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DEFINING CANADA'S EXTENDED CONTINENTAL SHELF IN THE ARCTIC

Jacob Verhoef and Julian Goodyear

The United Nations Convention on the Law of the Sea (UNCLOS) has sometimes been called the constitution of the oceans. With a total of 161 state parties, including Canada, which ratified it in 2003, the Convention has become one of the most broadly accepted treaties in the world. Its broad range of provisions deal with marine scientific research, navigation, resource development, protection of the marine environment, fisheries management, and dispute settlement.

The Convention establishes a series of maritime zones with corresponding rights and obligations. All coastal states, for example, are entitled to a continental shelf of 200 nautical miles (nm), or further if they meet certain criteria – as it may be the case for Canada and between 60 and 70 other states. A state has sovereign rights over the natural resources on and under the seabed of its continental shelf, and jurisdiction over some activities, such as marine scientific research. The seabed beyond the continental shelves is called the Area. The Area and its mineral resources are considered the common heritage of mankind and are administered by the International Seabed Authority.

UNCLOS AND ARTICLE 76

The sovereign rights a state has over the resources of its continental shelf, including those extending beyond 200 nm. are exclusive and do not depend on occupation or proclamation. However, states do need to determine with precision the area in which they may exercise these rights. In article 76 the Convention sets out a process for doing this.

To demonstrate that it meets the requirements of article 76 the coastal state must collect the geological and geomorphological data necessary for defining its extended continental shelf. Article 76 provides formulae for measuring the continental shelf seaward, as well as constraints beyond which the shelf cannot extend. The shape of the seafloor, its depth, and the thickness of the underlying sedimentary layer are the crucial factors. Coastal states apply these formulae and constraints to produce an outer limit and file a submission to the Commission on the Limits of the Continental Shelf (CLCS).

The CLCS – whose members are experts in geology, geophysics, or hydrography, elected by state parties to the Convention for a five year term – considers the submission and sends back its recommendations. If the state accepts these it then develops regulations to enact the coordinates (latitude and longitude) of the shelf and files them with the United Nations. Only the coastal state can establish the outer limits of its shelf, and once it does so, based on the recommendations of the CLCS, the limits are final and binding. It is important

Canada

Figure 1
Canada's potential extended continental shelf based on a preliminary study in the mid 1990's. The brown line denotes Canada's Exclusive Economic Zone (EEZ) and the green line gives the preliminary outer limit of the extended shelf. The graphic is for illustrative purposes only.

to note that the CLCS has no mandate to resolve disputes between states and that the actions of the CLCS are without prejudice to the delimitation of boundaries between coastal states. Disputes have to be resolved by the states involved through negotiation or a dispute settlement process.

States have ten years from the date they became party to the Convention to make their submission to the CLCS. Each country has a different deadline depending on when it joined. Canada ratified UNCLOS in December 2003 and so it must submit in December 2013.

CANADA'S EXTENDED CONTINENTAL SHELF PROGRAM

In the mid 1990's, Canada conducted a desktop study using existing data sets to give a preliminary indication of its extended continental shelf according to Article 76 (Figure 1). This analysis demonstrated that Canada potentially has a large extended continental shelf – the size of the three prairie provinces – in both the Atlantic and Arctic Oceans. (GSC, 1994).

After Canada ratified UNCLOS, work began to acquire the data needed for a scientifically sound and defensible submission to the CLCS. Securing international recognition for the full extent of Canada's continental shelf is a priority for the Government of Canada.

Canada's Extended Continental Shelf (ECS) program is the joint responsibility of Foreign Affairs and International Trade Canada (DFAIT), the Geological Survey of Canada (GSC), Natural Resources Canada and the Canadian Hydrographic Service (CHS), and Fisheries and Oceans Canada (DFO). Foreign Affairs and International Trade Canada provides the legal expertise and advice and is responsible for preparing and presenting the submission to the CLCS. The GSC and the CHS undertake the necessary scientific and technical work. This includes bathymetric and seismic surveys to determine the foot of the slope of the continental shelf, mapping the 2500-metre depth contour, and measuring sediment thickness to determine the point where the sediment thickness is 1% of the distance to the foot of the slope. Surveys are also needed to find out whether submerged elevations are natural extensions of the continental shelf.

We have designed a continental shelf survey program for the Atlantic and Arctic Oceans. The Atlantic surveys were done in 2006, 2007 and 2009, and the data is now being analyzed. We are currently collecting data in both the eastern and western Arctic.

THE ARCTIC PROGRAM

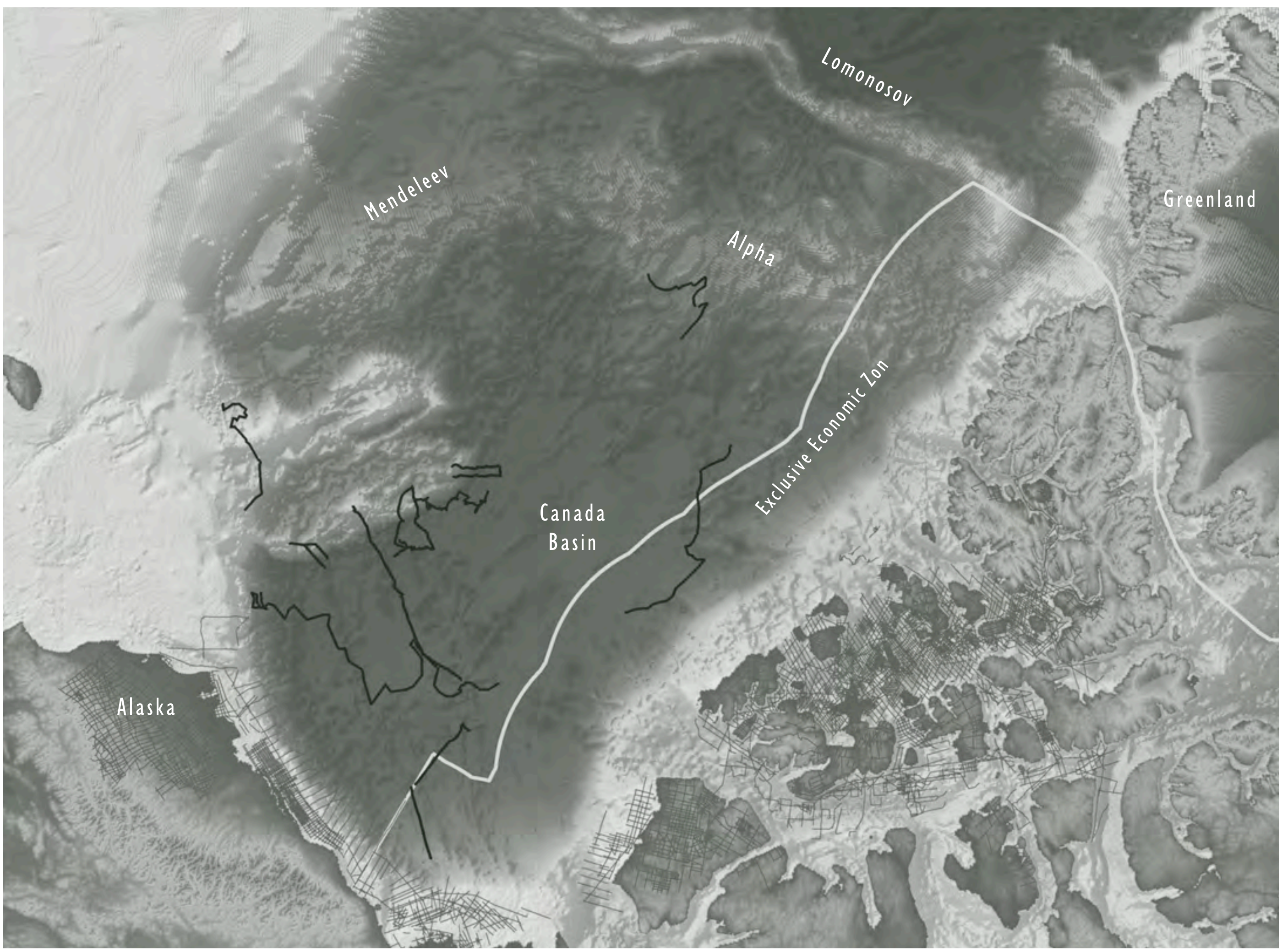
The Arctic Ocean is one of the most understudied oceans in the world. Its remoteness, harsh environment, unpredictable weather and ice, and its short field seasons, make research technologically challenging. Ice conditions in the western Arctic generally allow us to use heavy icebreakers, but in the eastern Arctic this is often very difficult, if not impossible. As a result, large expanses of the Arctic Ocean remain unmapped (Figure 2) and there is insufficient data to reliably determine the limits of the continental shelf.

The geology of the Arctic Ocean is complicated. The Canada Basin in the west has a flat seafloor covered by a thick layer of sediments (Figure 2). Their thickness, the key factor, is being determined by seismic and bathymetric surveys conducted by icebreaker. The Eastern Arctic, in contrast, is dominated by two large submarine mountain ranges, the Lomonosov and Alpha-Mendeleev ridges. To establish the outer limits of the continental shelf in the eastern Arctic, the first step is to demonstrate whether these features are naturally linked extensions of Canada's continental shelf. We investigate this from offshore base camps constructed on the ice, using helicopters, other aircraft, and undersea vehicles to collect data. Figure 3 shows the overall five year survey plan.

INTERNATIONAL COLLABORATIONS

Our neighbouring Arctic Ocean coastal states, Russia, Norway, Denmark, and the US, are all at different stages in defining their extended continental shelves. Russia's 2001 submission was the first to be filed with the CLCS, which recommended it be revised. Russia is now collecting more data and working on the revisions. Norway, whose 2006 submission received positive recommendations in 2009, is now in the process of establishing its outer limits. Denmark's deadline is November 2014, and that country has made partial submissions for areas around the Faroe Islands and is

Figure 2
General bathymetry of the Arctic Ocean (based on the International Bathymetric Chart of the Arctic Ocean, Jakobsson *et al.*, 2000). Also shown are the seismic data in and around the Canada Basin which were collected prior to Canada's ECS surveys.



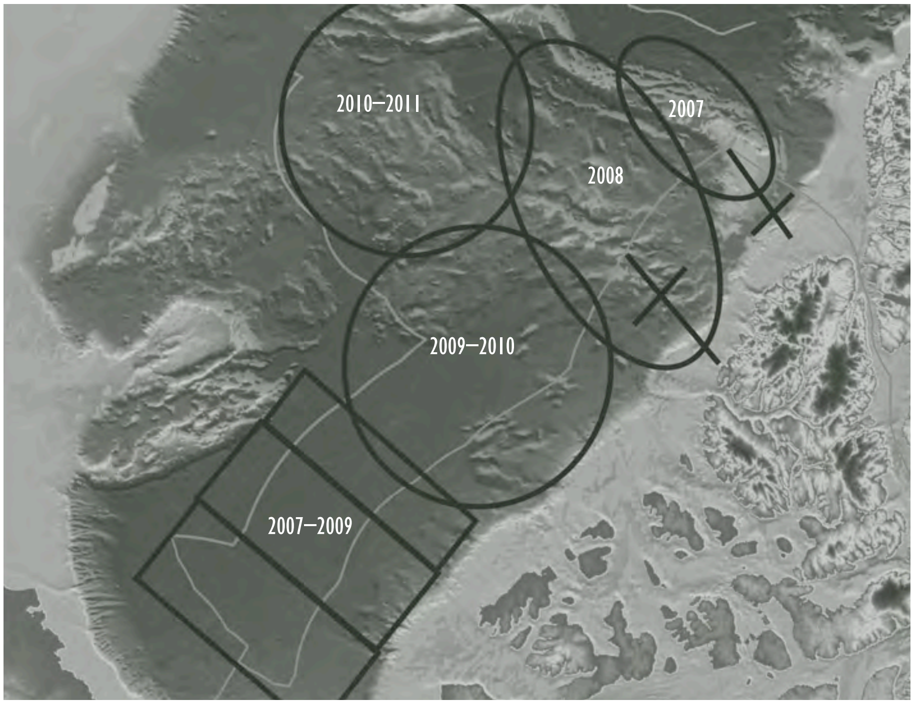


Figure 3
Canada's Arctic survey plan. The circles indicate areas where the data would be collected using ice camps.The rectangles denote areas where icebreakers would be used. The heave dark lines denote the refraction surveys over Lomonosov and Alpha ridges.

collecting and interpreting data for shelf areas around Greenland. The US is not currently a party to UNCLOS but is nonetheless collecting data to define its shelf.

Like Canada, its neighbours are also involved in data collection in the Arctic. Since this is a challenging and expensive undertaking, Canada has explored and implemented partnerships to collect data of mutual benefit. This cooperation mitigates the risks associated with innovative data collection in a high risk environment by providing more options for getting the work done. It reduces costs and environmental impacts while a common data interpretation by neighbouring countries enhances the probability of a successful submission.

