
Fisheries and Oceans Canada
Pêches et Océans Canada
Annual Report on the
Science Activities
of Fisheries and Oceans Canada, 2009–2010
Canada

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On the front cover:

The two killer whales on the cover are Pacific transient killer whales designated T124A1 and T124E. They were traveling past Nanaimo into Northumberland Channel, British Columbia when the photo was taken by Graeme Ellis, a Marine Mammal Specialist based at the Fisheries and Oceans Canada Pacific Biological Station in Nanaimo, British Columbia.

***At right*: The vibrant habitat of Queen Charlotte Strait in British Columbia, also known for its marine mammals, is accessible to divers. In Browning Passage close to Nigei Island, diver/photographer Mike Wetklo found red sea urchins (*Strongylocentrotus franciscanus*) beside a painted sea star (*Orthasterias kochleri*). Researchers are monitoring changes in such Pacific ecosystems.**





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Message from the Assistant Deputy Minister

I am very proud to present this, my first annual report on science activities at Fisheries and Oceans Canada, since becoming Assistant Deputy Minister. I am pleased to join this group of accomplished men and women whose scientific work spans both our country and our broad scientific mandate.

A key challenge inherent in our science activities is to provide science advice to inform policy and programs, even as we prepare to address emerging issues. Our scientific research, monitoring and collection of freshwater and ocean data are among activities that position us to do both. We do not do this alone. The ecosystem approach to managing our aquatic environments requires the engagement of the Canadian public and a deepening collaboration of policy makers in governments and of scientists in both government and academia, across Canada and internationally.

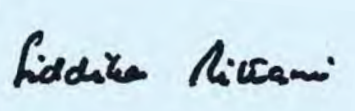
This report on our key activities of 2009–2010 underscores the scientific challenges presented by the changing and sometimes precarious nature of Canadian ocean and freshwater habitats in our most populated regions.

Nowhere are these changes more evident than along our Pacific Coast. There, commercial fishing is complicated by warming waters accompanied by an influx of Humboldt squid, whose northernmost range was once off the coast of California. Our research into potential Pacific sea level rise helps focus attention on the need to plan for the safety of people and infrastructure in areas of the low-lying Fraser Delta region.

Coastal and surface waters of the Pacific, Atlantic and Arctic Oceans show evidence of ocean acidification — a serious issue that stands to impact commercial fisheries in the future. Meanwhile, in freshwater ecosystems our scientists work to rebuild indigenous species such as the American Eel, and are working to prevent invaders such as Asian carps from entering the Great Lakes.

The benefits of the important science being done at Fisheries and Oceans Canada can only be fully realized when we ensure it is broadly accessible to others. To mobilize our scientific knowledge, we keep those who depend on our science informed. We provide email alerts of new peer-reviewed science. An online directory of our scientists assists collaboration, and a subscription service for weekly science feature stories enables everyone interested in aquatic science to learn more. We work closely with museums, science centres and aquariums and, in every region of the country, we welcome educators and students into our facilities.

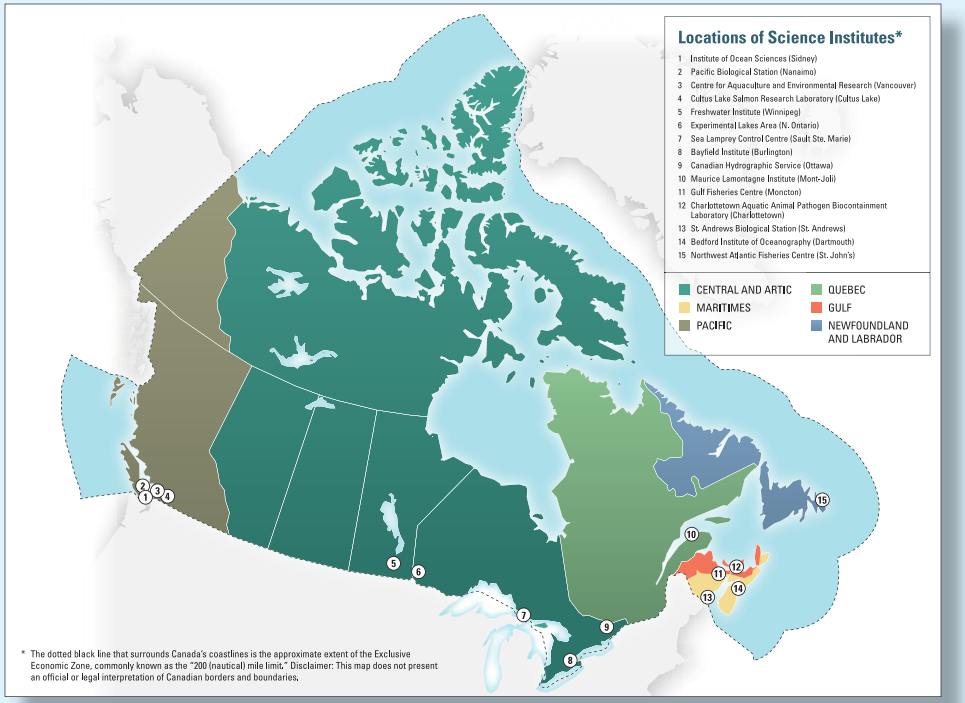
Last, but not least, we produce this annual report on our activities. I encourage you to take advantage of the wealth of information it offers to learn more about the progress of our science team on key scientific challenges relating to Canada's aquatic ecosystems.



Siddika Mithani, Assistant Deputy Minister
Ecosystems and Oceans Science Sector

Key Accomplishments

- Discovered new species of ocean life, ancient corals and more during a 20-day mission led by Fisheries and Oceans Canada to explore and document the biology and geology of the ocean bottom surrounding Flemish Cap and Orphan Knoll in the Northwest Atlantic.
- Explored ocean acidification in Canada's three oceans and its potential impacts in order to help predict how ecosystems and individual marine species will respond to increased acidification.
- Successfully deployed an autonomous underwater vehicle to map the seabed in the North, preparing this new technology to play other roles in long-range, unescorted missions in harsh environments. The bathymetric data collected will help determine the outer limits of Canada's continental shelf.
- Helped prevent the spread of several invasive Asian carp species to the Great Lakes by sending 15 staff from the Department's Great Lakes Laboratory for Fisheries and Aquatic Sciences in Burlington, Ontario, to join a Canada-United States effort to eradicate the invaders from a six-mile section of the Chicago Sanitary and Ship Canal.
- Developed a new genetics-based test to improve the detection of the aquatic disease Viral Haemorrhagic Septicaemia Virus (VHSV). The new test is highly sensitive, fast, recognizes all known strains of the virus and is suitable for screening large numbers of samples.
- Developed the Canada-Newfoundland Operational Ocean Forecasting System (C-NOOFS), which produces 10-day forecasts of ocean conditions in the Northwest Atlantic on a daily basis. Fisheries and Oceans Canada and Environment Canada are collaborating to combine the system into the next generation Canadian Weather Forecast System.
- Developed and tested a new laser tide gauge system to improve the reliability and timeliness of Canadian tide gauge data, which are used for a variety of purposes, such as making tidal predictions, improving nautical charts, recording sea level rise, and monitoring storm surge and tsunami activity in real time.
- Carried out research in collaboration with the Maritimes herring industry to address priority issues including the improvement of industry-based acoustic surveys and the herring stock assessment in Northwest Atlantic Fisheries Organization herring stock area 4WX.
- Tested new salmon forecasting models developed for assessing stocks of Coho Salmon off the west coast of Vancouver Island.
- Defined biological reference points for inclusion in harvesting strategies for Snow Crab in the southern Gulf of St. Lawrence and to be compliant with the precautionary approach to managing stocks.



- Developed seven "Pathways of Effects" documents and diagrams — which map the potential stresses of aquaculture activities on the environment and the potential effects of those stressors on ecosystems — to inform the regulation of aquaculture operations.
- Collaborated with industry and academia on research to improve the productivity and sustainability of marine aquaculture practices through the use of Integrated Multi-Trophic Aquaculture. Findings are being used to improve commercial operations.

To learn more about science at Fisheries and Oceans Canada please visit our website, at www.dfo-mpo.gc.ca/science. An email alert service is available to advise when new science is published. Our regular science feature stories are available by email subscription and the Canadian Science Advisory Secretariat provides access to peer-reviewed science related to the regulatory and policy priorities of the department.

Unidentified anemone anchored to rock.

Deepwater Mission Discovers New Species, Ancient Corals and More

Newly discovered species of sea life including corals, anemones, cylindrical glass sponges and sea stars, a volcanic seamount, and fossilized coral that holds clues to oceanographic conditions stretching back thousands of years — these are but a few of the findings of a deepwater mission led by Fisheries and Oceans Canada in July 2010. The goal: to explore and document the biology and geology of the ocean bottom surrounding Flemish Cap and Orphan Knoll, located in the Northwest Atlantic off the east coast of the island of Newfoundland outside the 200-mile limit.

On July 8, an international team of scientists and crew aboard the CCGS *Hudson* embarked on the 20-day mission. The multi-disciplinary, international team of contributing science staff and students included biologists, geologists, biogeographers and hydrographers from eight different organizations. Under their direction, staff from the Canadian Scientific Submersible Facility deployed an underwater vehicle known as ROPOS (Remotely Operated Platform for Ocean Science) to depths up to 3,000 metres. Fitted with a movable arm, cameras and other scientific equipment, the vehicle collected biological and geological samples, high-definition video and digital photographs of life on the sea floor.

The mission encompassed fishery areas that have been closed by the Northwest Atlantic Fisheries Organization to protect coral, sponges and other vulnerable marine ecosystems. Closure of these areas was based on bottom topography and bycatch data from research vessel surveys. The main goal of the mission led by the Department was to determine *in situ* coral and sponge density inside some of the closed areas for comparison with the survey estimates. The comparisons will be used to determine if the protected areas need to be refined or expanded when they are reviewed in 2011, and could determine future fishing policy in the regulatory area. Baseline information collected from outside of the closed areas and the fishing footprint, where fishing currently takes place, will be used to evaluate areas that are still too deep for existing fishing technologies but could be accessible in years to come and to inform exploratory fishing protocols in the future.

The biological and geological expertise on board allowed for a quick interpretation of mission findings, which included many potentially new and interesting species of corals and sponges as well as unique deposits of manganese nodules that are among the slowest growing geological phenomena on Earth; for each nodule, one centimetre of diameter represents several million years of growth.

Now that the mission is complete, scientists are also using the information collected for a variety of other research purposes including to:

- identify and define the newly discovered species and their role in local ecosystems;
- trace oceanographic conditions over thousands of years by analyzing the chemical composition of fossilized coral collected during the mission; and
- examine the impact of survey trawling gear on benthic corals and sponges (research by collaborator, the Spanish Institute of Oceanography).

