Canadian National Implementation Plan for AMAP 2012/13

Four major Canadian programs will be conducting research relevant to AMAP in 2012/13. These include the Northern Contaminants Program (NCP), ArcticNet, the Beaufort Regional Environmental Assessment (BREA), and the Cumulative Impacts Monitoring Program (CIMP).

The bulk of Canada's National Implementation Plan for contaminants under AMAP comprises 34 projects being conducted under the NCP. These projects are organized under three categories: Human Health, Environmental Monitoring and Research, and Community Based Monitoring and Knowledge Integration. Tables 1a, 1b, 1c, list the titles of each project and Annex 1, contains full plain language summaries for each of these projects.

ArcticNet is a broad based network of researchers with the central objective to translate our growing understanding of the changing Arctic into impact assessments, national policies and adaptation strategies. All 36 ArcticNet phase II projects are listed in Table 2 and described in Annex 2.

In August 2010, the Government of Canada announced the Beaufort Regional Environmental Assessment (BREA), a $21.8 million dollar investment in support of increased research to inform regulatory decisions for potential offshore exploration and development activities in the Beaufort Sea. Research project conducted under BREA are listed below in Table 3, and summarized in Annex 3.

The Cumulative Impact Monitoring Program (CIMP) aims to achieve excellence in environmental management and stewardship through effective monitoring and assessment of cumulative impacts in the NWT. Cumulative impacts include changes to the biophysical, social, economic, and cultural environments caused by the combination of past, present and "reasonably foreseeable" future actions. CIMP provides high-level guidance and coordination support to monitoring and research activities; ensures that regulatory, scientific and traditional knowledge information related to cumulative impacts is effectively and efficiently collected through enhanced partnerships; and ensures that information related to cumulative impacts is effectively and efficiently managed, analyzed and reported. Projects conducted under CIMP are listed below in Table 4, and summarized in Annex 4.

As a signature deliverable of its Northern Strategy, the Government of Canada committed to establish a new world-class research Station in the High Arctic. The Canadian High Arctic Research Station (CHARS) will provide a hub for science and technology (S&T) in Canada's North that complements and anchors the network of existing facilities across the North. The Station, to be located in Cambridge Bay, Nunavut, is currently in the design phase and opening is planned for July 2017. CHARS will embody a new model for Arctic S&T: working year-round in the North for the North. The programming for the Station will be solutions-driven and will explore new ways of bringing knowledge to

action. The Strategic plan for the Station, the S&T Blueprint, will identify short-term priorities to deliver on the mandate. This will include research and monitoring activities that contribute to the four main S&T themes: resource development, exercising sovereignty, environmental stewardship and climate change, and strong and healthy communities. During the first programmatic cycle, efforts will be targeted to build the program as the facility is built and to develop the core capacity and expertise required for a successful launch.

Additional updates may be provided over the course of the year to reflect any new projects, particularly as they may relate to issues of interest to AMAP.

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Table 1a, Projects being carried out under the Northern Contaminants Program related to Human Health

Project Number	Project Title	Project Leader
H-01	Assessment of contaminant and dietary nutrient interactions in the Inuit Health Survey: Nunavut, Nunatsiavut and Inuvialuit.	Laurie H.M. Chan (U of Ottawa)
H-02	Nunavik Child Cohort Study (NCCS): follow-up with late adolescents	Gina Muckle (CHUL)
H-03	Nunavik Child Cohort Study (NCCS): add-on study for follow-up with teenage children – observed behaviours and stress	Pierich Plusquellec(U Montreal)
H-05	Monitoring spatial and temporal trends of environmental pollutants in maternal blood in Nunavik (year 2)	Éric Dewailly (CHUL)
H-06	POPs and cardio-vascular diseases in Inuit	Éric Dewailly (CHUL)
H-07	In vivo Study of the Effects of a Northern Contaminant Mixture (NCM) on the Development of Metabolic and Cardiovascular Diseases under Conditions Typifying the Diets and Lifestyles of Northerners-Year 3 Sub-Study II: Effects of NCM on the development of metabolic and cardiovascular diseases in JCR rats under two different dietary fat/sugar conditions	Xiaolei Jin (HC)
H-08	Country foods and cardiovascular health in Nunavik: studying the complex balance between selenium and environmental contaminants	Pierre Ayotte (CHUL)
H-10	Quantifying the Effect of Transient and Permanent Dietary Transitions in the North on Human Exposure to Persistent Organic Pollutants	Frank Wania (UofT)

Table 1b, Projects being carried out under the Northern Contaminants Program related to Environmental Trends Related to Human Health and International Controls

Project Number	Project Title	Project Leader
M-01	Northern Contaminants Air Monitoring: Organic Pollutant Measurements	Hayley Hung (EC)
M-02	Air Measurements of Mercury at Alert	Alexandra Steffen (EC)
M-04	Temporal Trends of Persistent Organic Pollutants and Metals in Ringed Seals from the Canadian Arctic	Derek Muir (EC)
M-05	Temporal and Spatial Trends of Organic and Metal Contaminants in Canadian Polar Bears: Part III	Robert Letcher (EC)
M-07	Temporal Trends of Heavy Metals and Halogenated Organic Compounds in Arctic Marine Mammals (Beluga, Narwhal and Walrus)	Gary Stern (DFO)
M-08	Temporal Trends of Contaminants in Arctic Seabird Eggs: Inter-year Variability	Birgit Braune (EC)
M-09	Temporal Trends of Spatial Variations in Persistent Organic Pollutants and Metals in Sea Run Char from the Canadian Arctic	Marlene Evans (EC)
M-10	Temporal Trends of Persistent Organic Pollutants and Mercury in Landlocked Char in the High Arctic	Derek Muir (EC)
M-11	Spatial and Long-term Trends in Persistent Organic Contaminants and Metals in Lake Trout and Burbot from the Northwest Territories	Marlene Evans (EC)