Over the past five years Canada has worked with Denmark on seven joint surveys of the continental shelf north of Ellesmere Island and Greenland as well as in the Labrador Sea. We have also interpreted and published the results jointly with our Danish partners. In the western Arctic Canada has conducted three joint surveys with the United States (2008, 2009, and 2010) a fourth is planned for 2011. The two countries have interpreted and presented the data together, and joint publications are in preparation. Canadian, Danish and Russian officials have in fact met annually since 2007 to discuss their respective continental shelf research and have been joined by officials from the US (from 2009) and Norway (2010).

CANADA'S EASTERN ARCTIC PROGRAM

It is in the interest of both Canada and Denmark (Greenland) to establish that the Lomonosov Ridge is a natural prolongation of the continent. For Canada it is also important to show that this holds true as well for the Alpha Ridge. The bathymetry shows a trough north of Ellesmere Island that seems to separate the ridges from the mainland. Determining whether the ridges are in fact separate requires an image of the crustal structure below the seafloor. This can be obtained using seismic surveys to measure the crustal seismic velocities of the ridges (Figure 4) in order to compare them to those on the adjacent continent. In addition, the shape of the seafloor and the ridges can be measured using helicopters to conduct bathymetric spot-soundings.

Canada and Denmark collaborated in the spring of 2006 on the LORITA project (Lomonosov Ridge Test of Appurtenance) to conduct seismic and bathymetric surveys on the Lomonosov Ridge, using the Canadian Forces Station Alert as the main base and establishing a small ice camp about 100 km offshore. The project achieved its main objective, and collected high quality seismic data despite losing 65–70% of the days to bad weather. The scientific paper (Jackson *et al.,* 2010) that resulted from joint interpretation of the data concluded that there is continuity of the continental crust from the coasts of Ellesmere Island and Greenland across the trough and onto the Lomonosov Ridge, and that there is no intervening oceanic crust.

The next step was to do a similar project for Alpha Ridge. In March–April 2008 we conducted the ARTA (Alpha Ridge Test of Appurtenance) on-ice refraction experiment to

Figure 4
Image of the seismic recorders used in the LORITA and ARTA experiments. About 150 recorders were put on the ice, 1–2 km apart and this configuration was used to record crustal velocities. Photo: R. Jackson, GSC.

establish the ridge's structure. Our base was a large ice camp (Figure 5) near the mouth of Nansen Sound (Ellesmere Island) as well as a small camp about 100 km offshore. The results of this experiment have not yet been fully analyzed and published, but initial results have been presented (Funck *et al.,* 2010).

In the spring of 2009, we undertook a joint survey project with Denmark and collected a large amount of bathymetric data to measure the shape of the seafloor between the Alpha and Lomonosov ridges. This work again needed a large ice camp near shore. Building a large ice camp, including flattening a runway for the supply aircraft, is time consuming and expensive, but it generally works well. The predominant concern during all these surveys was the unpredictable weather: open leads caused ice fog, which grounded the helicopters, which meant less data was collected. Moreover, the area further offshore became dangerous because of floes breaking up, causing in 2009 the emergency evacuation of the smaller offshore camp. The eastern Arctic work in 2010 and 2011 (Figure 3) is even further from shore, again requiring the construction of large camps. Given the 2009 experience, the general opinion was that this would be very risky

One alternative, using icebreakers, did not appear feasible: a joint survey with the Danes in 2007, using the Swedish icebreaker *Oden* accompanied by a powerful Russian nuclear icebreaker, had failed to get into the area. That experience convinced us that we needed the capability to go under the ice rather than just on top of it or through it, and in September 2008 we initiated a joint project with DRDC (Defence Research and Development Canada) to collect data with autonomous underwater vehicles.

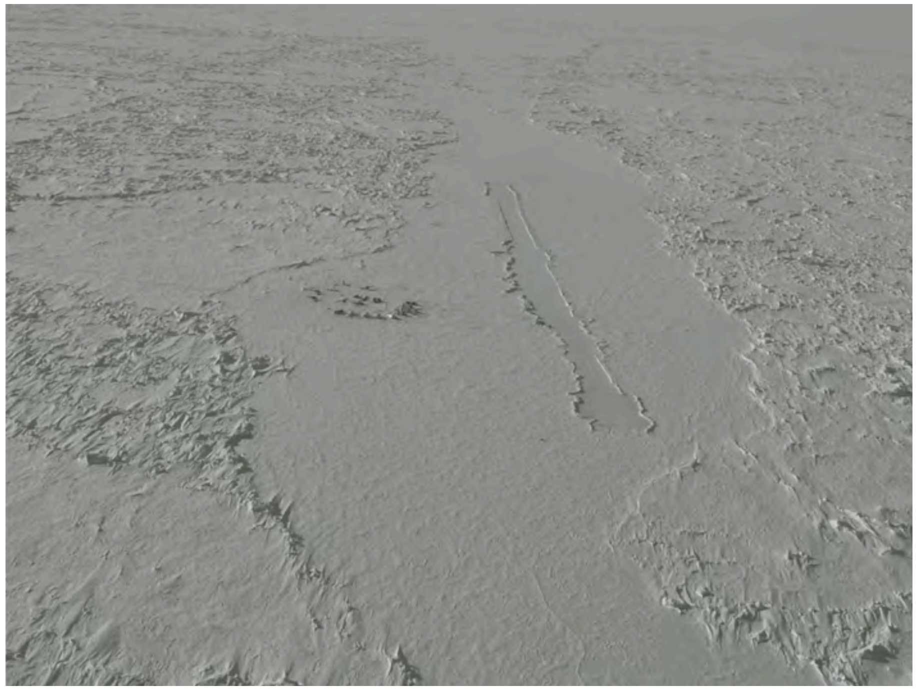


Figure 5
Image of the ice camp during the ARTA experiment, located offshore Ellesmere Island. Also shown is the runway, which was constructed to allow the aircraft to bring the equipment and supplies to the camp. Image: courtesy of Jon Biggar, CHS.

AUTONOMOUS UNDERWATER VEHICLE (AUV)

The AUV was built by Vancouver-based International Submarine Engineering Ltd. About seven metres long, it is battery powered, can cover 400 km and dive to 5,000 metres, and carry a high resolution multi-beam bathymetry system. At the end of each mission, the batteries can be recharged, the data downloaded, and the AUV sent out on another mission – all without removing the vehicle from the water.

The AUV starts its mission at the main camp near land and finishes at a remote offshore camp (Figure 6A). A typical mission will take about three days, during which there is no communication with the vehicle. During that period the offshore camp, which

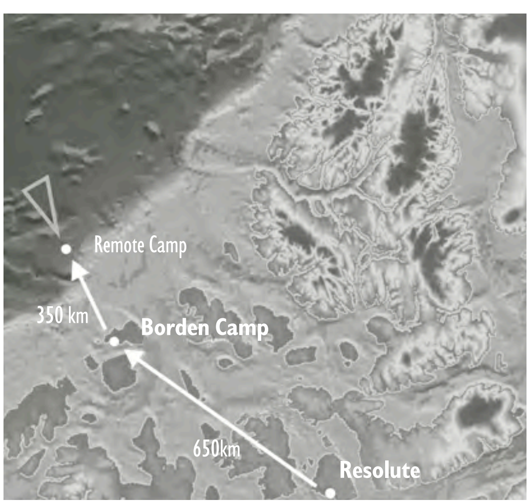


Figure 6A (left)
Location diagram of the Borden main ice camp and the remote offshore ice camp. All equipment was brought to Resolute and then flown to the two camps.

Figure 6B (right)
Image of the Borden main camp. The camp has 17 tents and a population of over 40 people. Also shown at the upper right side of the image is the runway. Image: courtesy of Janice Lang, DRDC.

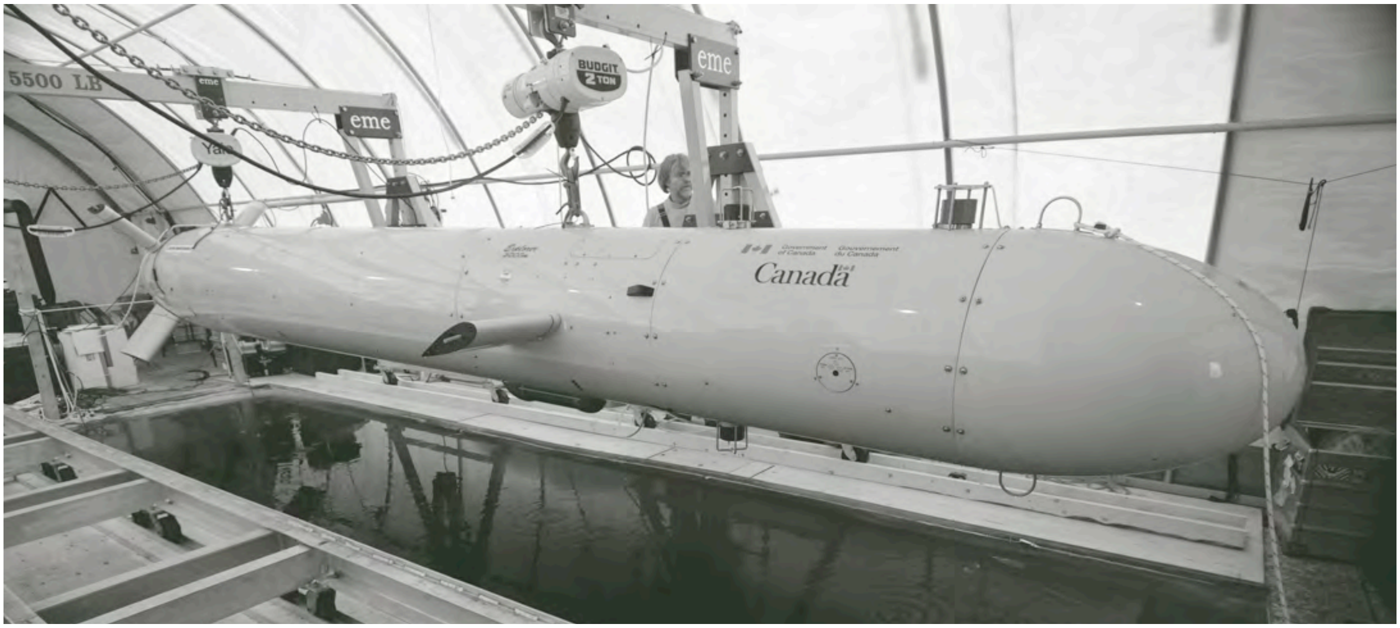


Figure 6C
Image of the AUV at the Borden ice camp, prior to being sent out on a mission. Also shown is the large hole that was created by removing over 30,000 kg of ice. Image: courtesy of Janice Lang, DRDC.

is on an ice floe, has often drifted away from its original position, sometimes by 10–20 km. This necessitates the development of a homing system so that the AUV can find its way to the camp's new location.

In April 2010, the AUV was deployed from a main camp near Borden Island (Figure 6) where bathymetric data was being collected using helicopter spot soundings. The two simultaneous operations, each with its own crew, made for a large camp, with more than 17 large tents and over 40 people; the remote camp had a population of 12. Poor weather and fog from large open leads north of Borden Island significantly hindered the helicopter operations – there was only one day of unobstructed flying weather during the entire month of April.

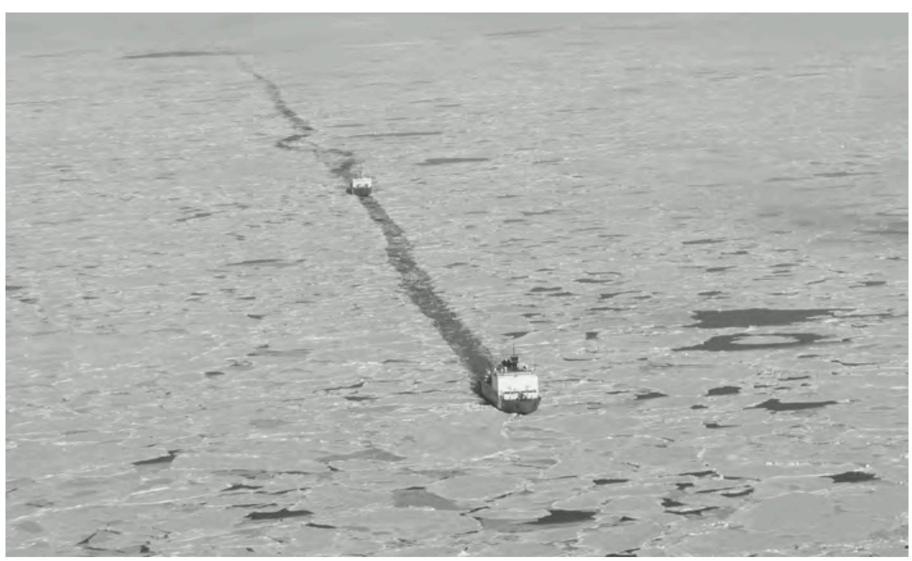
In contrast, the AUV operations were a resounding success (Figure 6C). The vehicle travelled over 1,000 km during a continuous operating period of ten days at depths of over 3,300 m under the ice, flawlessly homed in to a moving ice camp from a distance of 50 km, and completed about 500 km of bathymetric measurements in key areas. These achievements represent a world record for under-ice operations in the Arctic.