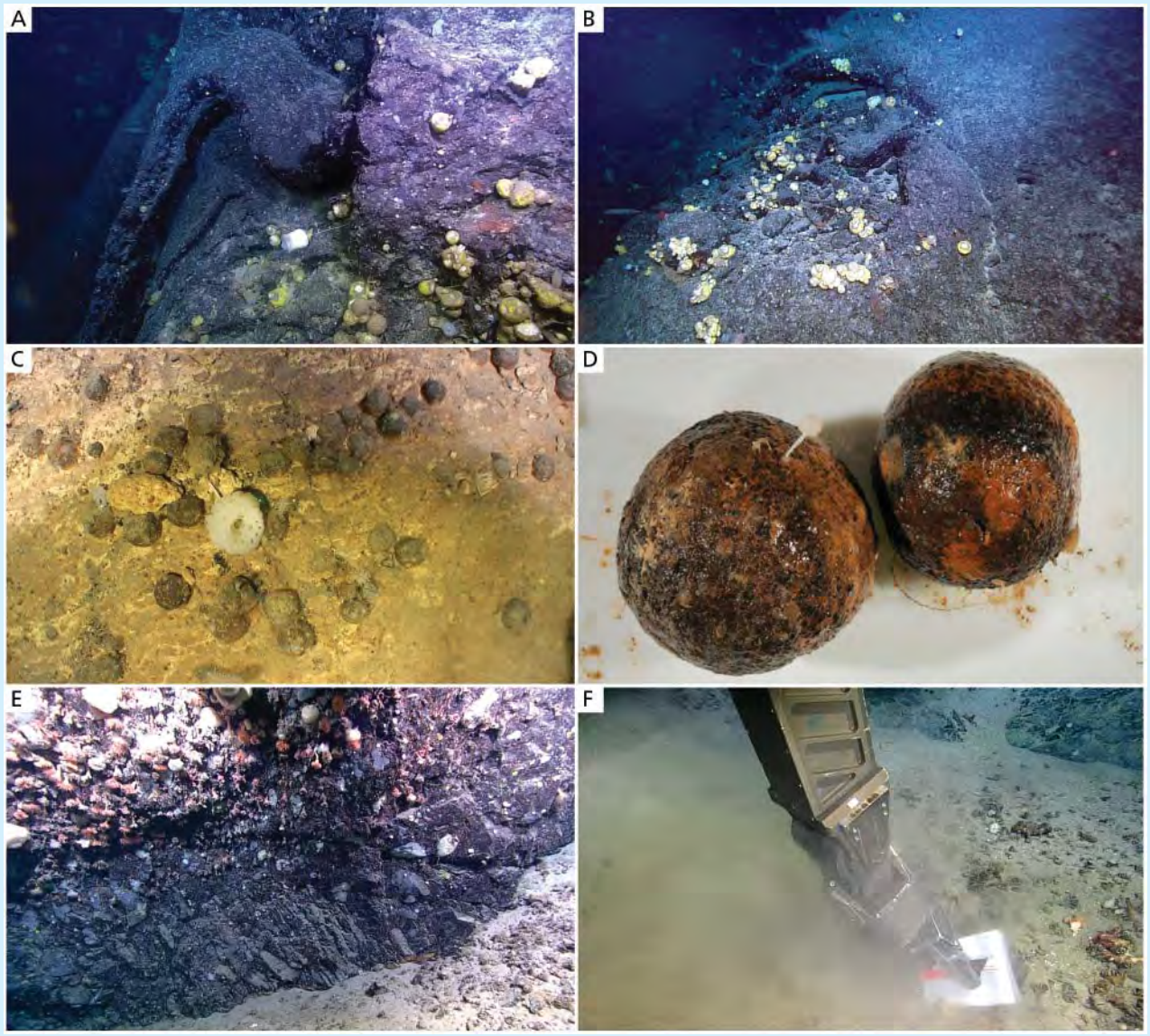
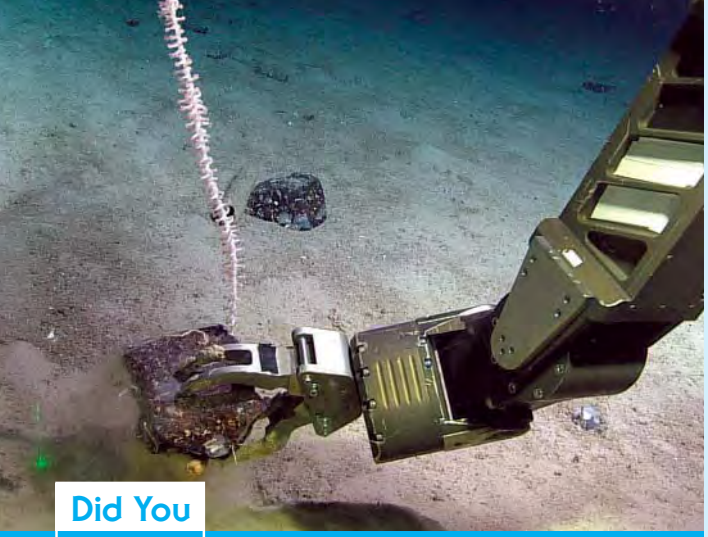


Figure A&B — Images of volcanic features seen on a seamount just south of Orphan Knoll. **C&D** — Manganese nodules on the ocean floor and in the lab, just 1 cm of diameter can equal millions of years of growth, a possible window on the ocean's past. **E** — A cliff covered in the hard coral *Desmophyllum* sp. **F** — When dead, the ~100-year-old *Desmophyllum* drop to the base of the cliff and are then covered by accumulated sediment from the water column. The investigation of select radio-isotopes within long-buried coral from these "graveyards" can provide clues to ocean climate and circulation phenomenon.



Did You KNOW?

COMMUNICATING FINDINGS FROM THE DEPTHS

While a remote-controlled underwater vehicle roamed the ocean floor during a July 2010 deepwater mission led by Fisheries and Oceans Canada, some members of the scientific team were contributing to an unprecedented scientific outreach initiative for the Department that involved commentating on live and recorded streaming video via Skype with the Canadian Museum of Nature in Ottawa, Ontario, The Rooms Museum in St. John's, Newfoundland and Labrador, and the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. This unique communications opportunity enabled researchers on board to collaborate with onshore partners that had a vested interest in the mission but were otherwise unable to go to sea. A mission blog (http://hudson0292010.blogspot.com) and Twitter account were updated frequently and provided another resource for the general public, media, managers and collaborators to stay up to date on the progress of the mission.

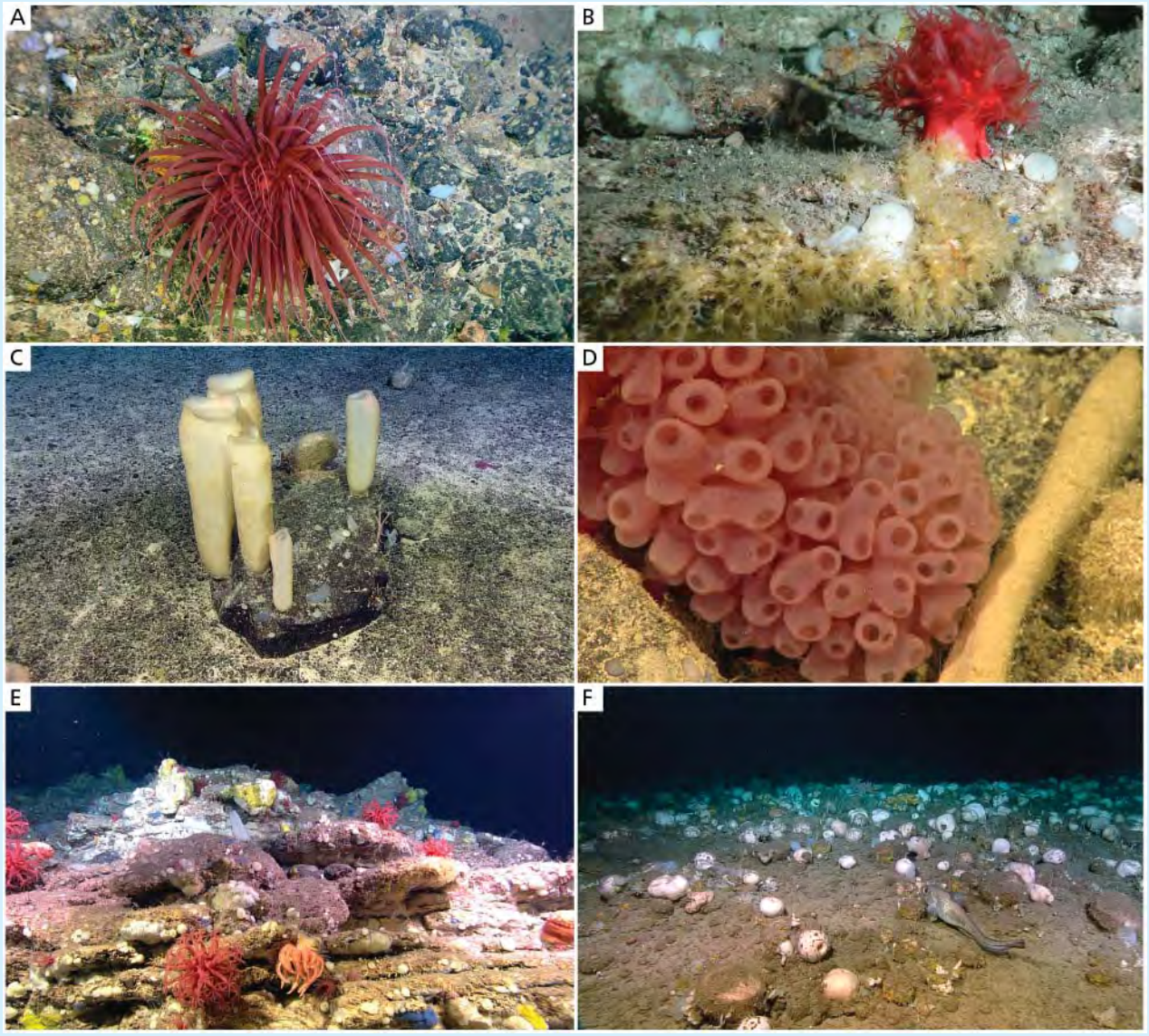


Figure A — Unidentified anemone anchored to rock. **B** — Soft corals *Anthomastus* sp. (red) and low-lying unidentified octocoral (cream). **C** — Unidentified vase glass sponge on transported boulder. **D** – Unidentified purple and cylindrical glass sponges. **E** — Diverse benthic fauna on outcrop. **F** — Abundant sponge grounds (mostly large structure forming *Geodia* sp.) within a Northwest Atlantic Fisheries Organization sponge closure area on the Flemish Cap. Canadian and Spanish research vessel bycatch records have been instrumental in identifying closure areas with high concentrations of both corals and sponges as further supported by visual evidence seen here.

Ocean Acidification — Researching Potential Impacts on Canada's Fisheries

Ocean acidification is a significant international governance issue and the scientific community is now moving more quickly to investigate its implications. Each year, about one third of the carbon dioxide (CO_2) in fossil fuel emissions enters the oceans. As the CO_2 dissolves in surface waters it forms carbonic acid, increasing ocean acidity. Eventually this excess carbon will become more evenly distributed, but in the short term (roughly 100 years) its impacts will be intensified near the surface where much of the marine life that humans depend upon live.

Over the past 200 years, global ocean pH (a measure of acidity) has decreased by 0.1 units — about a 30 percent increase in acidity. By the turn of the next century, the pH is projected to decrease by another 0.3 to 0.5 units, raising concerns about the potential impacts on marine food webs, ecosystem productivity, commercial fisheries and global food security.

Department scientists are exploring ocean acidification in Canada's three oceans and its potential impacts through two research initiatives: the Climate Change Science Initiative and the Science Program of the International Governance Strategy. Ultimately, this research will help predict how ecosystems and individual marine species will respond to increased acidification. There are particular concerns about the impacts on organisms that use calcium carbonate ($CaCO_3$) to form solid structures such as shells and skeletons (called "marine calcifiers") including shellfish, corals and some species of phyto- and zooplankton. The findings will also inform future fisheries management decisions.

Vancouver Island's coastal habitat includes creatures like this Kincaid coastal shrimp or "broken-back shrimp" (*Heptacarpus kincaidi*), seen here among corals and other small organisms that also require calcium carbonate to grow. Photo: Copyright Mike Wetklo.

In Canada, the mechanisms driving ocean acidification vary by region:

- In the Pacific, older sub-surface waters are naturally higher in CO_2 due to biological decomposition. Upwelling in the summer brings this acidic water to the surface over the shelf. Ocean uptake of anthropogenic CO_2 increases the acidity further.
- In the Arctic, cold and fresh water is inherently corrosive to marine calcifiers. Although ocean acidification is a global phenomenon, modeling studies predict that high-latitude surface waters will experience detrimental effects earliest, likely within decades, due to a variety of factors including sea ice melting. The pH of some Arctic surface waters is already at the level of possible corrosiveness to marine calcifiers.
- In the Atlantic, the threat of ocean acidification comes in two ways — the direct uptake of anthropogenic CO_2 (the Northwest Atlantic is the largest storehouse of anthropogenic CO_2), and the outflow of corrosive Arctic water through the Canadian Arctic Archipelago to the shelf regions of Canada's east coast.

These acidification mechanisms potentially affect the high biological activity and important commercial fisheries in Canadian waters.

Did You KNOW?

HUMBOLDT SQUID SWARM BRITISH COLUMBIA WATERS

Sightings of Humboldt squid (*Dosidicus gigas*), a large predatory species that isn't usually found north of California, have become more common in British Columbia waters. The sightings have increased since 2004 and Humboldts were extremely abundant and widespread in 2009. Stranded squid were reported from Tofino to Haida Gwaii, and squid also showed up in commercial and research catches. Humboldt squid can function as keystone predators, potentially affecting ecosystem structure and function. Their diet is largely determined by prey availability, and researchers are examining the potential effects of this new predator on commercially important hake, herring and salmon.

Kent Tebbutt and Meggie Hudspith, both graduate students from the University of Southampton, U.K., display specimens of Humboldt squid collected during the Fisheries and Oceans Canada month-long fall survey aboard the CCGS *W.E. Ricker.*

Integrated Multi-Trophic Aquaculture — From Research to Commercial Reality

A great deal of research around the world is exploring ways to improve the productivity and sustainability of marine aquaculture practices. One approach under investigation is Integrated Multi-Trophic Aquaculture, which involves growing finfish, shellfish and marine plants together for the benefit of these crops and the environment.