M-12	Temporal Trend Studies of Trace Metals and Halogenated Organic Contaminants (HOCs), Including New and Emerging Persistent Compounds in Mackenzie River Burbot, Fort Good Hope, NT	Gary Stern (DFO)
M-13	Long Term Trends of Halogenated Organic Contaminants and Metals in Lake Trout from Yukon Lakes	Gary Stern (DFO)
M-14	Caribou and Moose Contaminant Monitoring Program	Mary Gamberg (Gamberg consulting)
M-15	Validating experimental and modeled rate constants for reduction and oxidation of mercury species in Arctic snow:	Nelson O'Driscoll (Acadia University)
M-16	A latitudinal investigation of ecosystem sensitivity to methylmercury bioaccumulation in Arctic fresh waters	John Chetelat and Murry Richardson (EC and U of O)
M-20	Spatial and temporal variations of Hg isotope ratios in ice cores across the Canadian Arctic	Eva Kruemmel (ICC)
M-23	Investigation of Mercury Toxicity in Landlocked Char in High Arctic Lakes	Paul Drevnick (INRS)
M-25	Quantifying contaminant loadings, water quality and climate change impacts in the world´s largest lake north of 74°	Vince St. Louis (UofA) and Derek Muir (EC)
M-26	Monitoring of Radioactivity in Caribou and Beluga in response to the Fukushima accident	Trevor Stocki (HC)
M-27	Established and emerging contaminants in declining glaucous gull populations from the Canadian Arctic: Relationships with annual habitat-use, diet and biological effects	Johnathan Verreault (UQAM)
M-28	Temporal trends of mercury levels of fish in lakes with out-dated health advisories in the Northwest Territories, Canada	Kami Kandola (NWT HSS)
M-29	Anticipating the Effect of Climate Change on Contaminant Exposure in the Arctic	Frank Wania (UofT)
M-30	Community based seawater monitoring for legacy and current use organic contaminants in the Canadian, high Arctic	Derek Muir (EC)

Table 1c, Projects being carried out under the Northern Contaminants Program related to Community Based Monitoring and Knowledge Integration

Project Number	Project Title	Project Leader
CB-01	Mercury Levels in Food Fish Species in Lakes used by Dehcho Community Members with a focus on Choice and Risk Perception of eating Traditional Country Food	George Low, DehCho First Nations
CB-02	Evaluation of hydro-climatic drivers of contaminant transfer in aquatic food webs in the Husky Lakes Watershed (Inuvialuit Settlement Region, Northwest Territories)	Nikolaus Gantner, University of Victoria
CB-03	Paulatuk Beluga whales: Health and Knowledge	Diane Ruben, Paulatuk Hunters and Trappers
CB-04	Tlicho Aquatic Ecosystem Monitoring Project	Jodi Snortland, Tlicho First Nations

Table 2. Projects being carried out under ArcticNet

Project Title	Project Leader
Adaptation in a Changing Arctic: Ecosystem Services, Communities and Policy (*Community Adaptation*).	Smit, Barry (University of Guelph)
Effects of Climate Change on Contaminant Cycling in the Coastal and Marine Ecosystems	Stern, Gary; Macdonald, Robie and Wang, Feiyue (University of Manitoba/Fisheries and Ocean Canada)
High Arctic hydrological, Landscape and Ecosystem Responses to Climate Change (*Hydrology*)	Lamoureux, Scott and Lafrenière, Melissa (Queen's University)
Hydro-Ecological Responses of Arctic Tundra Lakes to Climate Change and Landscape Perturbation (*Tundra Lakes*)	Wrona, Fred (University of Victoria)
The Canadian Arctic Seabed: Navigation and Resource Mapping (Seabed Mapping)	Hughes Clarke, John (University of New Brunswick)
The Law and Politics of Canadian Jurisdiction on Arctic Ocean Seabed (*International Law*)	Byers, Michael (University of British Columbia)
Community-Driven Research on *H. pylori* Infection in the Inuvialuit Settlement Region (*H. pylori infection*)	Goodman, Karen (University of Alberta)
The Arctic cod (Boreogadus saida) ecosystem under the double pressure of climate change and industrialization (Arctic Cod)	Fortier, Louis (Université Laval)
Remote Sensing of Canada's New Arctic Frontier	Babin, Marcel (Université Laval)
Freshwater Resources of the Eastern Canadian Arctic *(Freshwater Resources)*	Vincent, Warwick (Université Laval)
Marine Biological Hotspots: Ecosystem Services and Susceptibility to Climate Change *(Marine Ecosystem Services)*	Tremblay, Jean-Éric (Université Laval); Gosselin, Michel (Université du Québec à Rimouski); Archambault, Philippe (Université du Québec à Rimouski)
Impacts of Vegetation Change in the Canadian Arctic: Local and Regional Assessments *(Arctic Vegetation)*.	Henry, Greg (University of British-Columbia)
Instability of Coastal Landscapes in Arctic Communities and Regions *(Coastal Landscape)*.	Bell, Trevor (Memorial University of Newfoundland); Forbes, Don (Memorial University

	of Newfoundland / Geological Survey of Canada)
The Emerging Arctic Security Environment *(Arctic Security)*	Huebert, Rob (University of Calgary)
Improving Access to University Education in the Canadian Arctic *(University Education)*	Rodon, Thierry (Université Laval)
Inuit Qaujimajatuqangit and the Transformation of High School Education in Nunavut *(High School Education)*	Walton, Fiona (University of Prince Edward Island)
Arctic Geomicrobiology and Climate Change	Rysgaard, Soren (University of Manitoba)
Effects of Climate Change on the Canadian Arctic Wildlife *(Arctic Wildlife)*	Berteaux, Dominique (Université du Québec à Rimouski)
Carbon Exchange Dynamics in Coastal and Marine Ecosystems *(Carbon Dynamics)*	Papakyriakou, Tim (University of Manitoba)
Freshwater-Marine Coupling in the Hudson Bay IRIS *(Freshwater-Marine Coupling)*	Barber, David (University of Manitoba); Sydor, Kevin (Manitoba Hydro)
Impacts of Global Warming on Arctic Marine Mammals *(Marine Mammals)*	Ferguson, Steven (University of Manitoba/Fisheries and Oceans Canada)
Integrating and Translating ArcticNet Science for Sustainable Communities and National and Global Policy and Decision-Making *(Science to Policy)*	Hik, David (University of Alberta); Furgal, Christopher (Trent University)
Long-Term Observatories in Canadian Arctic Waters *(Marine Observatories)*	Gratton, Yves (INRS-ETE)
The Role of Sea-Ice in ArcticNet IRISes *(Sea-Ice)*	Barber, David (University of Manitoba)
Climate Change and Food Security in Regional Inuit Centers *(Food Security)*	Ford, James (McGill University)
Adaptation, Industrial Development and Arctic Communities *(Industrial Development)*	Keeling, Arn (Memorial University of Newfoundland)
Climate Change and Commercial Shipping Development in the Arctic *(Commercial Shipping)*	Lasserre, Frédéric (Université Laval)
Food Security, Ice, Climate and Community Health: Climate Change Impacts on Traditional Food Security in Canadian Inuit Communities *(Community Health)*	Chan, Laurie (University of Ottawa); Furgal, Chris (Trent University)
Growth Variability and Mercury Tissue Concentration in Anadromous Arctic Charr *(Arctic Charr)*	Power, Michael (University of Waterloo); Furgal, Chris (Trent University)
Country Foods *Health* Benefits in a Changing Canadian	Dewailly, Éric (Université