CANADA'S WESTERN ARCTIC PROGRAM

In the western Arctic, defining the outer limits of Canada's extended continental shelf means determining the thickness of the sediment cover by seismic survey. This involves emitting a sound wave and using sophisticated techniques to analyse the echo as it bounces back from the ocean floor and from the sedimentary layers below it.

Collecting seismic data in the Arctic's ice-infested waters is not easy. Most of the previous seismic data in the western Arctic were obtained near shore, with only a few lines crossing the Canada Basin (Figure 2). The surveying must be done with an icebreaker, but the noise of the vessel's powerful engines interferes with the seismic sound source. Moreover, the standard equipment for seismic data collection needs to be strengthened to with-

Figure 7
Image of the CCGS *Louis S. St-Laurent* and UCGC *Healy* (leading and breaking ice). This configuration allows the Canadian icebreaker to collect high quality seismic data. Photo: Jon Biggar, CHS.



stand impact from the ice fragments in the icebreaker's wake. We therefore developed a modified seismic system and tested it during a 2006 survey on CCGS *Louis S. St-Laurent.*

In September 2007, again using the "*Louis*", we collected 3,000 km of high quality seismic data in the southern part of the Canada Basin, as well as over 7500 km of single beam bathymetry data. Ice conditions varied but were heavier to the north – where we planned to work the following year. We realized that two icebreakers would be needed for that survey.

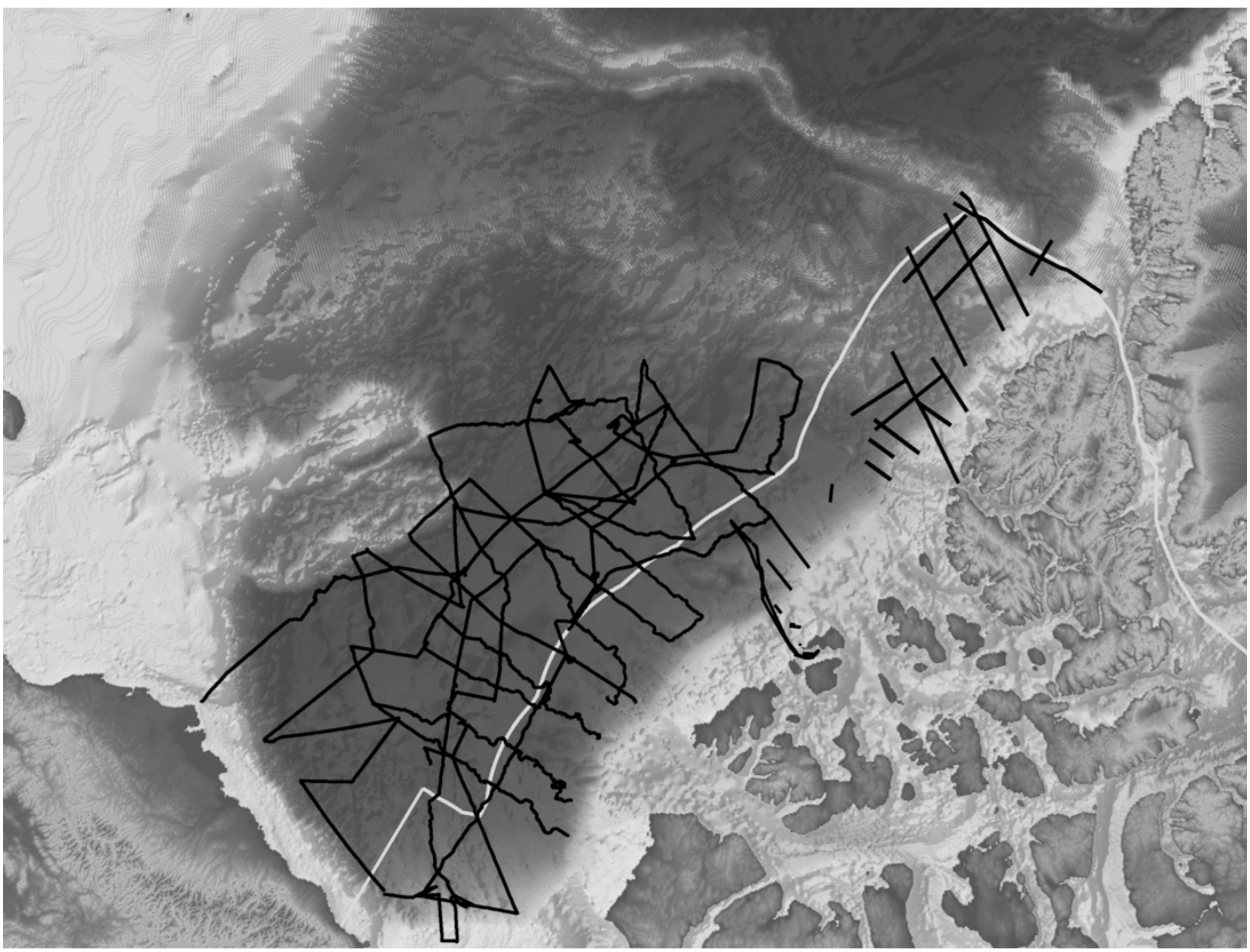
Our discussions with American scientists and officials led an agreement to work together. We undertook joint surveys in 2008, 2009 and 2010 using the CCGS *Louis S. St-Laurent* and the US icebreaker USCGC *Healy,* the combined capabilities of the two icebreakers enabling us to work successfully in heavy ice conditions. Where seismic data was important, the USCGC *Healy* broke ice and the CCGS *Louis S. St-Laurent* followed with its seismic system; where we needed to know the shape of the seafloor, the Canadian vessel broke ice and the US icebreaker followed with its high resolution multi-beam bathymetry system. Because the following vessel did not have to break heavy ice, the data quality was significantly better (Figure 7). These surveys collected over 13,500 km of high quality seismic data and more than 18,000 km of bathymetry.

The four major surveys in the western Arctic have covered most of the area where information was needed (Figure 8), more than tripling data coverage and significantly improving our knowledge of the region. The initial interpretations of the data have been presented at scientific conferences (Mosher *et al.,* 2010; Shimeld *et al.,* 2010) and publications are underway. In summary, we have found that the Canada Basin is generally covered by a layer of sediments over 4 km thick, which thins to the northwest. This finding will likely allow Canada to define a large area as extended continental shelf in this region.

CONCLUSIONS

The Arctic component of Canada's Extended Continental Shelf Program has proved challenging, and continues to face the risk of delays from weather and ice conditions. With the conclusion of the 2010 field season, we

Figure 8
Overview of seismic and key bathymetry data collected over the period 2007–10. A total of over 13,500 km of seismic and over 18,000 km of bathymetry data have tripled our data holdings in the Arctic.



have most of the data we require in the western Arctic but need more from the eastern Arctic. We hope to collect this during the fourth Canada–US joint survey planned for August–September 2011.

The amount and the quality of the data have surpassed our initial hopes. The effective and continuing cooperation between Arctic Ocean coastal states is a key contributor to this achievement.

In addition to providing strong support for Canada's submission to the Commission, the wealth of new data will no doubt lead to a better understanding of the origin and tectonic evolution of the Arctic Ocean.

Presently, Canada is on track to prepare and submit its outer limits of the extended continental shelf and substantiating information to the UN Commission by its deadline of December 2013.

Acknowledgements

This program has involved many organizations and dedicated staff to collect and analyse the scientific information. We would like to thank all those who did the logistics for the ice camps (Polar Continental Shelf Program, Environment Canada, Canadian Ice Service, all the pilots and technical staff); those who were involved in the shipborne operations (Canadian Coast Guard, the Commanding Officers and crews of the CCGS *Louis S. St-Laurent* and the USCGC *Healy*) and our staff and contractors who went out to ice camps and on board ships under rather difficult situations to collect the data. We would also like to acknowledge our partners in the scientific work in Canada, in the US and in Denmark.

Jacob Verhoef is Director, UNCLOS Program, Natural Resources Canada; Julian Goodyear is Director, Law of the Sea Project, Fisheries and Oceans Canada.

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IMPACTS OF ARCTIC STORMS AND CLIMATE CHANGE ON COASTAL OCEANOGRAPHIC PROCESSES

Will Perrie, Eyad Atallah, Melanie Cooke, John Gyakum, Azurhal Hoque, Zhenxia Long, Ryan Mulligan, David Small, Steve Solomon, Charles Tang, Bechara Toulany, Fumin Xu and Biao Zhang

Residents of the Arctic coast, for whom the sea is an integral part of life, know the destructive power of storms. Every Inuit community has its storm stories – hunters scrambling for their lives as the sea ice heaves and breaks up around them, boats and their occupants lost, infrastructure destroyed, and coastlines altered. Marine storms are influenced by heat, and with the warming climate the Arctic is experiencing stronger marine storms. In order to adapt – especially with offshore oil and gas exploitation a strong possibility – we need to understand how the ocean responds to storms in coastal areas.

Our group is studying coastal oceanographic processes – waves, storm surge and ocean currents, marine winds, coastal erosion and sediment transport – in the southern Beaufort Sea and the west Canadian Arctic, an area whose Inuvialuit communities use the

Zhenxia Long, Charles Tang, Bechara Toulany, Fumin Xu, Biao Zhang are at Fisheries and Oceans Canada's Bedford Institute of Oceanography, Dartmouth, Nova Scotia. David Small, Eyad Atallah, Melanie Cooke and John Gyakum are at the Department of Atmospheric and Oceanic Sciences, McGill University, Montreal, Quebec; Azurhal Hoque is at Water Control System Management Branch, Manitoba Water Stewardship, Winnipeg, Manitoba. Ryan Mulligan is at East Carolina University, Greenville, North Carolina, U.S.A. Steve Solomon is at Natural Resources Canada, Bedford Institute of Oceanography.

sea for hunting, fishing, and travelling, and which will probably see offshore hydrocarbon extraction within a decade.

Changes and variability in storm tracks and intensity, associated with warming related to climate change in the Beaufort-Chukchi region, can endanger coastal settlements and human activities in coastal marine environments. Weather and climate influence ocean dynamical processes (waves, circulation and storm surges), which induce sediment transport and coastal erosion, which in turn affect coastal communities, aquatic species, and offshore drilling operations. We are interested in time scales ranging from a few days or less, the duration of a single storm, to seasonal, inter-annual, decadal, and longer periods.

Like much of climate science, we rely on carefully constructed mathematical models to suggest how the storms will behave as the elements that cause them change. We build these numerical models using the best available data on storm behaviour. Once a model can accurately represent observed conditions, and includes reasonable physics, we can alter its components – like the amount of open water and sea ice – to simulate storms and predict how they are likely to develop and behave in future climate scenarios.

We have completed our basic numerical simulations and data studies and have built and implemented detailed coupled models – models that link subsystems of the earth's climate system (atmosphere, hydrosphere, cryosphere, etc.) – with components for atmospheric dynamics, snow, waves, ocean circulation, and a multi-category sea-ice model. We have assembled a data base of historical storms, climate reanalysis data, recent observational data, and computer analyses models and related software. Our models have been tested for time-scales that range from individual Arctic storms to decadal-scale regional climate, and have been improved using observations collected from field experiments, storms, and climate reanalysis data sets. Baseline verifications of these models use comparisons with international Arctic data-sets, climate reanalysis data, and recent field data.

In our storm simulations we have also implemented and tested high-resolution models of the waves, ice, currents, sediment transport, and coastal processes that are relevant to the southern Beaufort Sea coastal areas. Our focus has been on storms making landfall along the coast of the Mackenzie Delta near Tuktoyaktuk and affecting communities in that region. We assessed the benefits of high-resolution coupled ice-ocean-wave studies and detailed air-sea interactions, using ocean wave models to simulate conditions in the nearshore region off the Mackenzie Delta.

On shorter time-scales, further development work on the mechanisms that determine how waves break, dissipate, and in nearshore areas, erode the bottom and influence sediment transport, is needed to improve our models and thus our understanding of the impacts of storms and climate change. On longer time-scales, we are able to simulate decadal ice variations, including the rapid ice decrease in recent years (Figure 1), and long

Figure 1
Simulated total ice area in September from ice-ocean model simulation (brown) and Hadley Centre data (green). Units are in 106 km^2 (y-axis).