The program, led by Drs. Shawn Robinson of Fisheries and Oceans Canada (St. Andrews Biological Station) and Thierry Chopin of the University of New Brunswick in Saint John, promotes the practice in which the wastes from one species are recycled to become fertilizers or food for another. This creates an operation that is more socially acceptable, economically profitable and environmentally benign.

The shellfish culture portion of the program, carried out in collaboration with Cooke Aquaculture Inc., has recently made progress on several fronts:

- The design of a mussel raft evolved in 2009–2010, enabling more mussels to be grown in a smaller footprint and harvested more efficiently. This has led to additional studies measuring how currents flow in and around the rafts since the current carries food to the mussels.
- Research advanced on the distribution and timing of the settlement of mussels for the collection of seed to stock the new rafts. A network of sampling stations in Passamaquoddy Bay and the Fundy Isles revealed that the highest numbers of settling larvae are in Passamaquoddy Bay and that they settled primarily during the third week of July. This information enabled the Cooke team to determine the best time and areas to collect spat (very young mussels) for their operations.
- Studies of the relative growth and mortality of the animals within mussel socks found that all of the mussels grew well in and around the salmon aquaculture site, with the mussels that were hung closest to the salmon cage having slightly higher growth rates.
- Research into the zone of influence a salmon site can have on the local area revealed that although the zone is less than 100 metres, some organisms can do very well within it. Scallops and sea urchins grown beside a salmon site in the Bay of Fundy showed some of the highest growth rates ever seen in that area.

The success of Integrated Multi-Trophic Aquaculture research in collaboration with Cooke Aquaculture Inc. is being widely noted as new environmentally based methods and technologies are being developed. Scientists visited from Brazil and New Zealand in 2009–2010 and presentations were given at numerous industry and scientific conferences.

Oyster Farming — Why Are Oysters Grazing Slowly to Market Length?

Oyster farming and other bivalve aquaculture is becoming increasingly important in Canada. Since bivalves extract food (phytoplankton) from the environment, rather than being fed, there is an inherent sustainability in the practice, assuming that the oyster aquaculture operation is an appropriate size for the phytoplankton biomass available.

To learn more about the grazing rates of cultivated oysters in their environment, researchers at the Department's Gulf Fisheries Centre in Moncton, New Brunswick, developed a novel system called the Pelagic Ecosystem Tunnel. A fluorometer at the inflow end of the tunnel measures phytoplankton biomass before it reaches the oysters, which are positioned in the middle. A second fluorometer at the outflow end measures the phytoplankton biomass after it passes by the oysters. These measurements, combined with simultaneous monitoring of current speeds, enables researchers to calculate the grazing rates of the oysters.

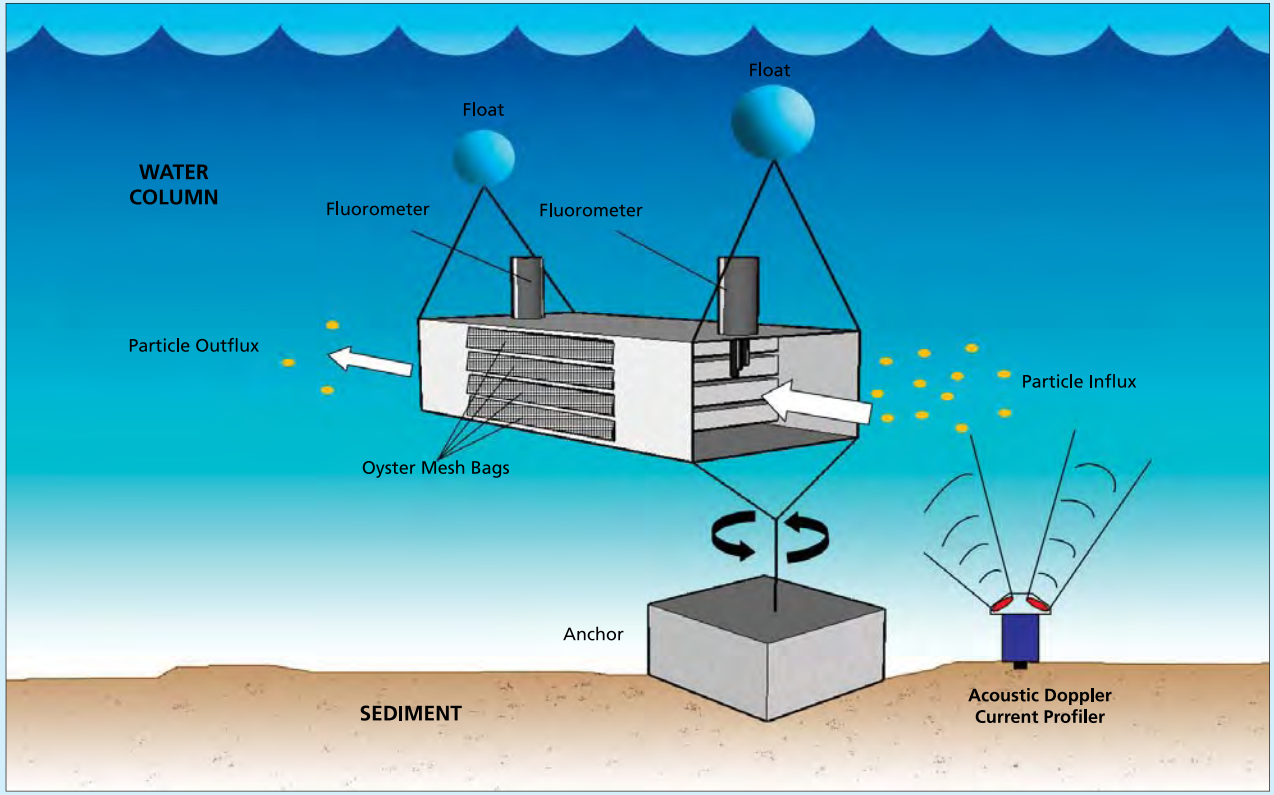


Diagram of the Pelagic Ecosystem Tunnel: The unit measured 153 cm × 57 cm × 45 cm. It was sealed by applying several layers of plastic wrap over a frame of Aquamesh®. Upstream and downstream ends were left open, allowing water to flow through the compartment holding the oysters.

During field trials, several of the specialized tunnels holding 500 oysters each were deployed in Baie St. Simon, a major oyster farming area in the Gulf of St. Lawrence. The tunnels were suspended in mid-water, enabling the current and phytoplankton to flow freely through them. In summer, the oysters consumed approximately 40 percent of the phytoplankton that flowed through the tunnel. In autumn, oysters initially grazed intensively on a developing phytoplankton bloom; however, consumption gradually declined later in the season before the bloom fully developed.

Two theories for the decline in grazing are that the oysters may have already fulfilled their food requirements or water temperatures fell below a critical threshold. Ongoing studies by the same research team indicate that oyster grazing rates can fall substantially when temperatures drop below 16°C. Regardless of the exact cause, the findings imply an inability of the oysters to take full advantage of seasonal phytoplankton blooms, which would partly explain the slow growth of oysters in the Gulf of St. Lawrence, where it takes four to eight years for oysters to reach the legal market length.

Science in Support of the Regulation of Genetically Modified Fish

The Fisheries and Oceans Canada Centre for Aquatic Biotechnology Regulatory Research in West Vancouver, British Columbia, conducts regulatory research related to fish products of biotechnology, including genetically modified fish. Investigation into the genetic, physiological and ecological characteristics of these fish provides scientific knowledge in support of their regulation under the *Canadian Environmental Protection Act*, which the

Department undertakes in conjunction with Environment Canada and Health Canada.

Physical and biological containment strategies can be used to reduce the risk of genetic impact on local fish populations in the event of an accidental release. One biological strategy is induced-triploidy, which produces fish with three sets of chromosomes and results in sterility, alleviating potential impacts on the environment. In 2009, the centre assessed this technique on a large scale and found that triploidy can be induced in 99.8 percent of the fish produced using this technique. Further research is under way to determine the reason for non-triploid exceptions and to improve containment methods using molecular genetic approaches.

Ongoing research into the effect of environmental factors on fish reveals that rearing conditions in small tanks typical of most aquatic facilities inhibit growth and alter physical characteristics and behaviour. To more closely mimic natural conditions for salmon, the Department developed new large tank marine facilities (mesocosms) with more than 1,000,000 litres of rearing space. The characteristics of the first wild-type fish reared in the new tanks were much more like those of their counterparts in nature.

Other research in 2009-2010 found strong genetic, physiological and behavioural similarities between strains of salmon growth-accelerated by domestication or by genetic engineering (the transfer of genes from one organism to another). Integration of these research findings with modeling approaches is providing a better understanding of the effects of genetic modification in fish, and how to reduce the potential risks they may pose to natural populations.

HydroNet — How Hydropower Operations Impact Canada's Aquatic Ecosystems

A national five-year research program involving Fisheries and Oceans Canada, academia and industry is focused on improving our understanding of the effects of hydropower operations on aquatic ecosystems. Initiated in 2010 by the Natural Sciences and Engineering Research Council of Canada, HydroNet provides access to a critical mass of national fisheries-aquatic scientists with valuable knowledge that can contribute to estimates of the environmental impacts of hydropower and the development of mitigation strategies.

Support for the program within the Department involves the Habitat Management Program and the Centre of Expertise on Hydropower Impacts on Fish and Fish Habitat, which is providing funding to scientists for collaborative research related to HydroNet's themes.

Research priorities developed by the Department and industry have been integral to the development of the HydroNet research program, which encompasses 21 projects under three themes:

- analysis of productive capacity of fish habitats in rivers, including an evaluation of biological, physical and chemical drivers, with a view to developing reliable models of habitat quality;
- modeling of the productive capacity of fish habitats in lakes and reservoirs; and
- using behavioural ecology and hydraulic engineering to predict the risk of fish becoming caught (entrained) in water diverting through hydropower turbines or other water release structures at dams, with the goal of developing and implementing strategies to actively reduce the risks of entrainment.

The knowledge generated by HydroNet is essential to balance the competing demands for limited water resources and to ensure that hydropower is sustainable and contributes effectively to healthy aquatic ecosystems and Canada's economy.

Aquatic Animal Health — Surveillance and a New Screening Test for VHSV

The National Aquatic Animal Health Program is a science-based regulatory program that addresses aquatic animal diseases of finfish, molluscs and crustaceans. The lead agency for the program is the Canadian Food Inspection Agency, which is responsible for its administration and enforcement. Fisheries and Oceans Canada co-delivers the program by providing laboratory diagnostic and research expertise through the National Aquatic Animal Health Laboratory System.

One disease of concern to Canada's Aquatic Animal Health Program is Viral Haemorrhagic Septicaemia Virus (VHSV), which causes devastating losses to both wild and cultured fish throughout the Northern Hemisphere, potentially leading to impacts on fish populations and trade. VHSV first appeared in Lake Ontario in 2005. In 2007, program specialists implemented a surveillance program for the virus in the Great Lakes Basin and the upper St. Lawrence River (Ontario and Quebec regions).

The goals of surveillance are to determine the current distribution of the virus in susceptible, wild freshwater fish populations in high-risk areas, and to build empirical evidence for substantiating freedom from disease in key regions to support disease control measures and minimize trade disruption associated with VHSV.

In 2010, the Ontario Ministry of Natural Resources and the Ministère des Ressources naturelles et de la Faune du Quebec collected approximately 2,200 fish samples for VHSV testing from 13 different sites in Ontario and Quebec. The samples were analyzed at three Department labs in the National Aquatic Animal Health Laboratory System.

Early in the surveillance initiative, samples were also used by the labs to develop and validate a rapid screening technique for VHSV. The key step to preventing and controlling aquatic viral diseases lies in the ability to accurately detect the agent responsible for disease. At the Department's Pacific Biological Station in Nanaimo, British Columbia, research scientist Dr. Kyle Garver has developed a new test for VHSV that overcomes the limitations of traditional cell culture detection methods. The new genetics-based test — VHSV quantitative reverse transcription polymerase chain reaction or VHSV RT-qPCR — is highly sensitive, fast, recognizes all known strains of the virus, and enables large numbers of samples to be screened within several days rather than weeks when using cell culture techniques.

The test developed in Canada by Dr. Garver is now the national screening test for VHSV in Canada and has been used in surveillance and survey efforts since 2007. This test has also been officially recognized by the United States Animal Health Association and the Joint Committee on Aquaculture of the American Association of Veterinary Laboratory Diagnosticians.