Arctic *(Health Benefits)*	Laval)
Permafrost and Climate Change in Northern Coastal Canada *(Permafrost)*	Allard, Michel (Université Laval); Pollard, Wayne (McGill University)
Population Dynamics of Migratory Caribou in Nunavik/Nunatsiavut *(Caribou)*	Côté, Steeve (Université Laval)
Understanding and Responding to the Effects of Climate Change and Modernization in Nunatsiavut *(Nunatsiavut Nuluak)*	Bell, Trevor (Memorial University of Newfoundland); Sheldon, Tom (Nunatsiavut Department of Lands and Natural Resources)
International Inuit Cohort Study: Developing the Next Phase *(Inuit Health Cohort)*	Dewailly, Éric (Université Laval)
Inuit Knowledge and Geospatial Ontologies in Nunatsiavut *(Inuit Knowledge)*	Furgal, Chris (Trent University); Sheldon, Tom (Nunatsiavut Government)

Table 3. Projects being carried out under Beaufort Regional Environmental Assessment:

Project Title	Project Leader
Active Acoustic Mapping of Fish in the Beaufort Sea, 2011-2013	Louis Fortier (ArcticNet)
Impacts of Development in the Beaufort Sea on Fish, their Habitats and Ecosystems, 2011-2015	Jim Reist (Fisheries and Oceans Canada)
Coastal and Marine Bird Usage of the Beaufort Sea Region, 2011-2013	Myra Robertson (Environment Canada)
Database and Atlas of the Birds of the Canadian Beaufort Sea, 2011-2012	Ross Harris (Upun-LGL)
Polar Bears in the Deep Offshore Regions of the Beaufort Sea: A Preliminary Study to Estimate Distribution and Density in Previously Under-Surveyed Areas, 2011-2012	Norm Snow (Joint Secretariat)
Biological Data to Assess the Net Environmental Benefits and Costs of Dispersants and In-Situ Burning in Oil Spill Response, 2011-2013	Ken Trudel (SL Ross)
Overwintering in the Beaufort – Assessing Damage Potential to Vessels, 2011-2013	Anne Barker (National Research Council)
Southern and Northeastern Beaufort Sea Marine Observatories, 2011-2014	Martin Fortier (ArcticNet)
CanICE – A Sea Ice Information Database and Web-Based Portal, 2011-2014	Leah Braithwaite (Environment Canada)
Beaufort Sea Environmental Database, 2011-2013	Ivana Kubat (National Research Council)
Delineation of Extreme Ridges in High Resolution Satellite-Based Radar Imagery, 2011-2012	Desmond Powers (C-Core)
Deep Water Seabed Geohazards, 2011-2015	Steve Blasco (Natural Resources Canada)
Measuring the Thickness and Strength of Deformed Multi-Year Ice in the Beaufort Sea, 2011-2015	Michelle Johnston (National Research Council)
Understanding Extreme Ice Features in the Beaufort Sea, 2011-2015	Christian Haas (University of Alberta)
Radarsat Mapping of Extreme Ice Features in the Southern Beaufort Sea, 2011-2015	David Barber (University of Manitoba)
Forecasting Extreme Weather and Ocean Conditions in the Beaufort Sea, 2011-2015	Fraser Davidson (Fisheries and Oceans Canada)
Seasonal Forecasting of Ocean and Ice Conditions in the Beaufort Sea, 2011-2015	Gregory Flato (Environment Canada)

Table 4. Projects being carried out under the Cumulative Impact Monitoring Program (CIMP)

Project Title	Project Leader
A multi-scale assessment of cumulative impacts in the Northern Mackenzie basin	Claire Marchildon (Aboriginal Affairs and Northern Development Canada AANDC)
A watershed approach to monitoring cumulative impacts of landscape change	Steve Kokelj (AANDC)
Changing hydrology in the Taiga Shield: Geochemical and resource management implications	Shawne Kokelj (AANDC
Arctic Borderlands Co-op: Community based ecological and cumulative impacts and monitoring program	Michael Svoboda (Arctic Borderlands Ecological Knowledge Coop)
Baseline monitoring of Arctic vegetation and snow changes over the Bathurst caribou habitat using satellite remote sensing and community-based field observations	Wenjun Chen (Canadian Centre for Remote Sensing)
Winter ecosystem and fish habitat in the nearshore Beaufort Sea	Christine Michel (Fisheries and Oceans Canada)
Community coastal based monitoring: A regional approach for the ISR	Lisa Loseto (Fisheries and Oceans Canada)
Monitoring Pacific salmon to understand cumulative impacts of climate change in the Arctic	Karen Dunmall (Fisheries and Oceans Canada)
Impacts of climate change on contaminants in consumed fish	Gary Stern (Fisheries and Oceans Canada)
Community and scientific monitoring of the Great Slave Lake ecosystem	Marlene Evans (Environment Canada)
Furbearer contaminants, population and harvest on the Slave River and Slave River Delta: historical and current conditions	Erin Kelly (Government of the Northwest Territories – Environment and Natural Resources)
Landscape scale flooding in the Great Slave Lake Plain: Expansion of lakes, flooding of wetlands and implications for bison habitat and local land users	Terry Armstrong (GNWT – Environment and Natural Resources)
Succession and regeneration response on seismic lines with respect to ecology, disturbance factors and time	Lisa Smith (GNWT – Environment and Natural Resources)
Visual analysis of predictors for increased mercury levels in predatory fish in NWT lakes	Kami Kandola (GNWT – Health and Social Services)
Investigating the cumulative effects of environmental change and human activity	Shawn Laidlaw (Ka'a'gee Tu First Nation)

in the Tathlina watershed	
Quantifying the cumulative effects of industrial activities on the health of fish in rivers in the Northwest Territories	Gary Scrimgeour (Parks Canada)
Understanding impacts of environmental change on char in the ISR: Science and Inuit knowledge for community monitoring	Chris Furgal (Trent University)
Monitoring environmental change in the Mackenzie Delta Region: Inuvialuit observations and participatory-multimedia mapping	Trevor Lantz (University of Victoria)
Snowpack accumulation: influence on caribou distribution, surface water chemistry and lake productivity	Michael English (Wilfrid Laurier University)
Tlicho aquatic ecosystem monitoring project	Jody Snortland (Wek'eezhii Renewable Resources Board)