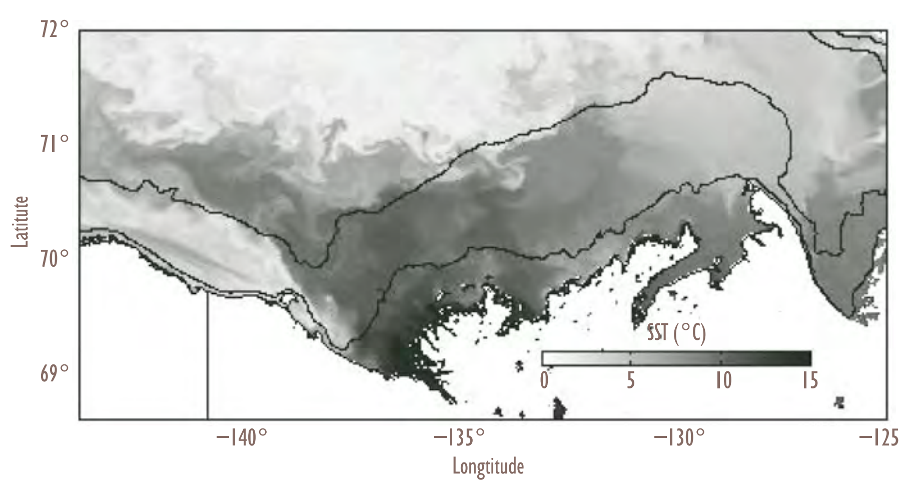

Figure 2
Sea surface temperatures (SST) from MODIS satellite observations on 25 August 2007, show the extent of the Mackenzie River plume in the Beaufort Sea. Easterly winds cause upwelling, stronger mixing, and a cooler plume (upper panel); light winds with minimal mixing and entrainment of underlying shelf water allow the warmer plume to spread as a thin surface layer (lower panel). The coastline and 20-m and 200-m bathymetric contours are shown. Instabilities are visible near the shelf break (200-m contour) where the Coriolis-dominated eastward flow on the shelf meets the westward-flowing Beaufort Gyre in Canada Basin.

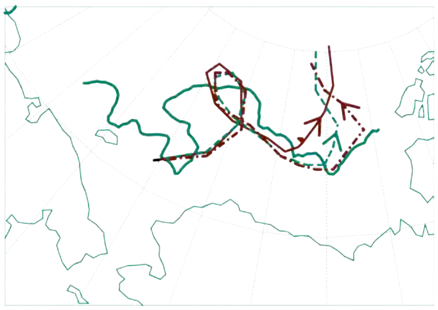

Figure 3 (above)
Comparisons of storm tracks and following a storm, showing coupled model (dotted brown line), uncoupled model (dotted green line), Canadian Meteorological Centre sea level pressure analyses (solid brown line) . The solid green line represents the National Snow and Ice Data Center ice edge. Arrows denote the direction of storm movement.

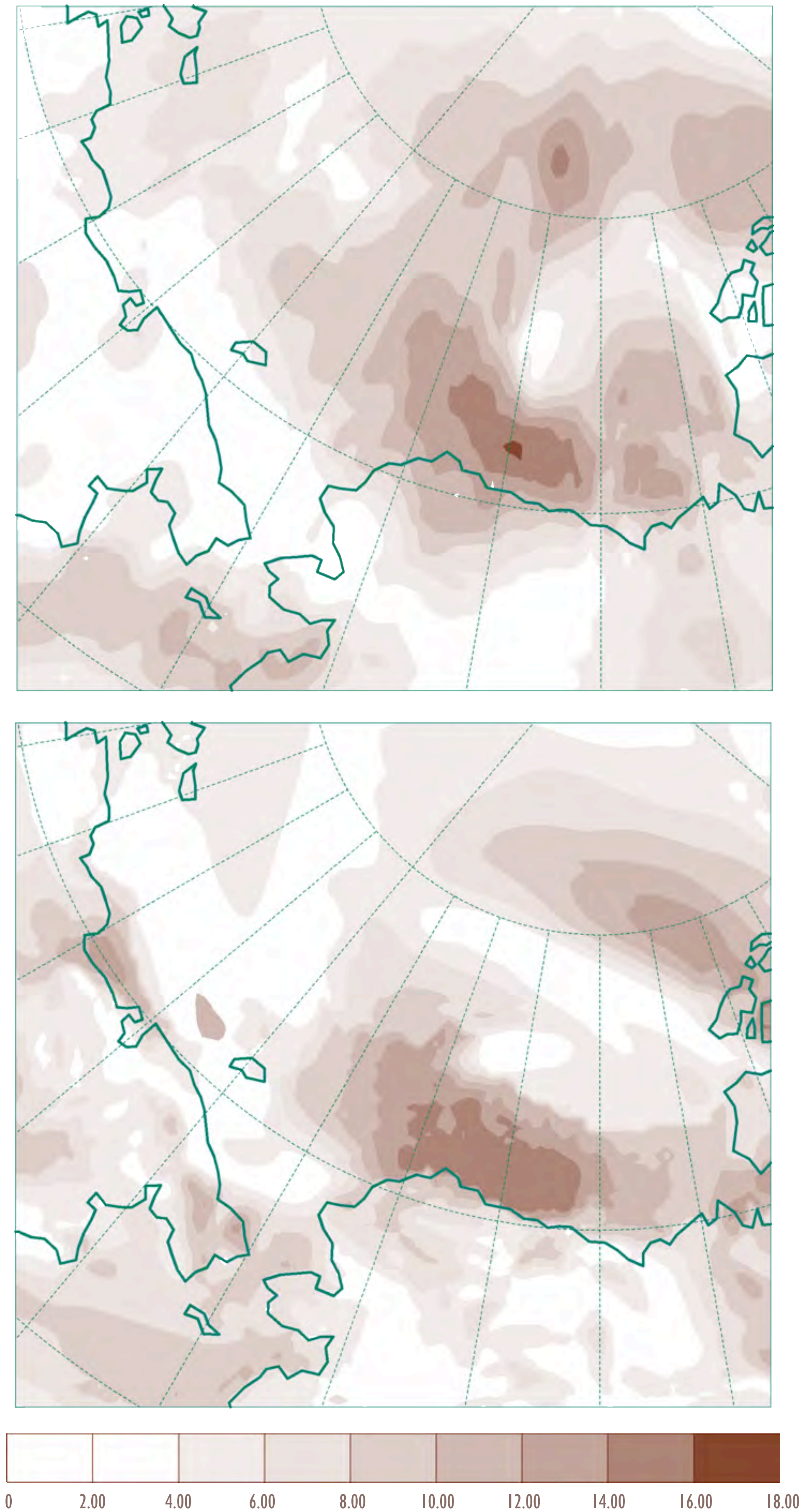

Figure 4 (right)
Wind speed at 12:00, 31 July for (a) QSCAT-NCEP, (satellite and weather centre data) (b) coupled model. Units are m/s.

time-scale variables such as the salinity minimum in the Beaufort Sea, the warm Atlantic water layer in the Arctic Ocean, and the maximum fresh water content in the Beaufort Sea as well as its year to year variations during the last several decades.

We have identified key atmospheric patterns associated with strong winds along the Beaufort Sea coast. We have also comprehensively documented the wind climatology during the warm season at the coastal station at Tuktoyaktuk. Meteorological processes that contribute to significant storm surge events are being studied. We are conducting detailed studies on the interactions between the Mackenzie Delta area and the Beaufort Sea during storms, including storm surges and coastal flooding. The sea surface temperature (SST) distribution in late August in 2007 from MODIS (Moderate Resolution Imaging Spectro-radiometer) satellite observations is presented in Figure 2, showing interactions among the warm river water, the coastal water, and, further offshore, the vast area of slowly circulating waters known as the Beaufort gyre. These features are also affected by wind. We use data from complementary projects that measured temperature and salinity about 25 km north from the Delta coastline and beyond, and high-resolution computer models to simulate salinity patterns similar to the temperature variations in Figure 2. A recent 40-year (1970–2008) reanalysis for Beaufort Sea wind and waves by the Environment Canada (EC) provides an important contribution to this project.

We need further investigations to clarify the role of increased open water during the summer. In summer, storms occur more often in the Canada basin than any other coastal area in the Arctic Ocean. There were about 14 storms per storm season (June–November); October has the highest storm frequency, and July the lowest. Cyclonic systems often sweep into this region from the Siberian coast and then stall in the Beaufort Sea. Intense storms play an important role in the variations of the heat and salt budgets in the upper Arctic. In the spring and winter when stratifications of heat (thermocline) and salt (halocline) in the Beaufort Sea are less distinct, the turbulence caused by intense storms causes deep mixing of water that can penetrate through the Arctic halocline and thermocline layers. When storms break up large ice floes and expose more open water, the heat exchange between air and water increases.

For example, an intense storm occurred in the Beaufort Sea in late July 2008 (Figure 3), when there was a large expanse of open water. The open water influenced both the storm's development and the surface winds it caused, as open water modifies the interactions and transfers of energy between air and sea. In turn, the storm generated surface currents and modified the ocean surface temperatures. However, due to the high albedo of sea ice – its high capacity to reflect solar energy because of its white colour, in comparison with the dark water, which absorbs solar energy – water surface temperatures were much warmer than they would be in a completely ice-covered ocean. The rising warm air, forced down by the turbulent air currents of the storm, provided extra energy to the storm. Compared to more ice-covered scenarios, open water resulted in a more intense storm, with enhanced wind speeds by about 3–4 metres per second.

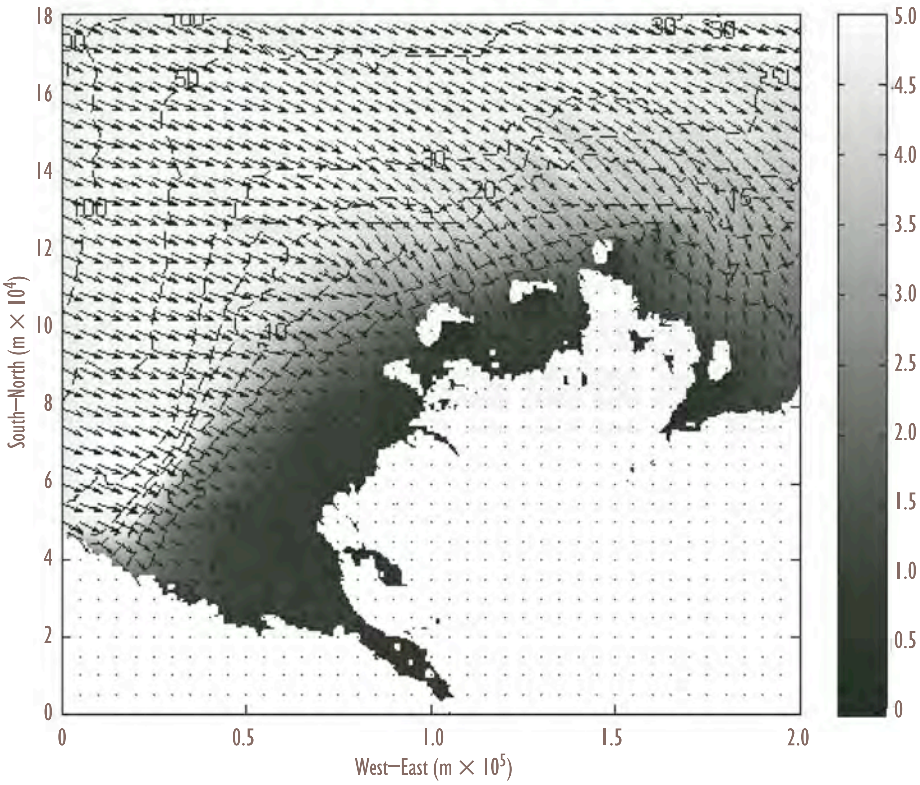

Figure 5
Significant wave heights (m) at 05:00 (coordinated universal time) on 8 October 2008 at the peak of the storm; winds are from the northwest for more than 50 hours at 50km/hour, waves are causing coastal damage along the southern coast of the Beaufort Sea.

The strongest surface winds along the southern Beaufort coast blow either from the northwest or from the southeast, in fall and winter. Our future work will analyse the life cycle of the planetary-scale atmospheric circulation regimes affected by these strong winds, and the trends observed over the past 60 years. So far we have found that storms causing major surges along Beaufort coast are associated with a series of strong upper-atmosphere forcing events spanning the hemisphere along 70°N. Ongoing investigations involve identifying whether these storms represent a unique, but not climatologically prevalent flow regime, or whether they are transitions in flow regimes such as the North Atlantic Oscillation or Pacific North American Pattern. We found that such events occur more often in the late summer and early autumn, after cold air trapped north of Brooks Range produces the strong northwesterly winds favourable for storm surges. We are documenting other meteorological phenomena of varying size, duration, and predictability, which may play significant roles in the strong northwesterly winds responsible for these extreme events.

Preliminary studies have looked at coastal erosion, sediment transport, and morphodynamic changes – specifically, changes to the seafloor – in nearshore areas along the Beaufort coastline. Under storm conditions, the water levels rise, and waves smash against the frozen cliff face gradually breaking off pieces of it, through a combination of melting and hydrodynamics (thermal and mechanical erosion). Storm surges, sudden and abnormal rises or drops in sea level, are most evident in shallow waters and along the coast; they are caused by strong winds associated

Figure 6
Photographs show, at the base of the bluff, an example of morphodynamic change in a thermo-erosion notch composed of frozen fine sand and silt with scattered cobbles and boulders: (a) development of the niche, and (b) later block failure of the same cliff.

with landfalling storms. Tuktoyaktuk, on the Mackenzie Delta coast, is particularly vulnerable to damage from strong surges, caused by storms blowing in from the Beaufort Sea.