Jackie Sutton, a technologist at the Gulf Fisheries Centre in Moncton, New Brunswick, performs a necropsy on fish from a diagnostic submission in order to harvest the tissues required for further testing. Kidney tissue is harvested in order to screen for VHSV using the test devised by Dr. Garver.

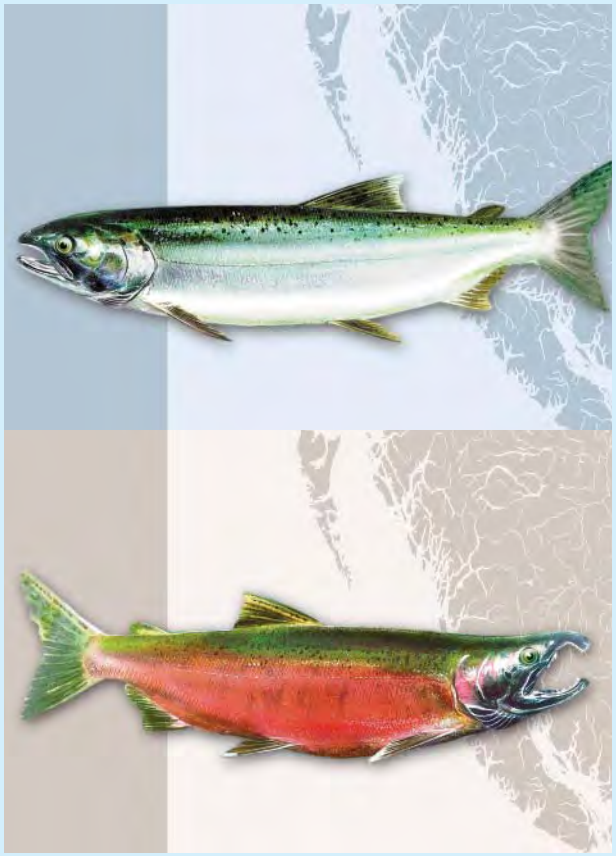
Exploring the Mysteries of Wild Salmon at Sea

Coho fry in a tank at the Pacific Biological Station.

Since the 1990s, there have been sharp declines in catches of wild Pacific salmon, which are important to the economy of British Columbia and the Yukon. Since this species spends most of its life deep in the ocean, far from shore, any management or conservation discussions or measures need to consider the impact of the ocean on salmon. However, what juvenile salmon do, where they go, and what happens to them after they leave their home stream or river and return to the sea is not fully known or understood.

To unravel some of these mysteries, the High Seas Salmon Program at the Pacific Biological Station is exploring how varying ocean conditions affect salmon migration and their chances for growth and survival at sea. The program team, under the leadership of Dr. Marc Trudel, spends up to 11 weeks at sea each year collecting samples of salmon, associated fish communities, water and plankton. Since 1998, the team has carried out juvenile salmon surveys from the west coast of Vancouver to southeast Alaska to determine ocean migration speeds and routes along the continental shelf. They are also exploring regional stock compositions and growth rates, the effects of ocean conditions and climate change on the salmon, and the overall capacity of the Pacific Ocean to support salmon stocks under changing climates. One unexpected finding is that even small changes in prey quality appear to have a large effect on the growth of juvenile Coho Salmon.

The team is also developing new salmon forecasting models based on the oceanic conditions they have monitored over the past 12 years. In 2009–2010, testing of these models determined that they perform better than the methods currently used by the Department to assess stocks of Coho Salmon off the west coast of Vancouver Island. As a result, it is expected that the new models will be incorporated into the annual assessment of those salmon stocks in the near future.



Coho Salmon in the at-sea phase (silver/green) and spawning phase (pink/green).

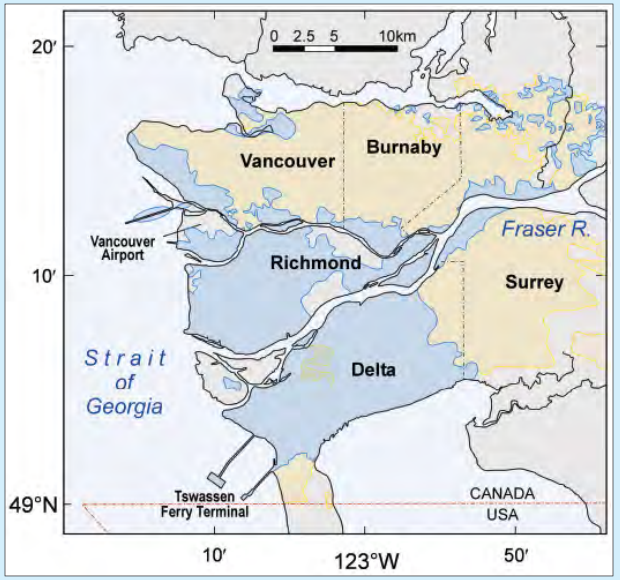
Factors Affecting Sea Level in Coastal British Columbia

Long-term water level observations from around the world confirm that mean sea level — the level of the sea with waves and other motions averaged out — has been increasing by about 30 centimetres per century. Most scientists now accept that this rise is the direct result of global climate change that is driven, in large part, by greenhouse gas emissions related to human activities.

Along the coast of British Columbia, areas that are particularly vulnerable to the rising seas include the Fraser River Delta region and the east coast of Graham Island in Haida Gwaii (Queen Charlotte Islands). Although there are large uncertainties in projected sea level rise relative to the position of the land, scientists are confident in the general trends.

It is important that coastal communities and governments at all levels be aware of these projected changes and potential impacts when planning coastal infrastructure and land use. To this end, Fisheries and Oceans Canada research scientist Dr. Richard Thomson of the Institute of Ocean Sciences in Sidney, British Columbia, led a study on projected sea level change in the province. Among the study's findings:

- Based on present rates of sea level rise and a projected 30 cm rise in mean eustatic sea level (global scale changes in mean sea level due to changes in the volume of water in the ocean) during the 21st century, Vancouver, Victoria and Prince Rupert are predicted to undergo a mean relative sea level rise of 20 to 30 cm by 2100, while a rise of 50 cm is predicted for the Fraser River Delta region. These estimates are up to 70 cm higher when one includes the possibility that rapid ice sheet melting will cause a 100 cm increase in global mean sea levels by 2100.
- Superimposed on the climate-related trend are annual cycles of 30 to 50 cm due to seasonal fluctuations in regional atmospheric pressure, ocean temperature, and alongshore winds and currents.
- Major El Niño events in the North Pacific add another 30 to 40 cm to coastal sea level, while intense storm surges in low-lying regions such as the Fraser River Delta can add another 100 cm. If the frequency and magnitude of these events increase with climate change, the impacts of storm surges will become increasingly more severe, with the potential for greater land erosion and flooding during periods of high tide.



Map of Vancouver and the Fraser Delta showing areas of documented subsidence or sinking (in blue) on the Fraser Delta and more stable surrounding areas (in yellow).

- There is a 5 to 10 percent probability of a magnitude 9.0 earthquake occurring off the West Coast of North America in the next 50 years. Such an event would cause a sudden land subsidence (rapid sea level rise) of 30 to 200 cm on the west coast of Vancouver Island.

Oceanographic Monitoring Supports Salmon Aquaculture on the South Coast of the Island of Newfoundland

Significant investment in salmon aquaculture in Newfoundland and Labrador has increased activity in the province's aquaculture sector. As a result, the increasing biomass and number of companies operating, the diversity of production strategies, and the increasing concentration of farm sites challenges biosecurity and the sustainability of this growth.

In 2008 it was recognized that there was a lack of data and understanding about the oceanography of the outer Bay d'Espoir and Fortune Bay areas, which precludes establishment of scientifically validated production and management areas to guide site licensing, production planning and sustainable management of the industry. To address this knowledge gap, a team of Fisheries and Oceans Canada scientists initiated an aquaculture oceanography project under the Program for Aquaculture Regulatory Research. This study is setting the foundation for Newfoundland and Labrador to understand the environmental effects and map potential zones of influence, which will ultimately be used to establish production management areas.

During the 2009 and 2010 field seasons, a significant amount of oceanographic data was collected off the south coast, including data on currents in the Bay D'Espoir-Hermitage Bay and Fortune Bay regions. Salinity, temperature, depth and other parameters were collected throughout the area. Multiple CTD (conductivity, temperature, depth) surveys were carried out over the two years to learn more about seasonal variations in the water column. A program using satellite-tracked surface drifting buoys was also launched to monitor the surface currents between various areas off the south coast. Data analysis is ongoing and work is under way to model currents in the region.

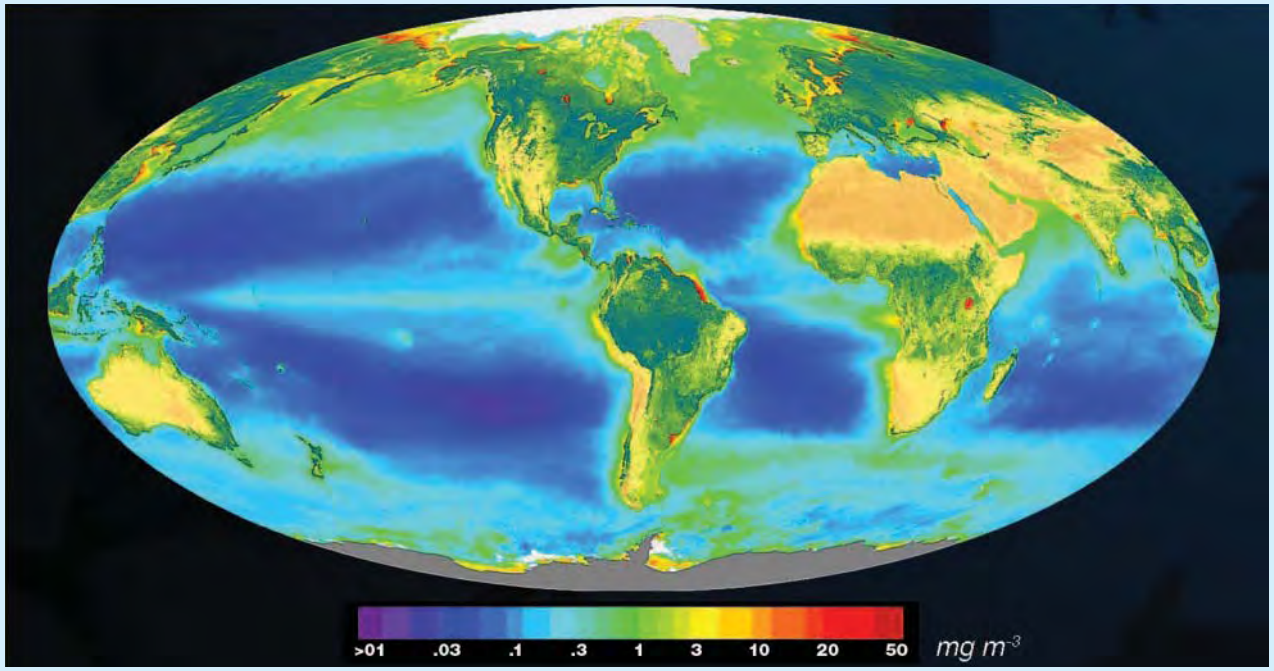
A conductivity, temperature, depth (CTD) instrument being prepared for deployment.

Monitoring Ocean Colour from Space for Ecosystem-Based Fisheries Management

Since healthy fish populations depend on healthy ecosystems, having an efficient and economical way to monitor the state of marine environments is essential. Ocean colour radiometry — remote sensing of the Earth's oceans by optical (light-sensing) satellite instruments — provides a continuous stream of information on the state of marine ecosystems in near-real time on a global scale.

At the Bedford Institute of Oceanography in Halifax, Nova Scotia, federal researchers are analyzing ocean colour imagery for a wide variety of information (e.g. chlorophyll concentration, bloom timing, presence of diatoms and sediment concentration) with a view to developing remote sensing approaches, methods, applications and products for improving ecosystem-based fisheries management.

The surface layers of the ocean vary in colour over time and space depending on a variety of conditions. For example, more greenish water generally indicates a higher production of phytoplankton, which forms the foundation of the oceanic food web. Differences in ocean colour, digitally recorded by remote sensing instruments, can be converted into estimates of phytoplankton biomass, productivity and functional types, which play different biogeochemical roles in the ocean. A time series of images reveal variations in biomass from season to season and year to year.



