such as heart disease. Yet the life expectancy at birth for Inuit is nearly 10 years lower than for the rest of the Canadian population.

To understand the reasons behind the disparity, IPY research projects focused on diet and chronic illnesses, environmental factors and infectious diseases. Researchers worked with members of northern communities and shared their findings with local health authorities. They sought ways to develop vaccines, preventive measures and health interventions that make sense for Arctic communities.

Over the past 60 years, the Inuit have experienced profound change. Where they once lived in seasonal camps close to the wildlife they depended on, they now live in settled communities. And climate change is altering an environment long understood and interpreted by traditional ecological knowledge.

Humans and wildlife alike are vulnerable to such

Key Findings

- A shift away from their traditional lifestyle has led to a number of health problems for Inuit relating to nutrition and chronic illness.
- The high cost of basic necessities and a rapidly growing population are contributing to significant food and housing shortages, key factors in maintaining good health.
- Vaccines used for human papillomavirus (HPV) and hepatitis B in North America may not be as effective for Inuit populations; either the structure of the virus itself, its method of transmission or the population's genetics affect the way the disease manifests.
- Diseases that can be passed from wildlife to humans must be monitored to determine whether or not disease rates are rising and to find ways to prevent transmission.
- Respiratory disease among the young is a significant health problem.

More than half of surveyed homes had insufficient food appropriate for children.

As part of an Inuit health survey, a nurse reviews test results with a resident of Resolute Bay.

environmental changes. The fat in caribou, Inuit hunters told IPY researchers, is different now. There is less of it and the texture has changed. Scientists speculate climate change may also make the Arctic environment more hospitable to parasites, worms and bacteria; during IPY, they tested this theory by having hunters send samples of the meat they harvested to laboratories for testing. Traditionally, some meat is eaten raw, making it easier for humans to pick up disease-carrying agents.

Yet Inuit and scientists alike know that "country" food is healthier than store-bought food. Because products have to be shipped great distances, store-bought food contains many preservatives. They also tend to be high in trans and saturated fats, both linked to a higher risk of obesity and chronic diseases.

The familiar diet recommendations of nutritionists are not as easy to prescribe in the North, where food prices are twice as high as in most other places in Canada due to shipping costs. Dairy, fresh vegetables and grains are expensive luxuries rather than dietary staples. Food products high in sugar are cheaper and more accessible.

Inuit health surveys tell the tale

For Inuit, health challenges can be traced to poverty, food insecurity and poor housing conditions. This grim equation was noted by researchers who visited 33 northern coastal communities while travelling aboard the Coast Guard icebreaker Amundsen, as well as by land-based research teams visiting three inland Inuit communities. Nurses distributed a voluntary survey to more than 1,900 households in which they asked about the kinds of medication used, administered a test to detect diabetes and collected blood samples for further study.

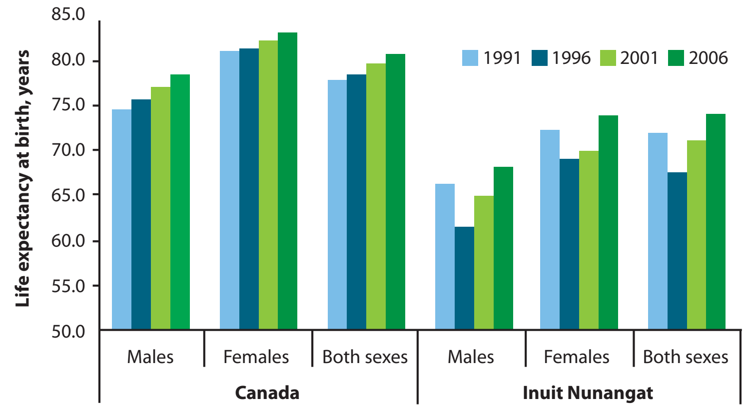
The survey found many homes that were overcrowded. Also evident were the effects of food insecurity, defined as the availability of, and access to, food. With the shift toward a market diet that is high in sugar and low in vegetables, grains, dairy and fibre, Inuit adults are at risk of developing high cholesterol, coronary heart disease and type 2 diabetes. In fact, the rate of these chronic diseases among Inuit, which has historically been low, is now approaching that of the general population in Canada.

Researchers also surveyed 388 households in Nunavut with children between the ages of three and five. They evaluated factors such as the degree to which families followed a traditional diet and lifestyle and whether mothers smoked or consumed alcohol during pregnancy.

This study found that nearly 70 percent of the surveyed homes experienced food insecurity, while more than half had insufficient food appropriate for children. Children experiencing food insecurity tended to eat more sugar and drink less milk. Many were overweight or obese and had dental cavities. If their households followed a more traditional diet, however, they were less likely to be deficient in iron and vitamin D.

At the Nunavik Research Centre in Kuujjuaq, seal stomachs are dissected to monitor food safety.

Life expectancy at birth, 1989-2007, Canada and Inuit Nunangat



Responding to infectious diseases

Most northern communities are isolated and have small but rapidly growing populations. Maintenance and repair costs for buildings are especially high given the extreme climate, so overcrowding in homes is not uncommon. With many people living in close quarters, diseases can spread easily.

Vaccines and antibiotics are designed to prevent or treat infectious diseases, but immunization programs are relatively new in the Arctic. Studies are underway to explore the effectiveness of flu and pneumonia vaccines among Inuit populations and children in particular.