Annex 1 – Summary of projects conducted under the Northern Contaminants Program

H-01

Assessment of contaminant and dietary nutrient interactions in Inuit Health Survey: Nunavut, Nunatsiavut and Inuvialuit

Project leader: Dr. Laurie H.M. Chan, Professor and Canada Research Chair in Toxicology and Environmental Health, Center for Advanced Research in Environmental Genomics, University of Ottawa

PLAIN LANGUAGE SUMMARY

The Inuit Health Survey (IHS) is a major study that provides a snapshot and baseline data on the health status of Inuit across the North for the first time. The **Assessment of contaminant and dietary nutrient interactions in the Inuit Health Survey: Nunavut, Nunatsiavut, and Inuvialuit** is a component of the Inuit Health Survey. In 2012-2013, the work will focus on: the data analysis for nutrient-contaminant benefit-risk assessment, secondary data analysis on the relationship between contaminant exposure and chronic diseases, the delivery of key messages in Nunavut, and the evaluation of risk perception and effectiveness of the benefit-risk communications. The survey, including sample collection, was conducted in Nunavut in 2007 and in Western Nunavut, Inuvialuit Settlement Region, and Nunatsiavut in 2008, on board the Coast Guard research ship (CGGS) Amundsen. Results describing the body burden and estimated dietary intake of contaminants were reported to each of the 3 regional steering communities in 2011 and key results/messages will be presented in community reports to be published and released in each of the 3 regions in March 2012. We have partnered with the communication teams of the Government of Nunavut and Nunavut Tunngavik Inc (NTI) to deliver the key public health messages via different media in Nunavut. Through our proposed work with these partners, we will obtain feedback on the proposed communication materials during three planned focus group meetings. Thereafter, in 6 communities in Nunavut, we will evaluate people's perceptions of these messages and general risk perceptions of contaminant exposure from country food consumption. The continuing data analysis on risk-benefits assessment will help the development of dietary advice. We will also partner with Dr. Eric Dewailly to study the relationship between contaminant body burden and clinical outcomes. Results of the study will provide useful information to assist health professionals and policy makers at the regional, provincial, territorial, national, and international levels in developing environmental health policies and aid Inuit in making informed dietary choices.

H-02

Nunavik Child Cohort Study (NCCS): follow-up with late adolescents

Project leader: Gina Muckle, Centre de recherche du CHUQ, Université Laval

PLAIN LANGUAGE SUMMARY

Prenatal Exposure to PCBs and mercury were associated with growth and effects on cognitive development in children. The Inuit from Nunavik are among the populations most highly exposed to these environmental pollutants due to their bioaccumulation in fish and marine mammals, which are consumed by the Inuit. However, consumption of fish and marine mammals also provides nutrients such as omega-3 fatty acids, which are known to enhance early brain development. We have conducted four studies in Nunavik over the last 18 years: monitoring of prenatal exposure from cord blood sampling, an effect study with infants up to 12 months of age, and an effect study at preschool age. In 2010, we completed the follow-up of 294 eleven year-old children and, during the years 2010 and 2011, we analyzed most of the 11-year data. In fall 2011, study results were presented to the the Nunavik population and public health recommendations were provided by the Public Health Director of Nunavik. A summary of study results and public health recommendations can be found at http://www.rrsss17.gouv.qc.ca. For the current year, we are proposing to follow the cohort seen at age 11 years during the late adolescence period (16-19 years old).

H-03
Nunavik Child Cohort Study (NCCS): add-on study for follow-up with teenage children – observed behaviours and stress

Project leader: Pierich Plusquellec, Université de Montreal

PLAIN LANGUAGE SUMMARY

Prenatal exposure to lead, PCBs and mercury were associated to behavioural impairments in children. In the last three cohort studies conducted in Nunavik (1 year-old, 5 years-old, 11-yearsold), we have assessed behavioural development and found subtle effects of lead on attention, activity, impulsivity, but also of PCBs on emotional outcomes. For year 2012/2013, we are proposing an add-on study to the main follow-up of children at age 16 proposed by G Muckle. Adolescence is thus a period at which mechanisms of hormone disruption by environmental contaminants become obvious, and at which emotional development is particularly at risk. Our proposal focus on the assessment of observational data on attention, activity and emotional reactivity obtained from coding of videotapes since those data have been shown to be highly sensitive to environmental contaminants exposure. Furthermore, this proposal focus on the assessment of the endocrine stress system through a self-report questionnaire, saliva samples and hair sample to assess basal glucocorticoids levels, reactive glucocorticoids levels following the testing situation, and chronic stress. This focus on the stress system is based on recent scientific results showing that exposure to environmental contaminants may impair this endocrine system, and thus impact behavioural outcomes.

H-05
Monitoring spatial and temporal trends of environmental pollutants in maternal blood in Nunavik (year 2).

Project leader: Eric Dewailly, Centre de recherche du CHUQ, Université Laval

PLAIN LANGUAGE SUMMARY

Inuit are exposed to a wide range of environmental contaminants through their traditional diet, which includes significant amounts of fish and sea mammal. During the past twenty years, several studies have monitored the exposure of Nunavik's Inuit to persistent organic pollutants and heavy metals. Since the late 90's, increased emphasis was placed on health

effects studies in relation to exposure to polychlorinated biphenyls, chlorinated pesticides, mercury and lead in Nunavik. This project proposes to restart the biomonitoring activities in Nunavik in order 1) to compare current exposure levels with those prevailing ten to twenty years ago based on our last surveys, 2) to assess exposure to emerging environmental contaminants for which increasing concentrations in wildlife and human samples have been reported worldwide and, 3) to monitor health effects in newborn related to contaminant exposure. Analyses will be conducted on maternal blood and will provide an update of geographical patterns of exposure, information about whether exposure levels to different classes of contaminants are increasing, decreasing or remaining the same in northern populations, and information about the efficiency of intervention programs implemented following earlier surveys. In 2011-2012 we have started this project as a pilot phase. 2012-2013 will be a complete year of monitoring.