At the peak of a storm in October 2008, dominant waves driving in from the northwest had their strongest impact on the fragile coast of the MacKenzie Delta (Figure 5). The north-facing side of Tuktoyaktuk Island sits at the entrance to Tuktoyaktuk Harbour and provides natural protection from waves. Niches form over time, which can reach 10 m into the bluff and can be up to 2 m high (Figure 6). Once the niche cuts far enough into the base of the cliff, the overhanging cornice collapses due to block failure. The frozen bluffs are also cut from above by patterned ground, tundra polygons caused by buried ice wedges. Days, weeks, or months after the niches form, the blocks fail, usually along the lines of weakness defined by the ice wedges. Over the last several years, the north side of Tuktoyaktuk Island has eroded at an average rate of about 2 m per year (up to 7 m during a single storm event). At this rate, the island will be little more than a shoal for much of its length by 2050, allowing large waves to enter the harbour. Tuktoyaktuk is the only developed harbour for hundreds of kilometres.

The project ends on 31 March 2011. By that time, we will have completed further studies and model tests. Simulations and our understanding will be improved by using IPY field data. Ongoing tests will focus on selected storms, as well as seasonal, inter-annual, and decadal time scales. The project will attempt to establish links among climate change, changing ice coverage, coastal oceanographic processes, coastal erosion and sediment transport.

It is our hope that Tuktoyaktuk and other Arctic coastal communities will benefit from the improved understanding of storms that our research is bringing, and that it will help them adapt to changing storm patterns and intensities along the Arctic coast.

Department of Fisheries and Oceans, Ocean Sciences Division is also included in three IPY-approved network projects: (1) iAOOS, the Integrated Arctic Ocean Observing System; (2) THORPEX, improved numerical weather forecasting and climate simulations by exploitation of in-situ, *airborne remote-sensing and satellite data, advanced modelling systems and basic research into polar processes and into polar-global interactions; and (3) ACCO-net, the Arctic Circum-Polar Coastal Observatory Network. Important support is also given by IPY field projects and other programs,* e.g., *the Federal Panel on Energy Research and Development, which actively collect data on wind, waves, currents, and related coastal ocean and marine boundary layer variables. We want to acknowledge the role that the Federal Panel on Energy Research and Development (PERD) played in supporting field experiments that are critical to understanding of coastal processes of the Beaufort.*

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SHAPING TOMORROW'S NORTHERN ECOSYSTEM: ARCTIC INSECTS, SPIDERS, AND THEIR RELATIVES IN A CHANGING CLIMATE

Louise Leborgne, Crystal Ernst and Christopher M. Buddle

Climate change is altering the Arctic landscape and the tundra ecosystem. Although we often hear of the effects on animals such as polar bears and other larger animals, a changing climate will also affect other creatures. Insects, spiders, and their relatives – the arthropods – play important roles in the Arctic, from feeding birds, to pollinating flowers and recycling organic matter. Our changing climate is having important effects on the life history, distribution, and diversity of native and introduced arctic arthropods. These changes, in turn, shape the arctic ecosystem. What are these effects, and what are their implications? In this article we will provide some of the answers by highlighting the key issues and discussing some of the knowledge gaps and needs for future research.

CLIMATE CHANGE IN THE ARCTIC

The mean annual temperature in the Arctic has been rising two to three times more than the global average over the past 150 years. The spring thaw arrives earlier and winters are not as cold. Snow and ice cover are also changing with abnormally thick snowfall and freezing rain becoming more common. Although we can measure these changes, the complex interactions between climatic, hydrogeological, and ecological processes make it difficult to predict their environmental effects. We know that arctic fauna have already survived changes in climate over geological time, and must therefore be relatively adaptive. We do not know, however, whether they can adapt to the significantly greater rate of change that is occurring today – change compounded by factors such as pollution, resource extraction, and different land use activities.

ARCTIC ARTHROPODS: ADAPTED TO A LIFE IN THE COLD

Arthropods are the most diverse and abundant group of organisms in the Arctic, with over 2000 known species living above the tree line.

All arthropods are ectothermic: they cannot generate their own body heat. In the Arctic they have developed a remarkable breadth of behavioural and physiological adaptations in order to cope with the harsh climate. Many arthropods bask in sunlight to raise their body temperatures; their dark colour (melanism) improves absorption of solar heat and helps protect them from UV-B radiation. Arthropods also regulate their activities to make use of warmer periods throughout the day.

They often choose favourable microhabitats to offset extreme environmental conditions – moist areas that counter the dryness of arctic summers, or sites with deep insulating snow that protect them from freezing during the winter. They have developed several physiological methods of coping with freezing: some overwintering arthropods can generate and store "antifreeze" – lactate, glycols, and other chemicals that prevent ice from forming in their bodies and damaging cells. Others allow ice crystals to form, but restrict them to areas outside cell walls.

The growth and development patterns of arctic arthropods also reflect adaptation to cold. Many need periods of consistently low temperatures in order to move through their life stages. During the coldest months, they must rest for a period of diapause, when growth slows sharply or stops altogether. As a result, most northern arthropods develop slowly, taking several years to complete their life cycles. Many of the world's invertebrates have flexible life cycles, and may be able to adapt to environmental or climatic change; but arctic arthropod life cycles tend to be more

Wolf spider, *Alopecosa hirtipes,* in the tundra of Bylot Island, Nunavut. Photo: Christopher M. Buddle.

rigidly structured and timed, perhaps to ensure that critical events (such as adult emergence) occur during the brief, favourable periods when resources are most abundant. An increase in either intensity or length of these limited windows of opportunity in the north might give more arthropods the opportunity to survive.

HOW DOES CLIMATE CHANGE AFFECT ARTHROPODS IN THE NORTH?

Distribution

Climate change affects directly soil, vegetation, water, and other characteristics of arthropod habitats. As temperatures rise, areas that were once inaccessible or inhospitable can become viable habitat; regions at the southern limits of High Arctic ecosystems, for instance, are now displaying some characteristics of the Subarctic. These altered habitats can support species whose ranges lie further south. For example, the structure of Yukon spider communities is known to be influenced by latitude, and using this type of information, we can predict how communities may reassemble as more northerly areas begin to resemble those at lower latitude (Bowden and Buddle, 2010). One study, by Parmesan and Yohe (2003), recorded a global average northward range shift of 6.1 km for a variety of plants, animals and microorganisms; the shift corresponded to an advancement of spring events by 2.3 days per decade. When species move northward they may either compete with arthropods already there, or fill an unoccupied niche. Other species whose life cycles depend on cold temperatures are more likely to experience range contractions, or, in extreme cases, regional extirpation or even extinction. Either way, changes to arthropod communities will directly affect their neighbours.

The effects of climate change on short-term habitat stability can influence arthropod distributions. For example, some researchers have predicted more frequent environmental disturbances like warming, drought, flooding or freezing events, which would change the thickness of surface ice. Experiments with ice patches have demonstrated that thicker, longer lasting ice cover can cause significant decline of some microarthropods.

Arctic moth, photographed on Bylot Island, Nunavut. Photo: Christopher M. Buddle.

Reproduction and development

In the Arctic, warmer temperatures and an earlier spring will likely affect the reproduction and development of certain arthropods. Laboratory research by Birkmoe and Leinaas (2000) has shown that the development rate of an arctic collembolan, *Hypogastrura tullbergi,* increases with temperature. These springtails, which are abundant and widespread on Devon Island, Nunavut, grew larger (which can influence fecundity) and reached sexual maturity faster at elevated temperatures. These changes could boost population growth. Similarly, the aphid *Acyrthosiphon svalbardicum* reproduced more rapidly in warmer temperatures: their populations increased within days of raised temperature treatments, and they produced an extra generation per year, in addition to their usual two (Hodkinson *et al.,* 1998). In Northeast Greenland, Hoye *et al.* (2009) found that the earlier onset of spring affects spider body size and rate of growth. Larger females can produce larger egg masses or larger eggs. Males also increase their reproductive success when spring comes earlier, by having more moults per season and by profiting from more time to search for females.

INTERACTIONS WITH OTHER SPECIES

Arthropod species respond differently to habitat change. Their responses influence, and will be influenced by, those of other organisms. Understanding the biology of individual species and how they interact within their community is vital to assessing and predicting the effects of climate change. Arthropods provide many crucial ecological services in the north, as decomposers, pollinators, herbivores, predators, and parasites. They are also an important food source for many other organisms including small mammals and migratory birds. Changes in their communities can have significant implications for the species that depend on them, and for the services they provide to the ecosystem.

Soil-decomposer

Soil arthropods play a major role in decomposition and carbon cycling, both fundamental to plant growth. Faster leaf litter decomposition and soil mixing by arthropods will speed the flow and amount of plant nutrients into the soil. However, if increased decomposition releases carbon faster than it can be captured by plant growth, it could contribute to the rate of climate change. Faster decomposition could also shrink the layer of leaf litter that protects arthropods and plant roots from the bitter cold of the arctic winter.

In Svalbard, Coulson *et al.* (2000) noted that soil microarthropod communities graze on cyanobacteria, which transfer atmospheric nitrogen to the soil, preparing it for plant succession. These soils also tend to be very patchy and many soil arthropods are limited to patches with low surface ice thickness. If microarthropod grazers experience a population explosion from warming temperatures, they may deplete important soil nutrients like nitrogen in some areas, rendering them less fertile for plant succession than others. As climate change acts on microarthropods, cyanobacteria, nutrients, and plants simultaneously, the arctic landscape may retain the patterns of these patches long after the composition of the ecosystem changes. The result could be a new landscape.

Plant-pollinator

The plants that pollinators depend on for food, and in some cases warmth, are also being affected by climate change. If changes in range put plants out of reach of their pollinators, they will face greater risks of extinction. Missed timing between plants and pollinators may also occur, if temperature changes cause flowering before the pollinators have emerged or matured. Pollinators are likely to suffer food shortages and plants may remain unfertilized, leading to extinctions of both. Ecosystem dynamics may change as relationships between species are broken and new ones established.

Pollinators indirectly affect other keystone species in the Arctic. Lemmings, for example – the main food of arctic foxes, weasels, snowy owls, jaegers and others – feed only on plants, some of which rely on insect pollination.

Plant-herbivore

Increased temperatures and soil fertility can increase plant productivity, but faster growing and larger plants can be less nutritious. They contain higher concentrations of water, nitrogen, allelochemicals – which can repel arthropods – and fibre. This may reduce the success of arthropod herbivores.

The geographic ranges of host-specific (specialist) arthropod herbivores are restricted to the areas where their food plants grow. Their response to climate change will be largely driven by the responses of their hosts: their ranges will contract or expand along with the ranges of their vital resources.

Predator-prey: Clues from the sub-Antarctic

Arthropods are a major source of food for birds that migrate to the Arctic in the summer to breed. As climate change alters arthropod phenology (life-cycle timing), migratory birds will have no way of predicting the new periods of peak prey availability. Earlier maturation or emergence of arthropods may favour birds that migrate earlier in the season. Those arriving later may discover that the food they depend on is less abundant or even

High Arctic *Diptera* (fly), photographed on Bylot Island, Nunavut. Photo: Christopher M. Buddle.

absent during the critical period when they are rearing their young. Even "early birds" may suffer if they depend on climate-affected prey in stopover areas en route to their arctic destination.

Many small mammals, including rodents, also depend on arthropods. While little has been written of the effects of climate change on arthropod-mammal relationships in the Arctic, we can find clues in the sub-Antarctic. There, climate change is causing a wild house mouse to expand its range, and Callaghan *et al.* (1992) have found that this mouse "prevents" the decomposition of at least 1000kg of plant litter per hectare because it eats soil invertebrates that normally do this work. Animals that prey on arthropods may therefore counteract the effects of increased soil arthropod populations (increased fertility, soil nutrient and carbon release). If an insectivorous mammal extended its range northward it could have a similar impact on the arctic ecosystem.

Predatory arthropods such as wasps and beetles have neutral or stabilizing impacts on the population dynamics of their arthropod prey. However, higher temperatures may boost a predator's ability to hunt. In Svalbard, a staphylinid beetle (*Atheta graminicola*) hunts only on warm, south-facing cliffs, despite the availability of prey on other cliffs. As the climate warms, the beetle may be able to colonize north-facing cliffs, and reach more of its prey population. These shifts in predator-prey dynamics could lead to population imbalances unless the prey is also able to adapt.

Parasites

Warmer summers may increase insect harassment and parasitism of caribou. For example, Hughes *et al.* (2009) have noted increased numbers of warble flies, a caribou parasite, in Nunavut. They found that the thickness of caribou back fat and the probability of pregnancy decreased as warble flies became more numerous. Insufficient fat means caribou may fail to breed in the fall or may die of starvation in winter. Furthermore, increased parasitism may be a contributing factor in recent northward shifts observed in caribou range – caribou may be moving northward to escape the insect pests.

Graduate student Anna Solecki using a sweep net in Iqaluit, Nunavut. Photo: Christopher M. Buddle.

RESEARCH NEEDS

Until the late 1990s, most research on arctic arthropods was descriptive, focusing primarily on identifying species and their distributions. This body of knowledge, although important, does not predict directly how arctic arthropods might respond to climate change. Despite many calls to fill the gaps in our understanding of the biology, life histories, and ecological influences of arctic arthropods, this work has only recently begun. Since the high cost and logistical challenges of arctic field research limit what can be achieved it is important that researchers focus on critical areas and organisms – those that will provide the most valuable and timely data.