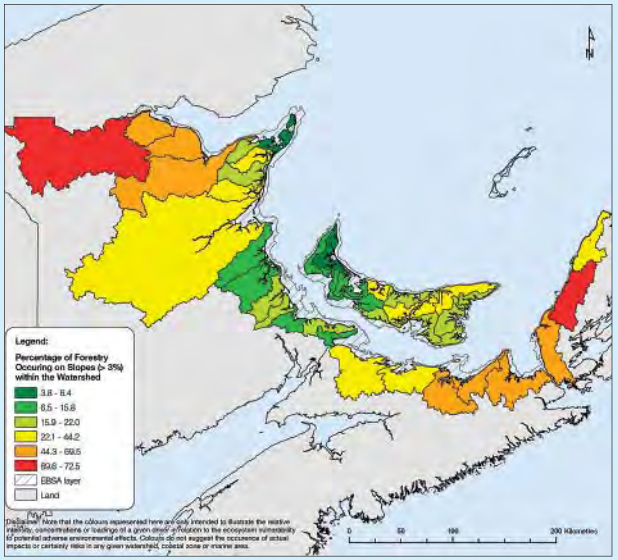
NASA SeaWiFS* satellite imagery from 1997 to 2000 was used to estimate the global average concentrations of surface chlorophyll-a. Chlorophyll-a concentration is used by researchers to estimate the phytoplankton biomass available to sustain lifeforms further up the food chain. Chlorophyll concentration is high in coastal areas (green to red areas) and low in the centres of the large ocean gyres (deep blue to violet). These deep blue and violet areas have very low nutrient levels, offer little to sustain life, and are therefore considered to be the biological deserts of the global oceans. Satellite image provided by the Ocean Biology Processing Group, NASA/Goddard Space Flight Centre. *SeaWifs is short for "Sea-viewing Wide Field-of-view Sensor."

Much work remains to be done in order to fully utilize ocean colour data for improving ecosystem-based fisheries management. Ongoing ocean colour radiometry research will:

- measure variations in phytoplankton biomass and other ecosystem variables that may affect the recruitment and growth of various commercial fish stocks. This application has already been demonstrated in Atlantic Canada for Haddock and Northern Shrimp;
- develop methods to improve the analysis of phytoplankton functional-type dominance in marine ecosystems;
- detect and monitor harmful algal blooms. Work continues on the development of a warning indicator for the presence of harmful algal blooms in the Bay of Fundy; and
- study interannual variations in marine production at large scales, thereby contributing to discussions on the role of marine biota in the global carbon cycle and climate change.

Integrated Coastal Zone Management — Bridging the Land-Water Divide

Under the Health of the Oceans Initiative (2007–2012), the Centre of Expertise on Coastal Management was established within the Department's Oceans and Science sector to increase the understanding of international tools and practices to support national integrated coastal zone management initiatives.



Map: Example of a regional environmental vulnerability profile for the southern Gulf of St. Lawrence, Canada. This draft map (regional scale) represents the "percentage of forestry lands occurring on slopes greater than 3%"* and the legend is a relative percentile distribution between the 38 watersheds. The map identifies watersheds that are likely to be at risk from soil erosion during severe rainfall. These watersheds (i.e. catchment areas) could be priority areas for conformity and compliance monitoring of the effectiveness of mitigation measures in order to reduce the potential of sediments entering into watercourses. Source: United States Environmental Protection Agency Regional Vulnerability Assessment Methodology.

There are many definitions of the coastal zone including "the area where the ocean meets the land, which constitutes 10 percent of the ocean's area but contains 90 percent of all marine species." However it is defined, one thing is certain; the coastal zone is very challenging to manage for many reasons:

- it is very ecologically complex;
- it is a zone of change and where three different ecosystems (land, fresh water and marine waters) meet in a very dynamic setting; and
- it is a zone of connectivity and transition between habitats and processes.

These interactions make coastal zones among the most productive on Earth. However, these ecosystems are also are under stress around the world due to population growth, pollution, habitat degradation, multiple resource use conflicts, over-exploitation of resources and other human activities.

Given this setting, it is particularly important that integrated coastal zone management be carried out strategically and efficiently with the best available information and tools. One of the objectives of the centre is to apply risk analysis principles to the development of ecosystem-based management approaches in order to avoid cumulative environmental effects. This can help decision-makers to deploy resources strategically to optimize management of human activities and ensure the conservation and protection of aquatic ecosystems. At its core, risk analysis assists decision-making. It provides a systematic way of gathering, evaluating, recording and disseminating information leading to recommendations for the consideration of management. These approaches can result in more effective and sustainable coastal zone management practices along Canada's 244,000 kilometres of coastline.

Mission to Map Arctic Seabed Succeeds in Proving New AUV Technology

Surveying the Arctic seabed is a challenging task due to the remoteness of the region and unpredictable weather and ice conditions. The successful use of an autonomous underwater vehicle (AUV) in the collection of bathymetric data in the North is preparing this new technology to play other roles in long-range, unescorted missions in harsh environments. Testing and using the new AUV technology to map the seabed involved a team composed of the

The autonomous underwater vehicle (AUV) *Yamoria* is a one-of-a-kind product: a remotely-controlled research submarine built to withstand the extreme pressure and cold of the Arctic undersea environment. The result of a scientific partnership between Natural Resources Canada, Defence Research and Development Canada and Fisheries and Oceans Canada and built by International Submarine Engineering Ltd. (ISE) of Port Coquitlam, B.C., *Yamoria* is seven metres long, 2,000 kg in weight, cylindrical in shape and powered by lithium-ion batteries that can be recharged under water. *Yamoria* is named for an ancient great traveler and lawmaker of the Dene people.

Canadian Hydrographic Service of Fisheries and Oceans Canada, Defence Research and Development Canada and the Geological Survey of Canada, part of Natural Resources Canada. Their mission is to determine how far Canada's continental shelf extends under the sea. The collected data will become an integral part of Canada's submission to the Commission on the Limits of the Continental Shelf. Pursuant to article 76 of the United Nations Convention on the Law of the Sea, coas tal countries with a continental shelf extending beyond 200 nautical miles must make a submission regarding the proposed outer limits to the Commission within 10 years of ratification (in Canada's case, by December 2013).

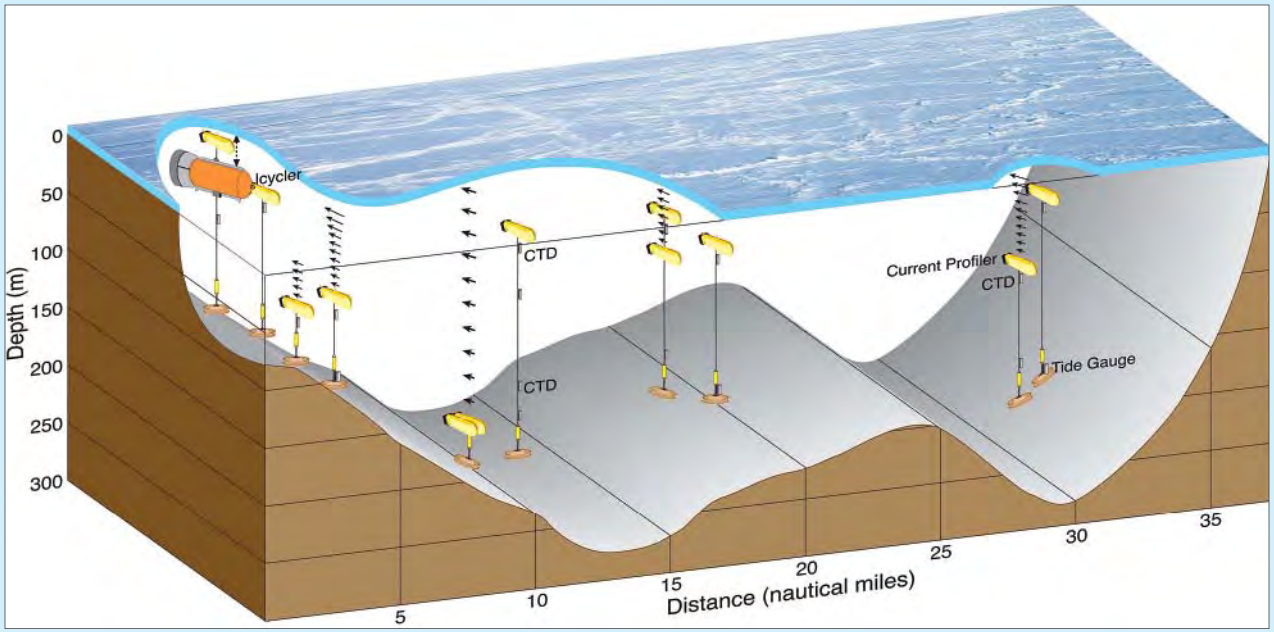
In a typical mission, the battery-operated AUV is launched from an ice camp in the Northwest Territories near Borden Island and follows a pre-programmed mission plan.

After diving to a predetermined operating altitude above the seabed, the AUV switches on its bathymetric sensors and moves from one way point to the next. At the end of the mission segment, it turns off the sensors and homes in on a beacon deployed through an ice hole at the camp. Back at home base, researchers download the bathymetric data from the AUV, then recharge and redeploy it to collect more data.

The surveys will augment spot soundings, and seismic, gravity and magnetic data collected to date. All of this data will be analyzed and then submitted, demonstrating that the areas and ridges surveyed meet the requirements of article 76 of the United Nations Convention on the Law of the Sea and are part of Canada's extended continental shelf. Since the surveys began, the underwater vehicles have covered approximately 1,000 kilometres. Another mission is planned for 2011 to gather the remaining Arctic Ocean data required for Canada's submission. This time the vehicles will be deployed from Canada's largest icebreaker, the CCGS *Louis S. St-Laurent*.

Probing Ocean and Ice Fluxes Passing Through Barrow Strait

Since 1998, researchers at the Bedford Institute of Oceanography have been exploring the flow of ocean water and sea ice (transports) passing through Barrow Strait, one of the three main pathways through the Canadian Arctic Archipelago. The aim of the research, which is part of the Arctic/Sub-Arctic Ocean Fluxes and the International Polar Year programs, is to measure and model the variations in ocean water and sea ice transports passing between the Arctic Ocean and sub-Arctic seas, including the North Atlantic. The Arctic Ocean Fluxes



The instrumented mooring array across Barrow Strait.

One of the moorings to measure sea ice transport in Barrow Strait is deployed from the CCGS *DesGroseilliers*.

component of this project concentrates on the direct effect of these transports on North Atlantic (Labrador Sea) circulation.

Increased knowledge of the processes that control these transports, and their relationship to the ocean and ice conditions of the Arctic Ocean and circulation and vertical ventilation of the Labrador Sea, will aid in the development of global climate models to predict the impacts of climate change on pack ice and marine ecosystems in the Arctic and Sub-Arctic regions.

Eleven years of mooring data provided detailed salinity, temperature and depth information as well as current speed and direction measurements, ice drift and ice thickness. These data have been analyzed, revealing that the atmospheric conditions over the Beaufort Sea, and to a lesser extent over the North Atlantic, control the ocean water and sea ice transports passing through the Northwest Passage, and these atmospheric conditions are changing due to climate change. Long-term trends and the seasonal variability in ocean water and sea ice transports will increase the open water season, which affects transportation through the Northwest Passage, biological timing and production, and ocean water and ice transports into the North Atlantic that affect the vertical mixing processes of the Labrador Sea and global circulation.

Understanding the processes that control variations in pack ice severity in the Arctic and surface water passing through the Northwest Passage will assist in:

- validating international climate models to enhance the accuracy of global warming projections of the Arctic and Sub-Arctic pack ice and marine ecosystem;
- managing marine transportation, offshore operation regulation codes, and search and rescue in the Northwest Passage as the open water season increases;
- regulating industrial developments in the Canadian Arctic and monitoring the oceanographic and pack ice conditions of the proposed National Marine Conservation Area in Lancaster Sound;
- assist in developing biological and food web models of marine ecosystems to predict climate change impacts; and
- managing national security and sovereignty issues in the Canadian Arctic.

Record-Breaking Temperatures in the Gulf of St. Lawrence

An annual helicopter-based survey of the physical oceanographic conditions in the Gulf of St. Lawrence, led by Peter Galbraith of the Maurice Lamontagne Institute in Mont-Joli, Quebec, reported record-high winter temperatures in March 2010. This anomaly is linked to air temperatures, measured at nine stations in the Gulf, which were 5.1°C above normal — the warmest on record since at least 1945.

The survey crew in March 2010: Rémi Desmarais, Electronics Technician, and Peter Galbraith, Researcher, Oceanography and Physical Modeling, both of Fisheries and Oceans Canada; Robert Audette, Aircraft Maintenance Engineer, and Daniel Dubé, Helicopter Pilot, both of Transport Canada. The probe used is in the centre of the group.