H-06
POPs and cardio-vascular diseases in Inuit

Project leader: Éric Dewailly, Centre Hospitalier Universitaire de Québec (CHUQ) and Québec National Institute of Public Health

PLAIN LANGUAGE SUMMARY

More and more data suggest that the cardiovascular system should be considered a potential target for Arctic contaminants. Since 2 years, we have investigated the role of mercury as a risk factor for CVD and many important findings and publications emerged from this work. Very recently, scientific papers have reported associations between cardio vascular risk factors (high blood pressure, heart rate variability, diabetes), diseases (atherosclerosis) and POPs. These health conditions are rising in the Arctic and our hypothesis is that this rise is not only due to a changing life style but also to contaminant exposure. This project aims at investigating associations between exposure to POPs and the emergence of heart diseases and related risk factors using a large epidemiologic studies conducted among adults in Arctic Canada and Greenland. Since heart diseases represent the most important causes of death, even a slight negative impact on the cardiovascular system could be of greater public health relevance than any other health effects related to contaminant exposure. In addition, we will finish the medical file follow up of participants to the Nunavik cohort.

H-07

In vivo Study of the Effects of a Northern Contaminant Mixture (NCM) on the Development of Metabolic and Cardiovascular Diseases under Conditions Typifying the Diets and Lifestyles of Northerners-Year 3 Sub-Study II: Effects of NCM on the development of metabolic and cardiovascular diseases in JCR rats under two different dietary fat/sugar conditions

Project leader: **Xiaolei (Dawn) Jin**, Health Canada

PLAIN LANGUAGE SUMMARY

Recent epidemiological and experimental studies demonstrated that persistent organic pollutants (POPs) such as PCBs and DDE, and heavy metals such as methylmercury, lead and cadmium found in the Northern traditional food may contribute to the development and progression of metabolic and cardiovascular disorders. Northern populations are exposed to a

mixture of a wide range of contaminants. The health effects of an individual chemical may be altered by the presence of other chemicals, as well as dietary factors and lifestyles. It remains unclear if and how contaminants found in the human blood of Northerners affect metabolic and cardiovascular health, and if and how changes from traditional protein rich diet to high fat/sugar diet, as well as heavy alcohol use interplay with these contaminants to influence human health. In 2011, we proposed to explore these questions using an animal model (JCR rats) of human metabolic and cardiovascular diseases. During 2010-2011, we completed the first part of the animal study (Sub-Study I) in which the effects of a Northern contaminant mixture (NCM) on the development of metabolic and cardiovascular diseases were investigated under conditions typifying Inuit contaminant exposure levels and daily alcohol use. During 2012-2013, we will continue the second part of this study (Sub-Study II) in which the effects of the same NCM on the development of 2 metabolic and cardiovascular diseases are being investigated under conditions typifying Inuit exposure levels and high fat/sugar diet.

H-08

Country foods and cardiovascular health in Nunavik: studying the complex balance between selenium and environmental contaminants

Project leader: Pierre Ayotte, Centre Hospitalier Universitaire de Québec (CHUQ) and Québec National Institute of Public Health

PLAIN LANGUAGE SUMMARY

Selenium (Se) is an essential element highly present in the traditional marine diet of Inuit and their exposure to this element is among the highest in the world. In fish and marine mammal eating populations, there is increasing evidence suggesting that high Se intake may play a role in offsetting some deleterious effects of methylmercury (MeHg) exposure. However, in other populations, elevated plasma Se concentrations have been recently associated to type 2 diabetes, hypercholesterolemia and/or hypertension. In addition to plasma Se levels, the most common biomarker of Se status, several other biomarkers (e.g. selenoproteins) have been identified and these may help to better characterise Se status. We will investigate relations between these new biomarkers of Se status and emerging health issues such as diabetes and cardiovascular diseases in Inuit adults, taking into account possible interactions with mercury and other environmental contaminants. We will also identify the forms of selenium and mercury present in various traditional foods and their bioaccessibility. These much needed data will improve our capacity to assess the risks and benefits of Se intake and the traditional marine diet in this population.

H-10

Quantifying the Effect of Transient and Permanent Dietary Transitions in the North on Human Exposure to Persistent Organic Pollutants

Project leader: Frank Wania, University of Toronto

PLAIN LANGUAGE SUMMARY

Human exposure to persistent organic pollutants (POPs) in both industrialized and remote regions is strongly influenced by diet. What we eat and where these food items originate are key determinants of body burden and risks associated with chronic exposure to such

compounds. It is well known that all foods are not equal with respect to contamination with POPs. This implies that contaminant exposure can be affected by changes in diet. Such dietary changes can be transient, e.g. if a woman who plans to become pregnant or already is pregnant temporarily avoids food items known to be more contaminated, such as the fatty tissues of marine mammals. Or such dietary changes may be more gradual and permanent, e.g. if someone gradually shifts from a traditional diet of locally hunted animals to a diet that includes more store-bought food imported to the community. Here we propose to develop and use a computer-based simulation model that quantifies how much such dietary changes can affect exposure to contaminants. At the same time we will seek to quantify how much these changes affect the intake of beneficial nutrients. It is hoped that the model can eventually be used to make informed decision on dietary choices that minimize the risk from contaminants while maximizing the nutritional food value.

M-01
NORTHERN CONTAMINANTS AIR MONITORING: ORGANIC POLLUTANT MEASUREMENTS

Project leader: Hayley Hung, Environment Canada
PLAIN LANGUAGE SUMMARY

The atmosphere is the main pathway for organic contaminants to enter Arctic ecosystems. This project involves the measurement of these contaminants in Arctic air. It is part of a continuing monitoring program started in 1992. The measurement of amounts and types of contaminants involves collecting large volumes of air through filters. The filter samples are then analyzed in a laboratory. Results from this continuing project are used to negotiate and evaluate the effectiveness of international control agreements and to test atmospheric models that explain the movement of contaminants from sources in the South to the Arctic. In this phase of the project, weekly sampling will continue at the baseline site of Alert, Nunavut, but only one out of four weekly samples will be analyzed for routine trend analysis. The remaining samples will be extracted and archived for future exploration of notable transport episodes and for emerging priority chemicals. Starting in Dec 2005, we have extended the program to screen for emerging chemicals, such as current-use pesticides, brominated flame retardants and stain-repellent-related perfluorinated compounds, in Arctic air at Alert. We would like to continue this work in the coming fiscal year with additional efforts in screening for more polar and volatile emerging compounds of concern. A request to Environment Canada's Chemicals Management Plan (CMP) will be submitted to complement this work under NCP. A newly-developed passive flowthrough air sampler specifically designed for use in cold environments has been deployed at the Little Fox Lake station in the Yukon since August 2011. We propose to continue measurements at this location in the western Canadian Arctic to further assess the influence of trans-Pacific and Asian contaminant sources on the western Canadian Arctic.