Studies on the biology and life-history of arctic arthropods must be expanded. Very few of the hundreds of arctic species have been studied in detail. To make accurate predictions about the effects of climate change on arthropods, we need baseline studies that focus on understanding the natural history of species and communities. Although arthropods are remarkably adaptable, it is unknown whether they will be able to respond to a rapidly changing climate. If not, this may have significant consequences on key ecosystem services, from pollination to feeding highly valued wildlife.

We suggest that greater effort be made to foster collaborative research that includes experts from different disciplines, including, for example, entomologists, climatologists, and ecologists. This will allow us to gain a holistic perspective of the complex arctic environment and will improve our ability to predict, and therefore plan for, the environmental changes and faunal responses that will shape future arctic systems. A network of research facilities and long-term data acquisition and monitoring programs similar to the EXAMINE network, which monitors aphids across Europe, would be ideal.

Some progress towards such a pan-arctic network has been made recently, particularly during the Fourth International Polar Year. The ArcticWOLVES project (www.cen.ulaval.ca/arcticwolves/en_intro. htm), while focused on wildlife species, also studies important food web components including the links between arthropod phenology and insectivorous birds. The Northern Biodiversity Program (www.northernbiodiversity.com), which operates large-scale surveys across 12 sites in the North Boreal, Subarctic, and High Arctic, builds upon the Northern Insect Survey of 1947–63, whose extensive historical data from across the North may help us understand the effects of climate change on arctic arthropods.

We need research not only on how individual species respond to climate change, but also on how the species with which they interact respond – particularly those in host-specific relationships – as well as on the effects on ecosystem processes and services. Arthropods are one vital component in the food webs of arctic ecosystems, and should be studied together with plants, birds, mammals and other important organisms that are also being affected by climate change.

In summary, arctic arthropods are fascinating, ecologically important, and represent a large proportion of biodiversity in the North. They exhibit a range of life-history adaptations that make them particularly suited to living in harsh environmental conditions, and they form the basis of many arctic food-webs. They are likely to be significantly affected by climate change and it is important that we play close attention to what is happening to them.

Louise Leborgne (undergraduate student, wildlife biology), Crystal Ernst (PhD candidate, insect ecology) and Christopher M. Buddle (associate professor, insect ecology) are at the Department of Natural Resource Sciences, McGill University.

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FROM STUDENT TO RESEARCHER: LESSONS FROM AN NSERC NORTHERN RESEARCH INTERNSHIP

Jana Tondu

Although I am a new northern researcher, I am not a newcomer to the North, and I know how important it is for researchers to develop strong relationships with northern communities. Long stays in the North are essential to building trust, developing collaborative partnerships, and creating opportunities for knowledge exchange.

Paul Nadasdy illustrates in his book *Hunters and Bureaucrats,* how difficulties and struggles arise when trust is not established between researchers and local First Nation members, ultimately leading to failed knowledge integration and lost confidence. The success of the new northern research paradigm, which emphasizes collaborative research and reflects northern priorities, will depend on the level of trust established between researchers and local communities. Wolfe *et al.* (2011) elaborates on how a northern, multi-disciplinary research project funded by the Government of Canada International Polar Year (IPY) program – "Environmental Change and Traditional Use of the Old Crow Flats in Northern Canada" – has worked with the community of Old Crow, Yukon to establish trust and incorporate northern priorities into research design.

Time and cost, however, make it difficult to spend long periods in the North. The Natural Sciences and Engineering Research Council of Canada (NSERC) created the Northern Research Internship (NRINT) program to enable new northern researchers to stay for several months in northern communities. Several years ago Ann Balasubramaniam, a member of my lab group, held an NRINT award in Old Crow. Her experience, which she described in a *Meridian* article (Balasubramaniam, 2009) strengthened community –researcher relationships and has had long-lasting positive effects on both her academic progress and relationships with the community. Inspired by her example, I applied to the program and subsequently held a NRINT award in Whitehorse from May to September 2010. The award involved collaboration with Parks Canada, partnership with Yukon College and knowledge exchange with the community of Old Crow.

COLLABORATION WITH PARKS CANADA

My project, part of the IPY project mentioned above, involves implementing a northern hydroecological monitoring program in the Old Crow Flats (part of Vuntut National Park) to be sustained by Parks Canada and the Vuntut Gwitchin Government (VGG) in the future. Like most northern communities, the Vuntut Gwitchin First Nation is concerned about the ecological integrity of their traditional territory and the impacts climate change will have on their health and future. Central to these concerns are recent observations of declining lake levels and the rate of change that is occurring in the Old Crow Flats. For Parks Canada, notable gaps in their current monitoring programs are unable to effectively determine the state of the aquatic ecosystem and assess how it is changing over time. The monitoring program uses a three-pronged approach to address these questions by analyzing: (1) water isotopes to measure lake water balance; (2) algae to monitor limnological conditions; and (3) paleolimnology to determine how hydrological and ecological conditions have changed over time.

Staff from Parks Canada (the primary stakeholder) and VGG had expressed the need for a monitoring program that would meet the specific needs of both organizations, while overcoming the logistical challenges of northern monitoring. In remote areas like the Old Crow Flats, site access is limited to helicopter and boat (provided the water levels are high enough). The majority of the approximately 2700 small thermokarst lakes are only accessible by helicopter, which is costly. Having researchers travel from southern institutions to the North is also time-consuming and expensive, especially in the context of an annual monitoring program; however, partnerships between universities, northern agencies, and communities can overcome these challenges. Empowering northern agencies and communities to implement their own simple and scientifically informative monitoring programs further enables the capacity for local stewardship over the land.

My first field season – two short trips to Old Crow in June and August, 2010 to collect samples – hardly offered enough time to collaborate effectively with my local partners, primarily Parks Canada staff. Implementing a successful long-term monitoring program would take more time and commitment. I hoped to leave a true "legacy of knowledge" – to help northerners gain a better understanding of ecosystem change and to develop an effective ecosystem stewardship strategy of that could provide information needed for wise policy decisions. At the same time, I hoped to expand my network of northern colleagues, renew past relationships and learn more about the community of Old Crow. To achieve these goals, I decided to spend additional time in the North working with the Vuntut National Park Monitoring Ecologist, Ian McDonald, towards implementing the monitoring program.

Figure 1
Graduate students from the University of Waterloo (Jana Tondu, left, and Ann Balasubramaniam) and Parks Canada staff (David Frost) at Mary Netro Lake preparing to deploy algal samplers. The mosquitoes were also out for the day, but we were prepared for them – although David did not seem to be bothered. Photo: Leila Sumi, Parks Canada.

Ian is based out of the main office in Whitehorse and despite our very different schedules for the field season in Old Crow – they were in fact polar opposites – we were able connect and plan strategies for implementing the monitoring program, especially in terms of being prepared for the potential challenge of fluctuating budgets. Over the summer I developed a framework for an analysis that outlined the major stakeholders, goals, logistical alternatives to sampling, and associated costs and benefits of the hydro-ecological monitoring program. This framework will help ensure that managers have the knowledge they need to make informed decisions should changing government priorities affect their funding.

Our meetings with Parks Canada and the Vuntut Gwichin Government also revealed a strong need to transfer knowledge from the researchers to the staff who will be doing the sampling. We invited Parks staff out into the field to gain firsthand experience with the monitoring program. We used a Parks boat to travel to Mary Netro Lake and invited staff on our June and August helicopter trips to the Old Crow Flats, to learn sampling methods (Figure 1). These trips were very successful in transferring knowledge to current Parks Canada personnel, but a high staff turnover rate means knowledge is often lost when employees leave. A more tangible source of information was required to help new staff learn proper field sampling methods and maintain continuity. I developed a field methods manual in collaboration with the monitoring ecologist who made sure that it met the needs of its intended audience. The manual, *Northern hydroecological monitoring in the Old Crow Flats (Vuntut National Park): A guide to field methods,* has been published in the Parks Canada Information Centre on Ecosystems (ICE) internal database. Working with the monitoring ecologist on this manual greatly improved my ability to create a document that conveyed scientific field methods in a language that was easy to understand. The end result was a document that will be useful to Parks staff, not only in Vuntut National Park, but also in other northern parks.

DEVELOPING A PARTNERSHIP WITH YUKON COLLEGE

One of the requirements of the NRINT program is a northern partner to provide in-kind support. The Northern Research Institute (NRI), a division of Yukon College, agreed to act as my northern partner, facilitating and supporting the internship. As a Yukon College alumni, establishing a link between a northern research project and the NRI – a mutually beneficial partnership that will likely continue – was personally enriching. When results from the research project are available I will present a guest lecture to classes in the college's School of Science, Trades and Technology, and give a public presentation to the Yukon Science Institute.

Staying and working at Yukon College during the internship gave me a broader perspective on research in the North. A professor and two graduate students from my home institution – Wilfrid Laurier University – who are conducting research in the Kluane area invited me on a road trip along the Alaska Highway to learn about their research, as well as other projects. I was fortunate to visit the community-based archeology camp (Little John) to learn about ethnographic and archeological research in the Upper Tanana watershed. Here, at the Alaska–Yukon border just outside the village of Beaver Creek, Yukon College anthropologist Norm Easton has worked and collaborated effectively with the White River First Nation to document the culture and history of the area. It was clear to me that the strong relationship between researchers and the local community has not developed overnight – rather, it has grown over 20 years of persistent research, consultation with the community and participation by researchers in local events.

KNOWLEDGE EXCHANGE WITH THE COMMUNITY OF OLD CROW

Of all of the enriching experiences I had during my internship, the most memorable was working with the science camp for children in Old Crow. The camp aims to create linkages between traditional ways of knowing and science using land-based and hands-on learning. Students are engaged in relevant ways of

Figure 2
Collecting freshwater invertebrates from a pond near camp. Students learned how to use a dip-net to collect samples, and used tweezers to capture specimens to take back to the camp lab and analyze. Photo: Jana Tondu.

learning so that they can become future leaders in the community and stewards of the land. For the past four years, the VGG has funded and coordinated this camp for Old Crow children between the ages of 9–14. The camp is held outside the village of Old Crow to provide the students with the opportunity to learn that science is not as hard as they think, and that it can be applied to things they already know.

Since I was staying in Whitehorse, the science camp coordinator asked if I would be interested helping coordinate the camp – and handle the "science" portion. I eagerly agreed, however I had never participated in a science camp before and I had no idea what to do. Fortunately, Yukon College's Science Quest camp was going on and Google helped me find the US Environmental Protection Agency's Water Source Books that gave me some great ideas. I developed a science workshop as well as small activities – such as making lava lamps and solar ovens, and engineering structures with marshmallows and spaghetti – that would entertain and educate. I prepared for all these activities in Whitehorse, as most of what I needed was not available in Old Crow, and somehow managed to get it all on the plane (thanks Air North). I also involved Yukon College as a sponsor: the School of Sciences, Trades and Technology lent field equipment, and the Technology Innovation Centre, the College Bookstore, College Relations, and International Development donated prizes.

This year, the science camp was held on the Porcupine River at the "School Cabin," otherwise known as Caribou Lookout. The boys and girls are divided into separate groups and stay at the camp for four days and three nights. The children all camp together in the cabin with a camp counsellor (an older youth who helps out with the camp) and the camp coordinators, camp cook and camp steward curl up in sleeping bags in tents. The boys and girls participate in the same science activities but learn different forms of traditional knowledge during the camp. For example, the girls learned about berries and how to cut fish and the boys learned how to collect tent poles on the river and set up the canvas tents.

The integration of traditional knowledge from local community members with the scientific activities that I provided was a true sign of knowledge sharing. For example, one day with the girls we travelled up the Porcupine River to Mary-Jane and George Moses' camp to learn how to cut fish, cook bannock, learn about medicinal plants, and pick berries (salmon [cloud] berries are now, by far, my favorite berry). The next day we talked about alternate forms of energy, which the children already knew a lot about. We made solar ovens out of empty pizza boxes and made pita pizzas to place in the box and let the sun do the rest. Most were skeptical of the idea and would have rather had an actual pizza, but surprisingly enough, it was a success and the cheese melted.

While we waited for the pizzas to cook, we began a bio-monitoring workshop that I designed, and discussed how benthic invertebrates and other organisms, such as the algae I collect for my M.Sc. research, can be used to gauge the health of aquatic ecosystems. Originally, we were going to assess the health of the Porcupine River by sampling the different types of macro-invertebrates; however, unusually high water levels from heavy precipitation flooded the shore and made sampling impossible. With a bit of luck and some contingency planning, we found a pond just behind the camp that we could sample to identify what types of benthic invertebrates inhabit the Old Crow area.

The students had a great time learning how to use a dip-net to collect specimens for analysis (Figure 2). The boys were very excit-

Figure 3
Identifying aquatic invertebrates at the camp lab. We used plastic egg cartons and ice cube trays as insect holders and hand-held magnifying glasses to observe the structure of individual specimens. The students found 6 different families: dragon fly nymphs (*Aeshnidae*, *Libellulidae*?), predaceous water beetle larvae and adults (*Dytiscidae*), phantom midges (*Chaoboridae*), water striders, and damselfly larvae. Photo: Jana Tondu.

Figure 4
Left to right: Researchers Jana Tondu and Ann Balasubramaniam, with Parks Canada employee Leila Sumi, at a stop to collect climate data from a weather station during June field work in the Old Crow Flats. Photo: Jana Tondu.