Sea ice was all but absent in the Gulf during the unusually mild winter of 2010, the least amount of ice coverage registered by the Canadian Ice Service since it began gathering data in 1969.

The survey, conducted by lowering a probe from a hovering helicopter into the water to measure temperature and salinity at more than 85 locations in the Gulf, revealed that the winter season surface mixed layer of water was exceptionally warm in March. About 75-metres thick, this layer usually nears the freezing point — around -1.7°C — in the Gulf; in 2010, it was on average 1°C warmer than normal. Temperatures were even higher in some areas, exceeding 0°C northeast of the Cabot Strait and in the St. Lawrence Estuary. This is the warmest winter season surface mixed layer ever recorded over the 15-year history of the survey.

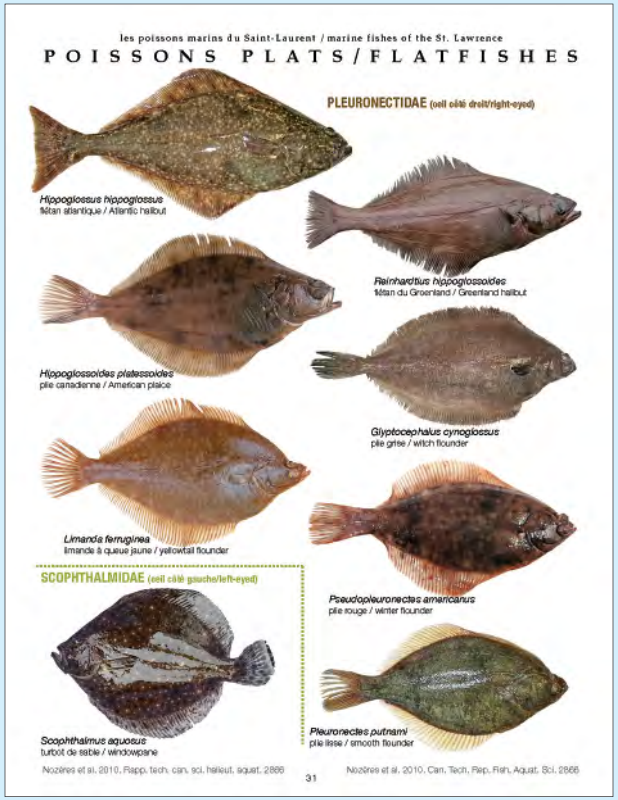
Analysis of the winter season surface mixed layer makes it possible to forecast summer oceanographic conditions, which is useful for biologists assessing fish, crab and shrimp stocks. While the surface waters warm in springtime, a subsurface cold layer remains partially insulated until the following winter, sometimes maintaining temperatures below 0°C at the height of summer. The record warm water temperatures in March led to above-normal core cold layer water temperatures in the summer of 2010. Ice-free winter conditions in the Gulf of St. Lawrence — likely to occur more regularly with climate change — may introduce a new dynamic in the formation of these layers.

New Identification Guide to Marine Fishes of the Gulf of St. Lawrence

Every year, Fisheries and Oceans Canada conducts a major biological survey aboard the trawler CCGS *Teleost*, a key source of information on the status of marine resources harvested in the estuary and northern Gulf of St. Lawrence. The main objective of the survey is to estimate the abundance and biomass of commercially important species, including Atlantic Cod, Greenland Halibut, Acadian and Deepwater Redfish and Northern Shrimp.

In recent years, biologists have sought to more fully integrate information on the status of these stocks and the ecosystems in which they live; to do so, they need to quickly and properly identify the dozens of other fish and invertebrate species caught during surveys. To facilitate this task, in 2010 Fisheries and Oceans Canada published the *Identification guide for marine fishes of the estuary and northern Gulf of St. Lawrence and sampling protocols used during trawl surveys between 2004 and 2008*. It describes the size and depth distribution of fish species encountered during surveys and provides colour plates and identification sheets for 115 marine fish species that occur in the region.

An essential volume for biologists and technicians, the guide is also a valuable tool for people who make their living from the sea or are simply interested in the diversity of marine organisms. It is available in PDF format or in hard copy with an accompanying CD at the Maurice Lamontagne Institute library at biblioIML@dfo-mpo.gc.ca or 418-775-0500.



The page on flat fishes shows their diversity in the region, from the *Identification guide for marine fishes of the estuary and northern Gulf of St. Lawrence and sampling protocols used during trawl surveys between 2004 and 2008*.

Canadian Science Advisory Secretariat — 2009–2010 Overview

Narwhals in Barrow Strait.

The Canadian Science Advisory Secretariat coordinates the departmental science advisory process in collaboration with the regional Centres for Science Advice. This network is responsible for maintaining high standards of excellence in the provision of peer-reviewed scientific information and advice that supports sound decision-making at Fisheries and Oceans Canada.

During 2009–2010, 111 peer-review advisory meetings and workshops were conducted and 284 publications were produced, including science advisory reports, research documents, proceedings and science responses. In addition to 59 stock assessments, these publications covered a broad range of issues including:

- advisory reports of key interest on Fraser River Sockeye Salmon, Snow Crab in the southern Gulf of St. Lawrence, Narwhal, Beluga, Harp Seals as well as cod off the south coast of the island of Newfoundland in the Northwest Atlantic Fisheries Organization 3Ps cod stock zone;
- mitigating impacts of seismic sound on marine mammals;
- a national framework for rapid response to aquatic invasive species;
- science advice on the development of a network of marine protected areas;
- ocean fertilization, a geo-engineering approach to mitigating climate change;
- impacts of at-sea disposal of dredged sediment material on the critical habitats of killer whales;
- pathways of effects for aquaculture; and
- the impacts of fishing gears on marine habitats and aquatic communities.

Two meetings covered departmental responsibilities under the *Species at Risk* Act to provide peer-reviewed information to the Committee on the Status of Endangered Wildlife in Canada to assess the status of aquatic species. In addition, recovery potential assessments were held for 20 species that have been designated Endangered or Threatened by the committee.

The secretariat also continued to implement a risk-based framework to prioritize peer-review meetings to ensure that needed science advice is provided in a timely manner. Published advice and the calendar of the secretariat's advisory activities are available at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

Environmental Impacts of Aquaculture — Assessing Pathways of Effects

In an effort to establish a consistent national approach to identifying, assessing and managing the environmental risks of finfish and shellfish aquaculture, Fisheries and Oceans Canada is collaborating with other federal, provincial and territorial governments to develop a national Framework for Aquaculture Environmental Management. Toward this goal, scientists in the Department developed seven "pathways of effects" research documents and diagrams, which map the potential stresses of various finfish and shellfish aquaculture activities on the environment, and the potential effects of those stressors on different components of the ecosystem.

Each research document focuses on a different stressor related to aquaculture activities including: chemicals used by the aquaculture industry, escaped aquaculture organisms, light, noise, nutrients, pathogens and the physical structure of aquaculture operations. Each stressor is associated with key components of aquatic ecosystems (fish habitat, water quality, fish health and fish communities) that are relevant to government regulators.

In October 2009, a Canadian Science Advisory Science meeting was held to peer review the draft stressor papers and diagrams. The final research documents will inform the development of the framework and policy documents, which will be used by government regulators responsible for managing aquaculture. The peer-review process also identified research needs and knowledge gaps, which is aiding in the development of research priorities for the Fisheries and Oceans Canada Program for Aquaculture Regulatory Research and the Aquaculture Collaborative Research and Development Program.

For more information about the meeting or to view the Proceedings, Science Advisory Report and research documents for the meeting, go to: http://www.dfo-mpo.gc.ca/science/advice-avis/index-eng.html

Studies Probe Risks of PCB Contamination off the West and East Coasts

Fisheries and Oceans Canada is at the forefront of efforts to understand the threats to British Columbia's southern resident killer whales, listed as Endangered under the *Species at Risk* Act. In 2010, federal researchers from the Institute of Ocean Sciences, the Pacific Biological Station, and Simon Fraser and Trent universities joined forces to study how polychlorinated biphenyls (PCBs) in materials disposed in the ocean affect the whales.

Previously buried bags of tar balls from the1970 *Irving Whale* oil spill have emerged years later from the sand dunes of Îles-de-la-Madeleine, Quebec.

The *Canadian Environmental Protection Act* governs the disposal-at-sea of permitted materials — mostly from dredging operations — at specific marine sites. While these materials are assessed for PCBs and other contaminants, the screening was not designed to protect species high on the food web, such as killer whales. Five ocean disposal sites are located in critical habitat for southern and northern resident killer whales.

Findings of the study confirmed that killer whales are particularly vulnerable to PCB contamination because of their high position on the food chain, long lifespan and inability to metabolize the chemical compound. As a result, a series of recommendations was made to improve decision-making on ocean disposal practices that will reduce PCB concentrations in killer whale habitat and reduce the uptake of this chemical compound by killer whales over time. Lessons learned from this research will provide guidance on emerging chemical concerns, such as for the flame retardant polybrominated diphenyl ether (PBDE).

Transient killer whale T087 off the Harmac Pacific pulp mill in Northumberland Channel, British Columbia.

PCB contamination is also the focus of a study undertaken in the summer of 2009 along the coastline of Îles-de-la-Madeleine, Quebec. In 1970, the *Irving Whale* barge sank in the Gulf of St. Lawrence, spilling its cargo of fuel oil, some of which washed up on the northwestern shores of Îles-de-la-Madeleine. During cleanup efforts, the oil, which had solidified into a tar-like substance, was bagged and buried in the surrounding dunes. In 1996, it was discovered that the fuel oil contained PCBs.

In their study, Michel Lebeuf of the Maurice Lamontagne Institute and Marie Chagnon of the Gaspésie-Îles-de-la-Madeleine Health and Social Services Agency assessed whether the buried bags of fuel oil are contaminating the environment with PCBs. Samples of surface sediments and marine organisms, including Rock Crab, Blue Mussels, Atlantic Surf Clams and Razor Clams, were collected at five coastal sites. Results showed no significant difference in PCB concentrations in samples gathered at test and control sites, indicating that the oil is not an identifiable source of PCB contamination.

Whale Watching — Monitoring the Beluga Population of the St. Lawrence

In line with the St. Lawrence Plan for Sustainable Development, Fisheries and Oceans Canada takes stock of the beluga population in the St. Lawrence Estuary at regular intervals. In 2009, teams from the Maurice Lamontagne Institute published its second fact sheet on the monitoring of this population, which is designated as Threatened.

The St. Lawrence beluga population is estimated at around 1,100 individuals and has remained stable for the past 20 years. This estimate is based on a population model that incorporates abundance estimates derived from a series of photographic surveys carried out between 1988 and 2003, and the results of a Fisheries and Oceans Canada carcass monitoring program that began in 1982.

Analyzing beached carcasses helps provide clues about mortality. With the help of the St. Lawrence National Institute of Ecotoxicology, the carcasses are sampled on the beach or transported to the faculty of veterinary medicine at the Université de Montréal. This collaboration has helped categorize the cause of death for 148 individuals. Infectious diseases have caused 38 per cent of beluga deaths, while 15 per cent of these animals died from terminal neoplasia (cancer) and nearly 30 per cent from unknown causes.

The beluga carcass samples have also been analyzed to identify the accumulation of contaminants, such as persistent organic pollutants from human activity (PCBs, DDT, Mirex, PBDEs). The level of pollutants measured in the carcasses remains high and is becoming more diverse.

Some contaminants have been reduced or remained stable while others have increased. This suggests that the risk of toxic effects on the population has not diminished over the years. Furthermore, the number of belugas has not increased. The reasons why the St. Lawrence population has not shown any significant growth or recovery have not yet been determined.

Integrating all data available on the beluga will provide, over the long term, a clear sense of what research and management approaches are needed to better protect this marine mammal.

Biologists at the Maurice Lamontagne Institute examining the carcass of a beached beluga whale.

Exploring the Effects of Seismic Sound on Salmon and Shellfish

Research led by Dr. Jerry Payne, with the assistance of Catherine Andrews of the Northwest Atlantic Fisheries Centre in St. John's, Newfoundland and Labrador, is addressing a known gap in knowledge about the impact of seismic sound on marine organisms. Seismic surveys are used in the search for new oil and gas deposits and involve the deployment of an array of airguns from a survey vessel. Over a 24-hour period, the airguns can produce thousands of intense-sounding shots. A considerable amount of survey work is being carried out in Atlantic Canada, particularly in waters around Newfoundland and Labrador on this subject.