M-02
AIR MEASUREMENTS OF MERCURY AT ALERT AND LITTLE FOX LAKE

Project leader: A. Steffen, Environment Canada
PLAIN LANGUAGE SUMMARY

This project looks at the levels of mercury (Hg) in the Arctic air from Alert, Nunavut and Little Fox Lake, Yukon. Changes of Hg levels in air with time, assessing how Hg arrives in the Arctic by air and what happens when it does get there are the primary goals of this project. Mercury is found in the air as a gas or attached to airborne particles. As a gas, it generally stays in the air for a long time but on particles it can fall onto the snow/ice surfaces quickly and end up in the ecosystem. This study provides data on how much mercury is in the air, how it is brought into the Arctic by air and how much falls onto the snow surfaces. The data collected is used in mathematical models to predict future scenarios of Hg in Arctic air. This information supports national and international policy negotiations to control the release of Hg worldwide. This research also contributes to understanding how climate change may influence Hg contamination in the Arctic. Finally, this research provides a part of the overall puzzle to try and understand how Hg affects those living in the north.

M-04
Temporal trends of persistent organic pollutants and metals in ringed seals from the Canadian Arctic

Project leaders: Derek Muir (Environment Canada), Michael Kwan (Nunavik Research Centre), and Marlene Evans (Environment Canada)

PLAIN LANGUAGE SUMMARY

The objective of this project is to determine changes in concentrations of legacy contaminants, such as PCBs and other persistent organic pollutants (POPs), and mercury, as well as new contaminants, in ringed seals. This project builds on previous work led by our team which collected ringed seal samples with help of the HTAs in 15 communities (Arctic Bay, Arviat, Gjoa Haven, Grise Fiord, Kangiqsujuaq, Kangiqsualujjuaq, Ulukhaktok, Inukjuaq, Mittimatalik (Pond Inlet), Makkovik, Nain, Pangnirtung, Quaqtaq, Resolute, Sachs Harbour) between 1998 and 2009. As of 2010 the project downsized to focus on only on annual sampling at Sachs Harbour, Resolute and Arviat as required in the NCP "Blueprint". However this year we are proposing to add Nain back into the project. We will use blubber samples of female seals to determine trends in POPs concentrations and liver and/or muscle of male and female seals for mercury other heavy metals as well as fluorinated chemicals. Muscle samples will also be analysed for carbon and nitrogen stable isotopes to assess seal diets; samples will be archived for possible future dietary contaminant studies. As concentrations of legacy chemicals, such as PCBs and DDT, continue to decline in most locations, we are focussing increasingly on new classes of chemicals which we have shown are increasing rapidly in the Arctic particularly brominated flame retardants and fluorinated stain repellents. All sampling is being done with the help of HTAs in each community who are supplied with sampling kits and instructions. Hunters are paid for each animal collected and HTAs receive funding to cover coordination and administrative costs. The work at Arviat is coordinated with DFO marine mammal scientists.

M-05
Temporal and spatial trends of legacy and emerging organic and metal contaminants in Canadian polar bears

Project leader: Robert Letcher, Environment Canada and Carleton University

PLAIN LANGUAGE SUMMARY

The polar bear (*Ursus maritimus*) is the apex predator of the arctic marine ecosystem and food web, and an integral component of northern (Canadian) Aboriginal culture and whose lifestyle depends on subsistence foods (seals) that polar bears prey on as well as polar bears themselves. The proposed work for 2012-2013 is ongoing temporal monitoring over the longer term and with higher annual resolution of priority persistent organic and elemental pollutants (POPs) in tissues of polar bears from the two territorial management zones in southern and western Hudson Bay (Nunavut). Hudson Bay is a hot spot with respect to Arctic warming and over time has and continues to be subjected to reductions in sea-ice condition, which has been related to shifts in the aquatic food web and the prey (seal) species of polar bears. Temporal monitoring of legacy POPs in the proposed work will include PCBs, chlordanes, DDTs and endosulfan and metabolites and other NCP priority POPs such as short-chain chlorinated paraffins (SCCPs), as well as bioaccumulative elements such as mercury (Hg). New and emerging POPs will include polybrominated diphenyl ether (PBDE) and hexabromocyclododecane (HBCD) flame retardants (BFRs) and polyfluoroalkyl compounds (PFCs). Other flame retardants, that may be of priority to NCP and potentially bioaccumulative and persistent in polar bears, will be assessed including a growing number of replacement flame retardants such as the chlorinated Dechlorane Plus. In controlling for variance due to confounding factors, we will continue to collect other important data such as age, sex, body condition, time of collection and lipid content. Also, carbon and nitrogen stable isotopes (SIs) and fatty acid (FA) profiles will continue to be used as ecological tracers of contaminant variance due to diet and/or food web change. Northerners and aboriginal peoples will continue to be integral partners as they carry out the annual harvest of polar bears and provide the collected tissue samples for this POP monitoring.

M-07 Temporal trends of heavy metals and halogenated organic compounds in Arctic marine mammals (beluga, narwhal and walrus)

Project leader: Gary A. Stern, Department of Fisheries and Oceans (DFO)

PLAIN LANGUAGE SUMMARY

The objectives of this project are to maintain current data on contaminant levels in marine mammals and to continue to assess the temporal trends of bioaccumulating substances such as heavy metals and halogenated organic compounds (HOCs). This will allow us to determine whether contaminant levels in the marine mammals, and hence exposure to Arctic people who traditionally consume them, are changing with time. These results will also help to test the effectiveness of international controls and, in conjunction with projects such as CASES (Canadian Arctic Shelf Exchange Study) and ArcticNet, to understand the effects that climate variation may have on these contaminant levels. Climate variation has been attributed to observed changes to atmospheric sea-level pressure, wind fields, sea-ice drift, ice cover length of melt season, precipitation patterns, hydrology and ocean currents and water mass distribution. It is almost certain that these primary changes have altered the carbon cycle, trophic relationships between species, and biological systems but the difficulty of observing these changes together with existing irregular, incomplete time series measurements makes it exceedingly difficult to discern what these changes have been (Macdonald et al 2005). Because contaminants enter global systems and transport through the air and water, the changes listed above will clearly alter contaminants pathways and ultimately the levels observed in the Arctic marine ecosystem.