Figure 5
Discussing proper sampling methods and how to assemble algal samplers at Mary Netro Lake. Left to right: David Frost (Parks Canada,), researchers Jana Tondu and Ann Balasubramaniam, Jeffrey Peter (Parks Canada). Photo: Leila Sumi, Parks Canada.

ed to witness predator-prey relationships and loudly proclaimed how "cool" it was as they watched a very large predaceous diving beetle larva chase and capture dragon fly nymphs. Once we collected our samples, we headed back to the camp lab where we learned how to identify the invertebrates we found (Figure 3). This activity went over really well with the students and they were very surprised to learn that the huge predaceous diving beetle larvae they found would grow up to be very small and different looking adults. I had vials and preservative so that each student could keep one invertebrate that they found and I also gave a sample of each invertebrate to the community science teacher to be displayed at the school.

Throughout Science Camp, people from Old Crow would visit and share some of their knowledge with the students or just stop by for dinner and tea. I fondly remember the interaction between one of the youngest children at camp and a camp visitor. The boy was struggling to make a bow, like the older boys, until he was shown how to find a proper stick and how to carve it. Being at the camp was a great way to get to know different people from the community and set the stage for knowledge sharing. In particular, I learned a lot about the history of the Old Crow area. I even found some archeological artifacts on the bluff near camp and a community member discovered an arrow head. One of the most instrumental things I learned at science camp was the community's perspective on researchers and how much they value the knowledge they can transfer to the community. It surprised me that the community viewed me as a "researcher" – a term I generally reserve for my supervisor.

As a new graduate student, I had labelled myself as a "student" and had not given much thought to the idea that, really, I am a researcher. This concept crept up on me when a few members from the Renewable Resource Council (RRC) came to the camp. One member explained how the Old Crow Flats are important to the Vuntut Gwitchin, the "People of the Lakes". He commented on how researchers are truly welcome on their land, and in the community, to help them understand how the Flats are changing. He stressed to the young students how important education is so that they could learn about the land and one day be a researcher – like me. Prior to this talk I almost felt out of place, but afterwards I realized that I had been invited to Old Crow because I had knowledge that I could pass on to the students. I came to science camp feeling like a student, and left feeling like a researcher.

Staying for an extended period in the North and spending time with local people outside of my own research demonstrated to the community that I was dedicated and committed to the project. In turn, community members have been very welcoming and receptive to my project. When I went to chat with one of the RRC members who came out to the science camp because his cabin is near one of the lakes that I sampled, he informed me that the lake – which I knew as OCF 49 – was actually called Marten Lake, and he generously offered to store his canoe nearby over the winter so that I could use it next summer.

I strongly believe that extended stays in the North are vital for researchers. In the North, interpersonal connections are a fundamentally important part of the cultural fabric – and can only be developed in person. Spending time in a community and collaborating with northerners who have a vested interest in northern research will leave an invaluable legacy for future northern researchers and citizens. The NRINT program is one of the only resources available to students to help support extended stays in the North – but it is scheduled to end in March 2011. This will only make it more challenging to accomplish collaborative research that truly reflects northern priorities. The need to train highly qualified northern researchers (students) has been clearly demonstrated by IPY – one of the main IPY goals was to train a new generation of polar researchers – and Canada's Northern Strategy, released in 2009, emphasizes leadership in science and technology. We are an Arctic nation and resources such as the NRINT program are needed to ensure world-class northern research continues.

Acknowledgments
On every level, I am grateful to NSERC for providing funding for the Northern Research Internship and thankful to Clint Sawicki of the Northern Research Institute for providing in-kind support. I would also like to thank Ian McDonald of Parks Canada for supporting the internship and setting time aside to meet with me. I would like to give a big thanks to Jessica Peters for inviting me to participate in Science Camp and letting me stay at her house. Thank you to the VGG for supporting my involvement with Science Camp and purchasing my July flight to Old Crow. A big thank you to Yukon College for welcoming me back, lending me equipment and donating prizes. An extended thanks goes to Scott Slocombe for taking me to Beaver Creek and the Arctic Research Institute. Lastly, but not least, thank you to my supervisors, Brent Wolfe and Roland Hall for encouraging me to do a northern research internship.

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THE BRANDON UNIVERSITY NORTHERN TEACHER EDUCATION PROGRAM: TWO WAY TEACHING AND LEARNING

Lynn Whidden

After several decades of travel and teaching in Canada's North it is intriguing to reflect upon the Brandon University Northern Teacher Education Program (BUNTEP). In my view, its very failure may be seen as its success.

The main feature of BUNTEP, many of whose students are Native, is that it is offered in home communities. We offer undergraduate degrees in arts and education to students from northern Manitoba who often do not have the academic prerequisites for courses. But with extra support, they achieve exit skills supposedly commensurate with on campus graduates.

And yes, upon completion students do have considerable knowledge and skill, yet critics of the program are correct in pointing out deficiencies, particularly in the area of communication skills. My response is that many of these so-called deficiencies are indeed cultural differences and that, as long as we offer courses in the communities, the differences will remain. To which some say that northern Native culture is mostly a culture of poverty shaped by a century and a half of colonialism and that education standards must be universal. Probably the truth of modern Native life is somewhere in between: the strands of Native and non-Native life are by now woven together and any effective education program has to take into account this reality. To fully understand, here are a few of my observations of a group of Cree, the *Iiyiyuu* of northern Quebec.

For generations the Cree have lived in the subarctic in family groupings suitable for successful hunting, mostly speaking the Algonquian language. In the 1970s a group living in Fort George was moved to Chisasibi, Quebec because of the hydroelectric project on the LaGrande River. But I noticed that even when moved into modern communities local conversations were primarily about the animals and the hunt. Still, as one would expect, people were quite familiar with southerners through the presence of fur traders, missionaries, and government employees (Whidden, 2007).

Although considerable hunting continues for food, trapping no longer provides a viable living, and by the 1980s the old lifestyle was moribund. Highways, many all season, now crisscross the northern parts of Canada's provinces; most communities have daily air service, and modern communications media connect every community to the outside world. There is great desire for southern goods and services, and frequent commuting to the south. I've driven with colleagues to Winnipeg, about 600 miles south on tenuous roads.

It is a common practice to leave after school on Friday and return late Sunday in time for work on Monday. Some youngsters are sent off reserve for high school education and many others attend university in Winnipeg and other urban centres. Frequently, southern-trained people remain in the south.

Meanwhile, education on reserves falls far short of national standards (Office of the Auditor General of Canada, 2000). Yet, even after the enormous disappointment of the residential schools, people still have faith that their local schools and teachers will work for them. They have not given up on education both at school and university levels. In the landmark 1971 declaration *Wahbung – Our Tomorrows* by the Manitoba Indian Brotherhood it is stated that, "We, the Indian people of Manitoba believe in education" (p. 116), and this support is further shown in the fact that bands allocate much of their budgets to students attending university, including the access programs at Brandon University. The result is that a preponderance of elementary teachers (up to 60% in some communities) in Manitoba's north have graduated from a Brandon University access program.

Why has tiny Brandon University (campus population approximately 3000) been so successful in training Native teachers for northern Manitoba schools? There is no doubt that Brandon University professors, like professors everywhere, were imbued with the spirit of social activism that began in the 1960s. They did get an early start: by the 1970s they were running a program called IMPACTE, the forerunner to BUNTEP, that provided degree programs to Native peoples in remote, almost inaccessible areas. But I suspect that the main answer lies in small size: Brandon has been able to personalize their offerings and to respond flexibly to the extraordinary needs and requests from the community students.

In ways that are subtle but significant for their education, I observe that northern students retain an essentially Native personality that is different from non-Native students: they are quiet in entering and exiting the classroom (which happens more frequently!); in contrast to non-Native society where time rules, in Native classes time is manipulated for the benefit of all; they quietly watch and listen, there is little overt reaction; voices are soft – in two decades I've not heard one raucous voice; there is an ethos of doing just enough to succeed, economy of effort in all pursuits; although not total, there is great tolerance for human foibles and considerable support, emotional and material, for others in substantial need.

On the other hand, in this new millennium, Native students are as trendy if not more so, than non-Native students, although there remains a predilection for subdued colours. They all have cell phones and laptops. Indeed I believe them to be some of the hippest students on earth: they are not rooted in western history; most homes have few books to be seen and these few are from the small selection occasionally carried by the Northern Store. But every home has a television and increasingly, internet service. Indeed, the literacy gap between Native and non-Native students (whose skill levels are falling) is lessening as young people everywhere seek to explore their environment by means of technology rather than with book reading. And finally, almost any situation can be given a humorous twist. Perhaps one could sum the classroom up as a non-hierarchal gathering that surely is in keeping with Colin Scott's characterization of Cree society, men-

tioned above, as less hierarchical and lacking the central control of non-Native society (Scott, 1996).

I suggest that the physical environment remains the impelling force of the northern personality. In fact, without their land, they lose the qualities, just described, that distinguish them as Native. While younger generations may not be hunting in great numbers, they are connected to the land by their ongoing knowledge of, and belief in, the old ways. Much of this is an assumed mental knowledge, seldom spoken, yet the old stories and practices continue, as does the language. While there is great interest in western science and the observable benefits of technology in the communities, there remains hesitancy to engage fully if they contradict the old knowledge of the local environment. Perhaps such truths are required for survival in that environment? In any case, it is apparent to me that my rants about the value of science are met with quiet skepticsm, a valuable reaction indeed.

And BUNTEP, through education offered in the communities, sustains this implicit heritage and yet rarely have I heard this fact articulated. This contrasts with the Brandon University Hutterite program (BUHEP) where the desire to maintain the life led on the colonies is forcefully asserted and, to some extent, enforced in the program. Perhaps much of Native worldview, as discussed above, is harder to concretize. And there is no doubt that at every turn non-Natives have tried, often forcibly, to integrate Natives into mainstream western society. Some attempts have been successful in removing people from their Native heritage. This is shown by an increasing urban middle class and by a growing rate of incarceration and use of social services by aboriginals.

Native leaders and politicians clearly recognize the differences, yet many choose to argue for their survival and well being as a people by using mainstream tactics – displays of power and aggression. They support grandiose external displays like powwows, impressive casinos and flamboyant dress which to northern Natives are not only irrelevant but also fodder for humorous remarks. Although I recognize the need for political action, in my opinion there's a more effective way to remain Native, as exemplified by BUNTEP: build your communities and educate your children there. Whenever Aboriginal students stay in their home environment to be educated, their worldview lives on in the above-mentioned, often intangible qualities passed down through the generations.

But educators must ask whether the old Native qualities, so different from those of modern societies, are worth preserving. More importantly, do they offer young people any chance for a good life in the face of a long history of outside oppression? I suggest that they are worth holding on to. Non-Native dominance is attenuating as the environmental crisis increases because westerners are seriously considering other ways of living on the planet. The fact that this northern worldview continues despite the pain caused from culture clash is evidence of its strength and of its adaptive advantage over the long term. Outside of the modern built environment northern aboriginal peoples lived a life acutely aware of, and delicately balanced within, the local natural environment of which they saw themselves as an endemic part. Read the creation myths! Their ongoing attitudes of humbleness, resilience rather than dominance, change versus stasis, and connectedness to family and locale may make them the peoples of the future.

Their roots in the old ways of thought are evident the moment you approach a reserve. To this day, and despite at least one new large building which is the local school, human architecture does not dominate the natural environment. There are no solid old buildings, iron fences, or monuments to past heroes. There is none of the dreary sameness caused by rigid building codes and no rectangles of green grass are to be seen. Buildings seem like they could merge with the forest, rivers, and rocks at any time. And clearly, few people see their homes as a lifelong dwelling, in keeping with the former necessity of building a new home each year with forest materials when following the animals. In some places horses, and more recently hogs, roam the community, which people view as whimsical. Dogs are everywhere and it seems to me that they are viewed as failed wild animals (wild animals are held in high regard) whose dependence upon humans is seen as contemptible. Even official buildings soon bear the stamp of the community. The weekend following 9/11 we waited on the tarmac in a northern community watching ravens rip open the bags of potato chips awaiting delivery. Icons of the local Christian saint hung over the ticket counter where we checked in, and at all times we were surrounded by the joking and laughter of local people.

How has BUNTEP, hundreds of miles south, fostered the local worldview? In my opinion, much of it has been inadvertent. And when recognized, it is seldom discussed, for it is not a matter of pride that despite our efforts, many of our graduates, although knowledgeable people, have never entirely bought into southern protocols of teaching.

BUNTEP employees in the communities are nearly all non-Native (in my view a telling statement about the reluctance of aboriginals to submerge themselves in the non-Native world). Yet, overall, successful BUNTEP professors tend, themselves, to be outside of the mainstream, often from minority groups, or women who did not find themselves fitting in well on the campuses of the 70s and 80s. At the very least, they are more accepting of differences and many push further to understand and accommodate the people they are teaching.