Dr. Payne is exploring the potential of seismic surveys to produce important sub-lethal effects (stress) in fish and shellfish. One key study explored a question by the fishing industry about the potential for seismic surveys to affect the movement of lobsters and Snow Crabs. The findings established that exposure of these commercially important shellfish to airgun discharges did not cause them to move; however, there are also concerns about potential damage to the organs of fish and shellfish as well as the ears of fish.

In collaboration with Dr. Matthew Rise of Memorial University, Catherine Andrews initiated exploratory studies on the impact of seismic sound on gene expression in the ears of salmon. Genes — hereditary units consisting of sequences of DNA (Deoxyribonucleic acid or genetic code) — provide direction for cellular structure and function. This laboratory study established that sound produced during seismic surveys has the potential to alter large numbers of genes in the ears of salmon, including those related to cell metabolism, programmed cell death, oxidative stress,* immune response and sensory perception.

The findings of ongoing research on this issue will help guide the Department's Habitat Management Program, which has responsibility for providing advice to the Canada-Newfoundland and Labrador Offshore Petroleum Board. There are currently no restrictions on seismic use in the world's oceans. There are general guidelines that recommend avoiding spawning areas for marine mammals at specific times; however, no such guidelines exist for fish or shellfish.

* Oxidative stress occurs at the cellular level and is a by-product of metabolism. It refers to the production of free radicals (electronically unstable atoms or molecules) that can have negative impacts on an organism's health, especially when combined with other environmental stressors.

Collaborative Research with Industry on the 4WX Herring Stock

Fisheries and Oceans Canada and the Maritimes herring industry have a long history of collaboration on stock assessment and related research. Currently, six collaborative agreements cover data collection and research to address priority issues identified by both the Department and the fishing industry. These agreements focus on a number of activities, including:

- surveying herring spawning grounds using commercial fishing vessels to estimate biomass;

Did You KNOW?

An information panel on the shoreline helps explain the Eastport Marine Protected Area to visitors.

THE EASTPORT MARINE PROTECTED AREA IS COMMUNITY-MONITORED

Bonavista Bay, on the east coast of the island of Newfoundland, is the location of the Eastport Marine Protected Area. It is also there that local fish harvesters and community members have come together to monitor and protect lobster habitat in the area. Marine Protected Areas are an integral part of Canada's management plan to protect and conserve marine ecosystems. The Oceans and Science sector of Fisheries and Oceans Canada provides support for monitoring programs in these areas. The Department provided funding to hire a Community Coordinator and to provide fish harvesters with technical training and equipment for monitoring activities aimed at conserving lobster in the area. This partnership ensures the collection of detailed information for determining the health of local lobster populations. Monitoring results from the past several years will contribute to the review and updating of the Eastport Marine Protected Area Management Plan.

- collecting length frequency data and biological samples from landings at major processing plants in New Brunswick and Nova Scotia to determine fish size and age of the catch; and
- conducting scientific research in support of the assessment of the herring stock in the Northwest Atlantic Fisheries Organization 4WX herring fishing zone. This stock is located in the Bay of Fundy, southwest Nova Scotia and on the Scotia Shelf.

Scientists use acoustics, the scientific study of sound, to survey fish populations. In 2008–2009, the Department and the herring industry jointly funded a three-year target strength study to better understand acoustic scattering from a single fish — how much sound energy is reflected when it hits a fish — to provide a better estimate of herring biomass. The funding was also used to purchase new, state-of-the-art scientific echo sounders and sonar acoustic equipment. Findings of this research will contribute to improved estimates of spawning stock biomass. Additional co-funding in 2009–2010 is being used to determine if spawning herring are being missed or double-counted during surveys, and to examine acoustic blind spots using alternative technology such as underwater cameras and sonar to determine herring biomass in these zones.

Other collaborative research includes the development of a juvenile herring index of abundance, based on acoustic estimates of fish numbers, and an investigation of herring migration patterns and linkages to other stocks using the tagging data from the last 15 years. All studies are scheduled to be completed by March 2012 and should make a significant contribution to knowledge of herring, and improve industry-based acoustic surveys and the 4WX herring stock assessment.

The Precautionary Approach and Southern Gulf of St. Lawrence Snow Crab

The Snow Crab (*Chionoecetes opilio*) fishery in the southern Gulf of St. Lawrence is a high-value resource that has been commercially fished since the mid-1960s. This fishery grew quickly, peaking at 33,400 tonnes (t) in 1982 and declining to a low of 8,900 t in 1990. Landings have fluctuated since with a recent peak in 2005 of 36,200 t.

As a signatory to the United Nations Agreement on Straddling and Highly Migratory Fish Stocks, Canada has committed to manage stocks using the precautionary approach. This approach entails being cautious when scientific information is uncertain, unreliable or inadequate, and not using the absence of adequate scientific information as a reason to postpone or fail to take action to avoid serious harm to the resource.

To be compliant with this approach, fishery management plans should include harvest strategies that incorporate a minimum abundance of animals to be maintained (Limit Reference Point that defines the critical/cautious zones) and a higher abundance of animals (Upper Stock Reference that delimits the cautious/healthy zones) for the greatest socio-economic benefit while minimizing risk to the resource. Management plans should also define the maximum proportion of the abundance that can be removed annually (Removal Reference) when the stock is in the healthy zone.

Guided by the recently published policy on the precautionary approach for fisheries from the Department (*A Fishery Decision-making Framework Incorporating the Precautionary Approach*), a scientific peer review was conducted in February 2010 to define biological reference points specifically for the Snow Crab stock in the southern Gulf of St. Lawrence. A risk analysis framework was also developed to evaluate catch options relative to these reference points and to assess management scenarios consistent with the approach.

Producing biological reference points for the southern Gulf Snow Crab stock was a first for crab fisheries in Canada. This progress was possible due to the availability of a multi-decade and robust fishery-independent survey and an extensive fishery monitoring program conducted by the Department in the region.

Modeling Ditch Maintenance Scenarios to Reduce Risk to Spawning Grass Pickerel

In the Niagara region of Ontario, researchers are exploring the potential impacts of agricultural drainage ditch maintenance on Grass Pickerel, which is listed as a species of Special Concern by the Committee on the Status of Endangered Wildlife in Canada. The ditches are prone to sediment build-up, causing water to back up onto nearby flood plains and providing spawning habitat for pickerel in the spring. Drainage ditch maintenance usually involves removing sediment, reducing the extent of flooding and spawning habitat. In such marshy food webs, the adults prey on other fish while young Grass Pickerel prey on wetland insects.

To determine the potential impact of less flooding on pickerel populations, the research team tagged more than 1,800 individuals to gather data on population size, habitat use and seasonal movements. This information will be incorporated into a computer model to determine the relationship between population size and habitat availability, as well as the effects of different drain maintenance scenarios. Project partners will then implement the best maintenance approach and monitor pickerel populations to validate the accuracy of the model. Eventually, the model may be used to manage other populations of Grass Pickerel and ditch-dwelling fish across Canada. This cooperative project also involves Ontario government agencies and a broad range of partners in the Niagara region including conservation groups and private land owners.

Tag being inserted into a Grass Pickerel.

An American Eel is semi-transparent in its "glass stage" (to about 10 cm in length). The tiny eel's pink gills and digestive tract are visible.

Geomatics to the Rescue of the American Eel

The American Eel population in North America has The American Eel population in North America has fallen sharply over the last 30 years, particularly in the Great Lakes-St. Lawrence River basin. Researchers have not conclusively determined the causes of the decline, but the loss of freshwater habitats and low spawning escapement — the limited numbers of eels that are able to return to the ocean to spawn — are among several key factors.

Dams and other obstacles built on watercourses block the passage of young eels swimming to growing sites upstream and hydroelectric dam turbines kill a large proportion of mature adults from certain watersheds as they make their way to breeding sites in the Sargasso Sea region of the Atlantic Ocean. The Committee on the Status of Endangered Wildlife in Canada has classified the American Eel as a species of Special Concern.

Fisheries and Oceans Canada, in collaboration with the Ministère des Ressources naturelles et de la Faune du Québec and the Ontario Ministry of Natural Resources, has created a geographic information system to help managers locate dams, assess their impact on migration and determine the surface area of stream and lake habitats available in the watershed below and above each obstacle. The tool will help them identify and prioritize where migratory passes should be built. It is currently in development and pilot projects are being conducted on three rivers: one in Quebec, one in Ontario and another in the Maritimes. It will soon be extended to other watersheds and adapted to other migratory fish species.

Federal researchers are collaborating with provincial and industry partners on two experimental projects, including a large-scale conservation stocking initiative involving the transplant of more than four million American eels in their 'glass stage' from rivers in the Maritimes into Lake Ontario since 2006. The second initiative is a trap-and-transport project involving the purchase of large eels from commercial fishermen from areas located above hydroelectric dams and their transport downstream to eliminate the risk of turbine mortality. Both experiments have been successful so far. Stocked American Eels have survived, dispersed and are growing rapidly, while transported yellow eels have sexually matured, initiated their spawning migration and are physiologically indistinguishable from eels that migrated naturally.

Project to Restore the Bay of Quinte in Lake Ontario Enters 40th Year

Situated at the northeast end of Lake Ontario, the Bay of Quinte is the site of a long-term research and monitoring program known as Project Quinte. This multi-agency program was initiated in 1972 to examine the effects of phosphorus control in an ecosystem affected by eutrophication — alteration to the physical, chemical and biological environment due to the water becoming enriched with dissolved nutrients such as phosphates. This condition typically stimulates the growth of aquatic plant life resulting in reduced levels of dissolved oxygen. In the mid-1980s, the Bay of Quinte was identified as a Great Lakes Area of Concern by the International Joint Commission.

Project Quinte partners include Fisheries and Oceans Canada, the Ontario Ministry of Natural Resources, Environment Canada, the Ontario Ministry of the Environment and local universities. Since the project began, the bay has experienced reduced nutrient loads, climatic events that changed the dominance of fish species, multiple invasions by non-native species, a resurgence of aquatic plants and increasing annual temperatures.

Invasive species have altered the Bay of Quinte ecosystem. Until the late 1980s, Project Quinte focused on how well the ecosystem was rebounding from limits on nutrient loading. Then, a massive invasion of Zebra Mussel (*Dreissena polymorpha*) and Quagga Mussel (*D. rostriformis bugensis*) confounded observations. Due to their high filtration rates, these mussels diverted energy away from the water column and initiated significant reastructuring of the food web.

Throughout these changes, Fisheries and Oceans Canada has conducted research on all parts of the Bay of Quinte ecosystem, including on nutrient levels, the microbial food web, community composition, and the abundance and production of phytoplankton, zooplankton, benthic invertebrates and fishes. The long-term data collected in this bay represents some of the most valuable, continuously collected data anywhere in the Great Lakes, and has served as the basis for the development of an ecosystem approach to managing and restoring the Bay of Quinte.

In 2010, a symposium on the Ecosystem Health and Recovery of the Bay of Quinte was convened at the 53rd Annual Conference on Great Lakes Research at the University of Toronto. As Project Quinte enters its 40th year, a collection of papers from the 2010 symposium on the Bay of Quinte research is being published in two special issues of the journal *Aquatic Ecosystem Health & Management* (Vol. 14, Issues 1 and 4).

Did You KNOW?

A single Bighead Carp pulled from the Chicago Sanitary and Ship Canal by the eradication team in 2009.

The Mississippi River in the United States is now home to several species of Asian carps, and hundreds of the invaders can be seen jumping here.

ON THE OFFENSIVE AGAINST AQUATIC INVASIVE SPECIES

For a week in December 2009, a team of Canadians — including 15 staff from the Department's Great Lakes Laboratory for Fisheries and Aquatic Sciences in Burlington, Ontario — were asked by colleagues in the United States to help in the eradication of Asian carps from a six-mile section of the Chicago Sanitary and Ship Canal, which links the Mississippi River to the Great Lakes. Such collaboration is key to preventing the spread of these invasive species — which weigh up to 50 kilograms and eat about 40 percent of their body weight each day — into the Great Lakes.

To increase awareness of invasive species in marine environments, the Quebec Region of Fisheries and Oceans Canada recently published the *Aquatic Invasive Species Identification Booklet*, in collaboration with other regions of the Department in Eastern Canada. The guide features the major species that have invaded parts of the Gulf of St. Lawrence and its estuary, the Bay of Fundy and the Atlantic Ocean. It describes the origin, characteristics and habitat of each species, as well as its ecological and economic impact and what the public can do to prevent it from spreading. (http://www.qc.dfo-mpo.gc.ca/publications/envahissant-invasive/index-eng.asp)

Restoring Aquatic Habitat in the Greater Toronto Area

Toronto and the surrounding region were designated a Great Lakes Area of Concern by the International Joint Commission in 1985 partly due to their impaired fish and wildlife habitats and populations. Such designated areas are locations where environmental quality has been degraded compared with other areas in the Great Lakes Basin Ecosystem.