M-08
Temporal Trends of Contaminants in Arctic Seabird Eggs

Project leader: Birgit Braune, Environment Canada
PLAIN LANGUAGE SUMMARY

Contaminants have been monitored in arctic seabird eggs collected from Prince Leopold Island in the Canadian High Arctic since 1975. Those data have shown declines in most of the legacy organochlorines (e.g. PCBs, DDT) as well as dioxins and furans. Contaminants such as mercury and β-hexachlorocyclohexane, however, have been increasing as have some of the newer chemicals, such as the perfluorinated compounds (e.g. perfluorinated carboxylic acids). Shifts in diet are affecting the contaminant temporal trends reflected in the eggs of thick-billed murres monitored in northern Hudson Bay since 1993. However, the Prince Leopold Island murres do not appear to have changed their diet. Annual monitoring of the thick-billed murre and northern fulmar eggs at Prince Leopold Island since 2005 has improved the power of the time series. Therefore, sampling will continue on an annual basis for these species, as specified in the Blueprint.

M-09
Temporal trends and spatial variations in persistent organic pollutants and metals in sea-run char from the Canadian Arctic

Project leader: Marlene S. Evans, Environment Canada
PLAIN LANGUAGE SUMMARY

This study is a core biomonitoring project investigating contaminants trends in sea-run Arctic char from Ekaluktutiak (Cambridge Bay), the site of an important commercial fishery, and Mittimatalik (Pond Inlet). Sea-run char are being investigated because of their importance in the domestic fisheries for most coastal communities. Contaminant levels are low in these fish, making them a good food choice. The contaminants which are being measured are "legacy" chemicals such as PCBs, DDT, and HCH which are not used as commonly as in the past and hence would be expected to decline in concentration, and newer chemicals such as PBDEs. In addition, many metals are being measured, including mercury. Mercury concentrations may increase in fish if more mercury is released to the atmosphere with coal burning or if warming trends cause the mercury that is present in the environment to be more readily transformed and taken up by the fish. Our studies began at Cambridge Bay in 2004 and at Pond Inlet in 2005 and fish have been collected annually (Cambridge Bay was not sampled in 2005) since then. In addition some older data exist allowing for investigation of change over longer time periods. In 2012 fish will again be collected from these two communities by community members from areas where they do most of their fishing. Twenty fish of an ideal size range of 400-800 mm will be captured at each location and frozen whole for shipment to Saskatoon; people will be paid for providing these fish. Length, age, weight, lipid (fat) content, and sex will be determined for each fish along with stable isotope measures of feeding. We also will make note of parasites on the fish, whether the fish seems skinny, discolorations of the liver, etc. as measures of fish health. We will determine concentrations of a broad suite of legacy and new persistent organic contaminants and on 31 metals including mercury. Information will be used for a variety of purposes including providing needed information for dietary advice, assessments of the successes of international agreements limiting contaminant use and release, and understanding how

economic development (increased contaminant release) and climate change may affect contaminant pathways.

M-10
Temporal trends of Persistent Organic Pollutants and Mercury in Landlocked char in the High Arctic

Project leaders: Derek Muir (Environment Canada)**,** Günter Köck (Austrian Academy of Sciences)

PLAIN LANGUAGE SUMMARY

This purpose of this project is to investigate changes in concentrations of contaminants over time in landlocked Arctic char from lakes in Nunavut. Our approach is to measure concentrations of pollutants such as persistent organic pollutants (POPs) and mercury in the fish each year to see if levels are decreasing or increasing. The project began in 1999 by studying Char and Resolute Lakes because samples had been previously collected from both lakes in 1993. Since then we have continued to sample Resolute and Char Lakes each year and have added Amituk Lake, and Hazen Lake in northern Ellesmere Island which were originally sampled in the early 1990s. All of the fish collected so far have been analysed for mercury and other metals. A smaller number have been analysed for PCBs and other persistent organic pollutants (POPs). Mercury concentrations in Arctic char have not changed significantly over time in all 4 lakes and since 2005 they have declined in all four lakes. Mercury concentrations in most char from Char Lake and Amituk Lake are above guidelines for human consumption. PCBs and other POPs have declined overall in all four study lakes over the period 1992/93 to 2010. While concentrations of brominated flame retardants (BFRs) increased in char in Resolute and Amituk Lake until about 2005 they are now declining. Fluorinated chemicals used in stain repellents and fire fighting foams are detectable in all char and appear to be increasing in Char Lake. For 2012-13 we plan to continue annual sampling of Amituk, Char, Hazen, and Resolute lakes. We will analyse samples for mercury and POPs (PCBs, chlorinated pesticides such as DDT) as well as BFRs and fluorinated chemicals. Sampling will be carried out by hand methods or gill netting. The fishing effort on the lakes near Resolute will utilize the traditional knowledge of local people in the community. Results of the project will continue to be reported annually to the HTA of Resolute Bay.

M-11
Spatial and long-term trends in persistent organic contaminants and metals in lake trout and burbot from the Northwest Territories

Project leaders: Marlene S. Evans (Environment Canada) and Derek Muir (Environment Canada)

PLAIN LANGUAGE SUMMARY

Our study is measuring contaminant levels in lake trout harvested from the Lutsel K'e (East Arm) and Hay River (commercial fishery; West Basin) areas and burbot from the Fort Resolution area (Slave River outflow, West Basin) of Great Slave Lake; burbot sampling at Lutsel K'e was formally discontinued in 2007 although we have continued this monitoring with mid-year NCP and other funds. Our monitoring results are encouraging showing that some persistent organochlorine pollutants (POPs) such as HCH, DDT, PFOS, and PFCAs are

declining in concentration. However, other contaminants such as PCBs and PBDEs are showing little change and mercury concentrations are increasing in both species; nevertheless, mean concentrations are well below the guideline for commercial sale of fish. In 2012-2013 we will again work with Fort Resolution in the collection of burbot and lake trout from their domestic fisheries: lake trout from the Hay River area which will be provided by a commercial fisherman. Reimbursement will be provided for the provision of these fish. All fish will be shipped frozen to Saskatoon where length, age, weight, lipid (fat) content, and sex will be determined for each fish along with stable isotope measures of feeding. We also will measure liver weight, gonad weight, and note the unusual appearance of the liver, the presence of parasites, a skinny appearance, etc. Legacy and new persistent organic contaminants and 31 metals, including mercury, will be measured on 10 fish from each location with the remaining 10 placed into our archive. We report the results of our studies in the annual NCP reports, at the NCP workshop, various communications with communities. We also are working with other partners in their mercury trend monitoring studies in the Mackenzie River Basin.