Two prevalent infectious diseases are HPV and hepatitis B. HPV is commonly linked with cervical cancer while hepatitis B is linked to liver cancer. Cancer rates for both diseases are now higher among Inuit than Caucasians. But the HPV vaccines available today may not be effective for Inuit populations. Public health programs in the North are now gearing their efforts toward raising awareness and offering more education about risk and prevention.

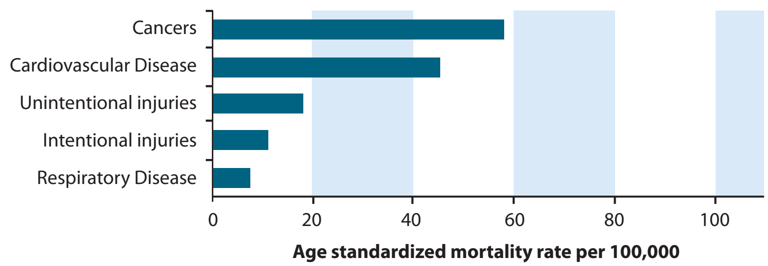
While HPV is thought to be a fairly recent disease introduced to Inuit, hepatitis B may have existed for centuries. Some researchers suggest early groups that crossed the Bering Strait and established themselves in the Canadian Arctic may have brought the disease with them.

One intriguing finding from Canadian IPY research is that the hepatitis B virus in Northern Canada differs from the virus found in aboriginal populations of Alaska and Greenland; the Canadian version changes its appearance much more frequently. As a result, the patient's defence system has trouble recognizing the virus and much of the liver injury that results from the immune system attacking the virus occurs less often (or is delayed) in infected Canadians.

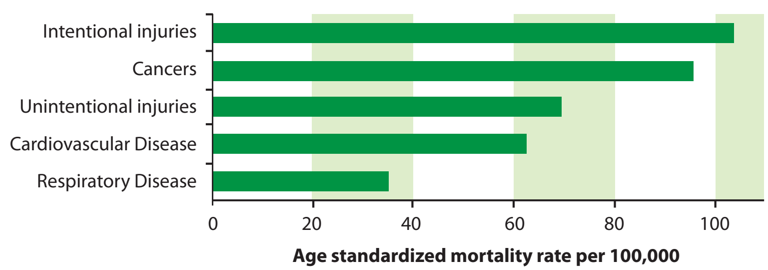
> A legacy of IPY is the Association of Polar Early Career Scientists, one of the world's leading institutions supporting the next generation of polar scientists.

Five primary causes of death, Canada and Inuit Nunangat, 2006

Canada



Inuit Nunangat



To download a copy of this report, visit the Canadian Polar Commission website at **www.polarcom.gc.ca**

What's Next?

To address life expectancy and the infant mortality rate, two important health indicators and a standard by which to compare health between Inuit and the rest of Canada's population, future research should pay close attention to common causes of death among young males, older women and infants.

Some projects will study how shifting diets and lifestyles affect circumpolar Inuit populations. The International Cohort study, for example, will compare the rates of chronic diseases across Inuit populations in Canada, Alaska and Greenland.

Some health policy changes have already been implemented. One success story is the Trichinellosis Prevention Program, established in 1996 in Nunavik, which helps identify a worm in animal meat that can infect humans. It has been adapted to analyze several types of meat, including walrus and bear. Other methods have been developed to detect parasites, worms and bacteria in wildlife so that Inuit hunters can ensure their meat is safe to eat. Laboratories are being set up in various communities to help spread the program beyond Nunavik.

Canadian IPY Research in this Area

"Inuit Health Survey: Inuit Health in Transition and Resiliency"; Project leader: Grace Egeland, McGill University

"An Integrated Research Program on Arctic Marine Fat and Lipids"; Project leader: Eric Dewailly, Centre Hospitalier du L'Université Laval

"Engaging Communities in the Monitoring of Country Food Safety"; Project leader: Manon Simard, Makivik Corporation

"Evaluating the Effectiveness of Vaccination against Respiratory Infections for Young Children of the Nunavik Region"; Project leader: Philippe DeWals, Université Laval

"Coordinated Effort to Clear Hepatitis Viruses from the Canadian North"; Project leader: Gerald Minuk, University of Manitoba

"Human Papillomavirus and Cervical Disease in the Northwest Territories"; Project leader: Yang Mao, Public Health Agency of Canada

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Page 24: Ed Struzik
Page 25: Martin Fortier/ArcticNet
Page 26: Gérald Darnis/ArcticNet
Page 27: Varela et al, based on unpublished data
Page 28: Geneviève Ringuet/ArcticNet
Page 29: Ruth Errington
Page 30: (left) Steve Fick; (right) Antoni Lewkowicz
Page 31: Jennie Rausch
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Page 33: Jennifer Provencher
Page 34: (top) Keith Levesque/ArcticNet; (bottom left) Ed Struzik; (bottom right) Thierry Gosselin/ArcticNet
Page 35: Anne Gunn and Don Russell, "The dwindling number of caribou in Canada's Arctic", Meridian, Fall-Winter 2010, Canadian Polar Commission
Page 36: Kevin Turner
Page 37: Courtesy of "Dynamic Inuit Societies in Arctic History" project
Page 38: (left) Glen Mackay; (right top) Martin Fortier/ArcticNet; (right bottom) Alexandre Forest/ArcticNet
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Page 40: James Ford
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