Most search the community for local expertise and content to incorporate into courses – local landforms for geology, local legal hearings and political meetings for Native Studies, oral narratives for English class, and so on. Just as content changes, so does the vocabulary used for teaching. For example, Professor David Westfall compiled a volume of non-Native idioms that are incomprehensible to northerners (Westfall, 1995). As mentioned earlier, professors are soon trained to begin when everyone gets there, not at an arbitrary time. They learn to schedule classes around extreme weather conditions and fuel shortages that prevent transportation, but most frequently around wakes and funerals, which the entire community must attend to support each other. While the vagaries of classroom schedules are easy to accept, the physical discomforts such as no indoor plumbing (or more often, failed indoor plumbing) are harder. Yet most are discussed with a great deal of humour, and even realization that valuable insight is gained into the lives of local people who endure similar conditions.

Moreover, centre coordinators are employed to help with facilities, to help students study and professors teach. The contrast between the centres run by local coordinators and outside coordinators is immediate. Invariably, local coordinators show little concern with appearance of the centre, and the local radio station frequently provides a constant aural background where the time of day is known by whose music is being played – elders take the microphone during the morning slot and young people show up later. Local coordinators create a casual, informal setting where there is quiet acceptance of all sorts of problems followed by a measured, thoughtful response (or not) to their resolution. In contrast, outside people take great care for neatness, for organization of books and reference materials, and for maps and educational messages on the walls. They tend to take a more critical stance and then immediate and forthright action to resolve problems. Despite the informality of the local coordinators, the BUNTEP building usually stands in solitude and I have noted that people on the reserve do not visit the centres.

I suggest also that Brandon University's access programs have flourished for four decades because of distance from campus supervision and because its rules are not subject to the intractability that large numbers of people require. Local exigencies require adjustments at every level if our students are to succeed. BUNTEP office staff are called upon regularly to mediate with on-campus office staff issues regarding student registration, late grades, missing grades (and students!). When bills are not paid, or more likely, not paid on time, the system shudders. In the early days when BUNTEP personnel were eager to show results to the communities, new courses were sometimes offered before university senate approval and occasionally students completed courses before they were registered (Nicol, 2006).

While the stated goal of BUNTEP is to provide a community-oriented educational perspective no one could have foreseen the extent to which the Native presence changes both the content and structuring of university programs despite the efforts to run an "on time, bottom line" system. In 2007 I wrote, "Each class of Native graduates changes the system and the approach of their teachers" (Whidden, 2007). This brings to mind Robert Pirsig's observation in his book *Lila* that it is the aboriginal population that has made North America quite different from Europe:

> *The slips went on and on detailing European and Indian cultural differences and their effects, and as the slips had grown in number a secondary, corollary thesis had emerged: that this process of diffusion and assimilation of Indian values is not over. It's still with us, and accounts for much of the restlessness and dissatisfaction found in America today. Within each American these conflicting sets of values still clash.*

Although the quote is now dated, my observations indicate that the differences remain and that for Natives seeking education in non-Native institutions and for the educators in those institutions, the dilemma of satisfying both populations will be ever present. But it is also evident that flexible programs such as BUNTEP are a workable model: students graduate and the school gymnasiums are packed with proud relatives to celebrate their success and with community leaders who are delighted to have local teachers.

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BOOK REVIEW

Bernard J. Brister

The Canadian Forces and Arctic Sovereignty: Debating Roles, Interests, and Sovereignty 1968–1974, Whitney Lackenbauer and Peter Kikkert, eds. Wilfrid Laurier University Press, 2010. 398 pp., $34.95, paper. ISBN: 9781926804002.

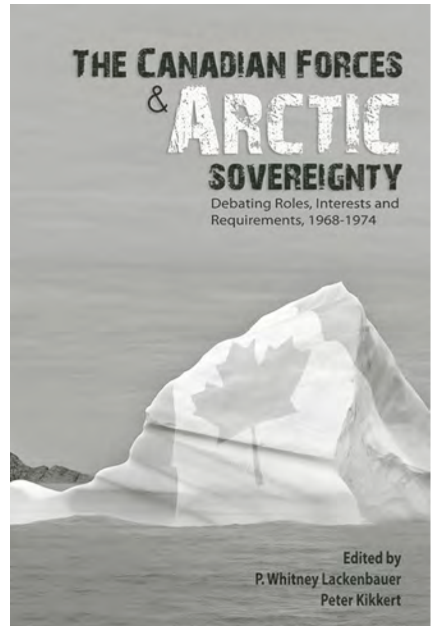
This review has gone through a number of phases including both enthusiasm and disappointment since I agreed to do it in the fall of 2010. Initial enthusiasm for the review of a new work on a topic of central professional and personal interest gave way to a sense of disappointment when the book arrived in the mail and I discovered it to consist primarily of research material lifted from the archives. Upon consideration however, a renewed sense of interest developed for an assessment of the intellectual and academic contribution to the body of knowledge that such a work could make. I am compelled to say that my initial sense of disappointment and misgiving regarding this contribution is without merit and that the work represents an interesting and valued addition to the scholarship on this topic.

The book is rich with information and guidance for both the Arctic neophyte and the experienced researcher. The full value of the work cannot be derived without careful consideration of each of its main components. As such the review and analysis of the book will cover each of the main sections of the book to include the introduction and research pieces themselves, the afterword, further reading section, and the index.

The main focus of the book, the introduction and the documents themselves, provides both an excellent historical context as well as key linkages and comparisons with contemporary concerns that reflect, as mentioned by Dr. Huebert in his afterword, exactly how little things have changed over the years. The introduction raises and discusses in a rough chronological and issue-based order, the key aspects of the military role in the Arctic that correspond to the documents themselves in the chapters that follow. The introduction also contributes to the treasure trove of research information and references by way of the numerous footnotes that support the commentary and discussion of the era.

The introduction begins with an overview of the history of Canadian sovereignty concerns. These included the lack of those concerns in the immediate post-war era that subsequently evolved into serious ones as the Cold War era developed and nuclear submarine capabilities of the major powers established the Arctic waters as areas of strategic concern. Debates on exactly how sovereignty should be exercised led to discussions of military contributions to that objective. Inevitably came discussions of exactly what utility the military would have in this situation, as a direct confrontation with any major power was not seen as a viable option by any Canadian government.

The book documents well the evolution of American interests and rhetoric regarding Canadian claims and their influence on the overall Canada–United States security relationship, and links this to the geopolitical and strategic security concerns of the two countries. Also covered in this section is the genesis of the current Canadian concerns regarding environmental pollution, exploitation of strategic resources, and the immense economic potential of the region as a transit route for global trade. Of specific interest with respect to the evolution of military thought on Arctic sovereignty is the parallel but not necessarily congruent evolution of Canadian diplomatic efforts and strategies. Over the timeframe under study and in the subsequent evolution of Canadian policy, these ranged from quiet negotiation to higher-profile public statements and commitment of resources, and changed priorities in government spending. This higher profile Canadian response is



seen primarily as a response to the development of a more aggressive profile in American actions and policies as their interests in the Arctic grew from negligible to substantial, encompassing strategic security, mobility, and resource ownership.

When this higher-profile response did not achieve Canadian objectives, there was a shift, under Prime Minister Trudeau, to an environmental stance – protecting the Arctic as the environmental guardian of the region on behalf of the world. This evolved into a search for functional sovereignty: control over the use of the waters as opposed to a declaration of outright ownership. This approach is echoed today in Canada's application under the United Nations Convention on the Law of the Sea (UNCLOS) due by 2013, to determine the area of its extended continental shelf – and appears to be an enduring strategy with good legs.

Even the shift in strategy from a pure sovereignty approach to one of global environmental guardian resulted in a continuation of the unresolved national debate on the role for the Canadian military. This was especially problematic given that, at the time, the biggest challenger appeared to be the United States whose regional environmental interests were similar to Canada's. Into this mix the editors have inserted a challenge to the whole concept of using military force to achieve Canadian objectives by Eric B. Wanger, who contends that the use of the military may even hurt the Canadian sovereigntist cause.

The subtext of the whole discussion highlights the overall message the editors are attempting to convey – that the Canadian strategy and its military component, whatever that may be, should be the subject of a carefully thought out process. The combination of the introduction narrative and the supporting documentation that follows certainly meets the stated objective of providing a partial but revealing source of information on the issues surrounding the military role in Canadian Arctic sovereignty in this critical period.

My first reaction upon seeing that an afterword by Dr. Rob Huebert had been inserted was that this was an innovative way of getting a pre-review review done by one of the leading authorities in the field – and indeed it was. Having concluded thus, I resolved not to read his thoughts, comments, and recommendations until after I made my own review and assessment. I am happy to report that Dr. Huebert's thoughts are different enough from my own that we both bring emphasis to the strengths of the work without being repetitive; and they were similar enough that I did not feel compelled to reconsider my own thoughts and comments. I am not sure why his recommendations were not included as a foreword, but their presence in the book no doubt serves the intended purpose of recommending the work to the reader.

The section on further reading is both an interesting and valuable contribution to the overall utility of the work. The editors have provided undergraduates and other newcomers to the topic a basic and valuable summary of relevant publications. These works furnish an excellent starting point for serious students of the Canadian Arctic who wish to include the issue of Arctic sovereignty in their research programs.

The index to this work is a critical component of its overall utility as a research resource for readers at every level of interest and expertise. While a number of readers will peruse the entire book for a general overview of the topic and the era, these same people and a large group of others will go to the index to locate references that pertain to their own specific research interest, question of the day, or project. As such the detail and completeness of the index was a central concern in my overall assessment of the work.

From reading several of the references and reviewing their coverage in the index it was clear that the editors have done a good job of referencing key words in the documents. The value and utility of the work could have been improved, however, had they chosen to go beyond the rigid norms of an index and inserted references to concepts, ideas, or policies mentioned or discussed in the pieces. Expanding the index beyond its somewhat traditional boundaries would have added worth to an already valuable component of the work.

Taken as a whole, Lackenbauer and Kikkert's book represents an important contribution to the evolving body of knowledge on the Canadian Arctic in general and the military aspects of that issue in particular. The introduction provides an effective summary of Canadian policy and activities in an era that is central to understanding what has transpired over the intervening 36 years. The selection of research documents gives newcomer and established academic alike an effective overview of what is available in the archives and a ready reference for some of the key issues and perspectives of the time.

The elements presented after the research material add to the value of the work. The afterword by Dr. Huebert provides additional perspective, and the "further reading" section and the index both contribute valuable research and references that connect the information in the book with its greater context and ensure that it will become a handy reference for ongoing use. *The Canadian Forces and Arctic Sovereignty* is a valuable work that makes a significant contribution to research on the Canadian Arctic.

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NEW BOOKS

La femme de la mer : Sedna dans le chamanisme et l'art inuits de l'Arctique de l'Est, by Frédéric Laugrand and Jarich Oosten. Les Éditions Liber. ISBN: 978-2-895-78-209.

"This work discusses [Inuit shamans] and the non-human world with which they dealt. Among the 'imaginary' beings that inhabit this world is Sedna, a central figure in many Inuit legends. The authors examine the variants of Sedna and different versions of the legends in which she appears. They also present images of contemporary works of Inuit art that give shape to the many transformations of Sedna and bear witness to the profound influence that the ancestral shamanic tradition still exerts. [translation]"

(Les Éditions Liber)

Making a Living: Food, Place, and Economy in an Inuit Community, by Nicole Gombay. Purich Publishing. ISBN: 978-1895-830-590.

". . . Quoting local residents and drawing upon academic literature, [the author] explores how some Inuit are experiencing the inclusion of the market into their economy of sharing. While the subject of the study is the Inuit community of Puvirnituq, the issues the author addresses are equally applicable to many Indigenous communities as they wrestle with how to incorporate the workings of a monetized economy into their own notions of how to operate as a society. In the process, they are forging new ways of making a living even as they endeavour to maintain longstanding practices." (Purich Publishing)

Acts of Occupation, Canada and Arctic Sovereignty, 1918–25, by Janice Cavell and Jeff Noakes. University of British Columbia Press. ISBN: 9780774818674.

"*Acts of Occupation* pieces together the engrossing story of how the self-serving ambition of explorer Vilhjalmur Stefansson ultimately led Canada to craft and defend a decisive policy on its claims to the Arctic. Drawing on a wealth of previously untapped archival sources, including the private papers of explorers Shackleton, Rasmussen, and Stefansson, historians Janice Cavell and Jeff Noakes show how unfounded paranoia about Danish designs on the north, fueled by Stefansson's deliberate dissembling of his own motives and by the fears of civil servant James Harkin, was the catalyst for Canada's active administrative occupation of the Arctic."

(UBC Press)

HORIZON

68th Annual Meeting of the Eastern Snow Conference
Montréal, Québec
14–16 June, 2011
www.easternsnow.org/annual_meeting.html

7th Conference of the International Arctic Social Sciences Association (ICASSVII) – Circumpolar Perspectives in Global Dialogue: Social Sciences beyond the IPY
Akureyri, Iceland
2–26 June 2011
iassa.org/icass-vii

POAC 2011: 21st International Conference on Port and Ocean Engineering under Arctic Conditions
Montréal, Québec
10–14 July 2011
poac11.com

13th Arctic Ungulates Conference: Challenges of Managing Northern Ungulates
Yellowknife, Northwest Territories
22–26 August 2011
www.auc2011.ca

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