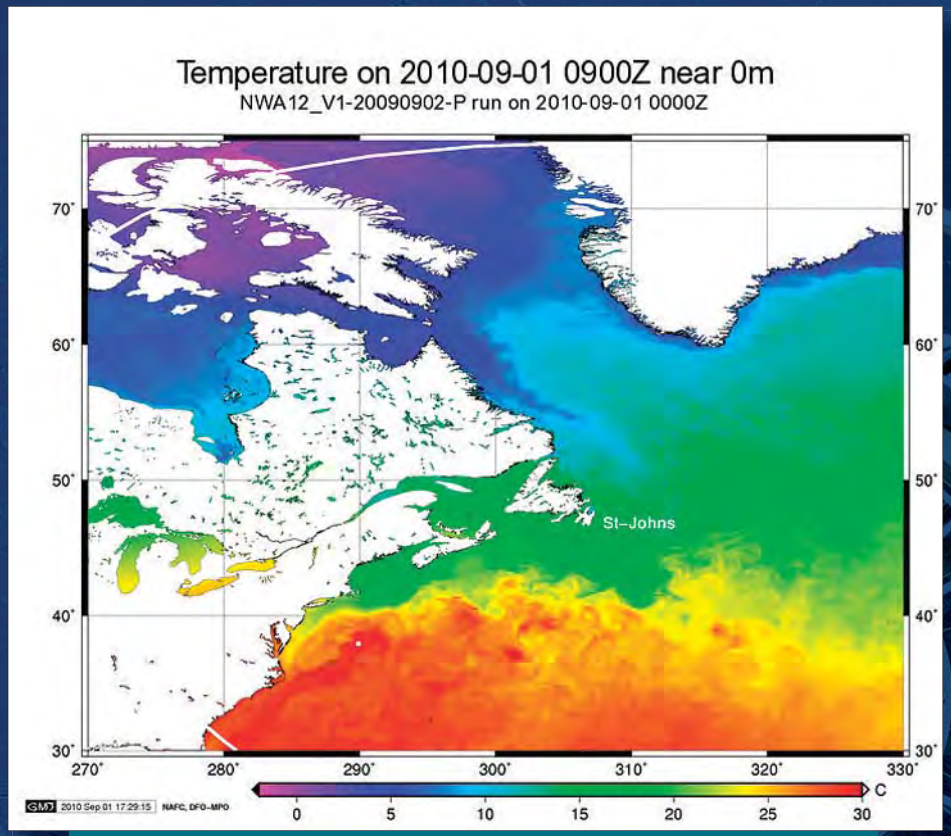
In an effort to restore environmental and habitat quality in coastal areas of the Toronto and Region Area of Concern, researchers from Fisheries and Oceans Canada are collaborating in a multi-agency initiative (Aquatic Habitat Toronto) to study area- and ecosystem-based approaches to habitat compensation (how to compensate for altered, disrupted or destroyed habitat) and restoration.

Scientists at the Department's Great Lakes Laboratory for Fisheries and Aquatic Sciences in Burlington, Ontario, are providing expertise and conducting research to provide targeted advice and tools for habitat decision-makers. Federal, provincial and municipal partner agencies are working together to develop whole system, area-based, best management practices. These will help scientists and managers quantify and implement habitat targets, such as for water quality improvements or wetland reconstruction, which will ultimately lead to delisting of the Toronto Region as an Area of Concern.

In collaboration with other partner agencies, the Department's activities include:

- comparing temperature and the accessibility of coastal bays with early growth and survival in fish populations;
- studying constructed bays of different ages for their effectiveness as restored habitats;
- producing guidance documents for habitat restoration based on local fish community needs;
- using bottom trawling and acoustic surveys to examine fish depth and habitat distributions;
- using numerical models to compare habitat supply between Toronto Region, other Areas of Concern, and reference areas in Lake Ontario as a quantitative tool for delisting the area;
- using quantitative tools to ensure no net loss of habitat for compensation and restoration projects;
- compiling spatial information about habitats into a geographic information system;
- creating a conceptual framework for implementing ecosystem-based habitat management in the area; and
- using acoustic telemetry to track pre- and post-habitat construction movements and seasonal habitat usage of three fish species: Northern Pike, Largemouth Bass and the Common Carp.

Lake Ontario — with the Toronto Islands and the Toronto city skyline — as seen from the shoreline of the Leslie Street Spit.
Photo: Copyright www.patanderson.net



The C-NOOFS ocean modeling system has application in improving Canada's weather forecasts for use in transportation and search and rescue and to improve our understanding of ecosystems, such as input to a model used for annual predictions of the ideal habitat for snow crab in the southern Gulf of St. Lawrence

An Ocean Forecasting System for the Northwest Atlantic and Canadian Arctic

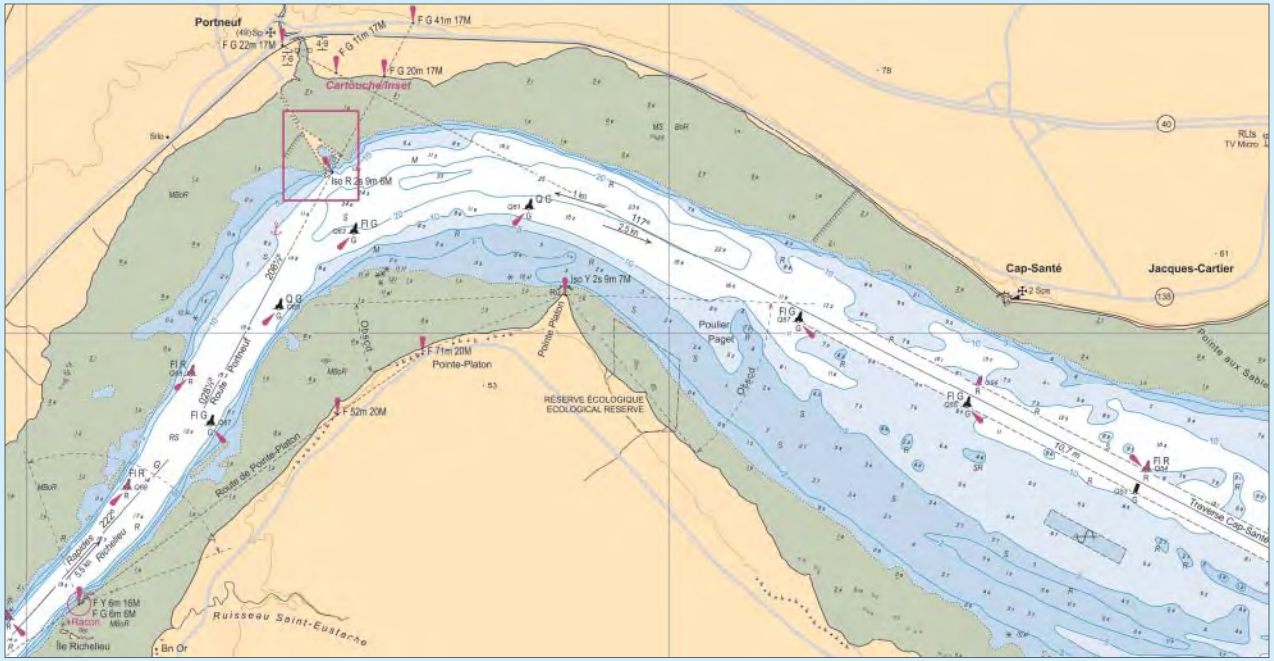
Research scientists at the Northwest Atlantic Fisheries Centre in St John's, Newfoundland and Labrador, have developed a pre-operational ocean forecast system for the Northwest Atlantic. The Canada-Newfoundland Operational Ocean Forecasting System (C-NOOFS) produces forecasts and analysis of oceanic conditions in the Northwest Atlantic, including currents, temperatures, salinity and waves.

A new feature of the system that was developed in 2009–2010 is a validation package and methodology to provide researchers and end users with a description, in near-real time, of how well the ocean forecast system reproduces observations taken by satellite or measurements gathered by the Department during *in-situ* ocean monitoring. This validation methodology is essential for using ground truth data* to improve the forecasting system.

*** In remote sensing, "ground truth data" refers to measurements made on the ground to confirm and calibrate observations made from aerial or space platforms.**

The new system integrates all available ocean data collected by international ocean agencies, including Fisheries and Oceans Canada, satellite information collected by the European Space Agency and NASA, global ocean forecast information from the French national ocean forecast agency (Mercator-Ocean) and atmospheric weather conditions supplied by Environment Canada. Based on this information, the system produces a 10-day forecast of ocean conditions on a daily basis. It can also be used in historical reconstruction mode to provide a best available description of ocean conditions in the Northwest Atlantic over the last 10 years.

The integrated system from the Canada-France collaboration now provides a six-kilometre resolution ocean forecast in which realistic features such as the meandering Labrador Current are visible. The Canadian Navy is planning to use the system and the Canadian Coast Guard has already adapted its software to use the system. Work is under way to expand the area covered to include the Canadian Arctic. In addition, Fisheries and Oceans Canada researchers are collaborating with Environment Canada to combine the ocean forecasting system into the next-generation Canadian Weather Forecast System. For more information, please visit: www.c-noofs.gc.ca



The SPINE system can be used to determine water levels in the navigable portion of the St. Lawrence River between Montreal and Saint-Joseph-de-la-Rive. The calculation is done on a series of individual points (called steps) that are close enough together to perform linear interpolation. The water level values calculated are adjusted with the most up-to-date observations from 15 Coastal and Ocean Water Level Information System network stations.

The SPINE System Ensures a Safe Trip

SPINE (Service de prévision et d'interpolation des niveaux d'eau), a water-level prediction service developed by the Canadian Hydrographic Service, provides accurate, real-time estimates of water levels in all parts of the navigable waterway between Montreal and Saint-Joseph-de-la-Rive, downstream from Québec City. Navigators on the St. Lawrence using a recent Electronic Chart Display and Information System tool will be able to integrate water levels and see the available water column, either in real-time or when planning their trip.

Having undergone a trial run in 2008, this web-based data service is currently in its demonstration phase. It can provide water level values for the navigable portion of the St. Lawrence in real time and up to 30 days in advance. The system uses results from a one-dimensional digital circulation model that integrates upstream flows from Lake Ontario and the Ottawa River, flows from lateral tributaries and estimates of water levels at Saint-Joseph-de-la-Rive driven by winds and tides. The Canadian Hydrographic Service eventually hopes to be able to respond to requests for historical data, to help mariners with post-trip analysis so they are able to validate the water level and use it to make the best estimate of the actual underkeel clearance of their ship at a given time and location.

New Laser Tide Gauge System Delivers Reliable Tide Data Faster

The Canadian Hydrographic Service operates Canada's tide gauge networks — an essential safety resource for mariners and coastal communities. Tide gauges provide the data to make tidal predictions, improve nautical charts, seamlessly link land topography with ocean bathymetry, monitor sea level rise, and allow Canada's emergency measures organizations to monitor storm surge and tsunami activity in real time.

Dr. Phillip MacAulay, Head of Tides, Currents and Water Levels for the Canadian Hydrographic Service, Maritimes Region (on land), and Multidisciplinary Hydrographer Christopher Coolen (in water) seen here installing the St. Lawrence unit, helped develop the new laser tide gauge system for ice-prone locations. The small cost-effective units can be serviced without heavy equipment and provide three independent water level measurements.

As part of work that began in 2005 to improve the reliability and timeliness of Canadian tide gauge data, the service's technical staff developed an important new laser tide gauge system. Using this system, Canada now provides more accurate data from ice-prone locations to the Global Sea Level Observing System (GLOSS), which coordinates and collects data for sea level rise, climate, oceanographic and coastal sea level research. The first systems were deployed late in 2008 at locations near Halifax, Nova Scotia, St. John's and Nain, Newfoundland and Labrador (where winter temperatures routinely drop below -30° to -40° C).

The new laser tide gauge is ideal for its mission — simple, accurate, precise and reliable, it provides stable and repeatable results, and is inexpensive to build, deploy and maintain. For cold, ice-prone locations, the new laser system achieves a better balance of these characteristics. Its insulated and heated multi-well stilling well provides for three independent water level measurements and its main laser sensor has no moving parts, requires no on-site calibration and is accurate to within 1.5 mm.

During 2009–2010, the new laser systems proved their capabilities and four more systems were built, two of which were deployed in 2010 at Bonavista and St. Lawrence, Newfoundland and Labrador. Plans are under way to install similar systems at other ice-prone Atlantic tide gauge sites.