M-12
Temporal trend studies of trace metals and halogenated organic contaminants (HOCs), including new and emerging persistent compounds, in Mackenzie River burbot, Fort Good Hope, NWT

Project leaders: Gary Stern (DFO) and Gregg Tomy (DFO)

PLAIN LANGUAGE SUMMARY

The objective of this project is to maintain current data on contaminants levels in Mackenzie River burbot and to continue to assess the temporal trends of bioaccumulating substances such as trace metals (e.g. mercury, selenium, arsenic, lead and cadmium), organochlorine contaminants (e.g. PCBs, DDT, toxaphene and selected current use chemicals such as brominated flame retardants (e.g. PBDEs, HBCDD), and fluorinated organic compounds (e.g. PFOS and it's precursors) so as to determine whether the levels of these contaminants in fish (health of the fish stock) and thus exposure to people living in Arctic communities who consume them as part of their traditional diet, are increasing or decreasing with time. These results will also help to test the effectiveness of international controls.

M-13
Long term trends of halogenated organic contaminants and metals in lake trout from two Yukon Lakes; Kasawa and Laberge

Project leaders: Gary Stern (DFO), Gregg Tomy (DFO) and Cindy Dickson (Council of Yukon First Nations)

PLAIN LANGUAGE SUMMARY

The objective of this project is to maintain current data on contaminants levels in lake trout from two Yukon lakes (Laberge and Kusawa) to continue to assess the temporal trends of bioaccumulating substances such as trace metals (e.g. mercury, selenium, arsenic), organochlorine contaminants (e.g. PCBs, DDT, toxaphene), selected current use chemicals such as brominated flame retardants (e.g. PBDEs, HBCDD), and fluorinated organic compounds (e.g. PFOS and it's precursors) so as to determine whether the levels of these contaminants in fish (health of the fish stock) and thus exposure to people who consume

them are increasing or decreasing with time. These results will also help to test the effectiveness of international controls.

M-14
Arctic Caribou and Moose Contaminant Monitoring Program

Project leaders: Mary Gamberg (Gamberg Consulting), Lorna Skinner (INAC), Mitch Campbell (Government of Nunavut) and Mary Denniston (Nunatsiavut Government)

PLAIN LANGUAGE SUMMARY

This project will determine contaminant levels in Canadian Arctic caribou to determine if these populations remain healthy in terms of contaminant loads, whether these important resources remain safe and healthy food choices for northerners and to see if contaminant levels are changing over time. Previous studies have found that cadmium and mercury levels in caribou kidneys and livers are higher than in domestic animals grown for food consumption. This has prompted a health advisory from Yukon Health and Social Services, based on a health assessment from Health Canada. Although a study by the Centre for Indigenous Peoples' Nutrition and Environment confirmed that traditional foods are safe to eat at the estimated consumption rates they did recommend that a trend-monitoring program be established to verify that the levels are not rising from local or long-range inputs and that new contaminants be addressed as they arise. Although organic contaminants have been measured in the past in caribou and found to be low, new analytical methods suggest that this should be revisited to confirm organic contaminant burdens. In addition, new organic compounds are being considered for inclusion in the Stockholm Convention on Persistent Organic Pollutants. Little data exist on levels of these contaminants in the Arctic, so measuring them in caribou will not only provide much-needed data for policy makers, it will also ascertain whether these compounds are accumulating in the Arctic terrestrial ecosystem. This project monitors two caribou herds, the Porcupine (YT) and the Qamanirjuaq (NU). Monitoring populations from the eastern and western Arctic will also give scientists a better understanding of the distribution of contaminants in the Arctic and the variability of contaminant burdens between herds.

M-15
Validating experimental and modeled rate constants for reduction and oxidation of mercury species in Arctic snow: Assessing the modeling error

Project leader: Nelson O'Driscoll, Acadia University

PLAIN LANGUAGE SUMMARY

The movement of pollutants to the earth's poles (global distillation) has resulted in elevated levels of mercury in traditional food sources in the Arctic, putting local Arctic communities at risk for exposure to methyl mercury. Methyl mercury is not the main form emitted by human industry but rather is formed from methylation of other forms of mercury (such as divalent mercury) in the environment. Therefore, a better understanding of the availability and retention of divalent mercury is required to predict methyl mercury distribution in the Arctic. This information will be useful in various mercury management initiatives to reduce the exposure of aboriginal peoples to mercury. It is also critical supporting research for the UNEP initiative to develop a legally binding global agreement on mercury. Our recent work has developed accurate measurements of mercury speciation in snow in response to solar radiation and we are updating predictive models based on these results. However, these new kinetics and modeling results need to be validated through a comparison to mercury measurements in the field (*in situ*). Once validated, these models will help predict mercury availability and retention in Arctic ecosystems, as well as evasion of mercury to the

atmosphere. An accurate assessment of the error in comparison to *in situ* data will allow for the quantification of seasonal/ climate change impacts on divalent mercury availability in the snowpack. To do this, mercury flux measurements will be taken at three previously sampled sites in the Resolute Bay Area in the High Arctic (74° 41′N, 094°49′W), and compared to predicted flux using our kinetics-derived models. This work will help us to better predict the movements of mercury into Arctic ecosystems and may help manage future mercury exposure with a changing climate.

M-16
A latitudinal investigation of ecosystem sensitivity to methylmercury bioaccumulation in Arctic fresh waters

Project leader: John Chételat, Environment Canada, and Murray Richardson, Carelton University

PLAIN LANGUAGE SUMMARY

Mercury is a priority contaminant of the Northern Contaminants Program (NCP) due to its prevalence in the Arctic and high levels found in some traditional food species. The main objective of this proposed project is to investigate climate-related environmental controls on methylmercury (MeHg) bioaccumulation in Arctic lakes and ponds. Over three years (2012 to 2015), we will compare MeHg bioaccumulation in three study areas that cover a latitudinal gradient in ecosystem types in the Canadian Arctic, specifically Kuujjuarapik (sub-Arctic taiga), Iqaluit (tundra) and Resolute Bay (polar desert). In water bodies from each of these study areas, we will investigate two key aspects of MeHg bioaccumulation, specifically MeHg bioavailability to benthic food webs and organism growth rates. We will apply novel techniques to evaluate: 1) MeHg bioavailability in sediment pore waters with passive DGT samplers (Diffusive Gradient in Thin films) to emulate biological MeHg uptake; and 2) the influence of growth rates (estimated by tissue DNA/RNA contents) on MeHg concentrations of invertebrates and fish. We will also measure watershed characteristics and water chemistry to account for differences in terrestrial loadings, particularly of Hg and organic carbon, among ecosystem types at different latitudes. Project results will provide a conceptual model of climate-related environmental processes that affect the exposure of Arctic freshwater fish to MeHg. This information is critical to understand how climate change is affecting temporal and geographic trends of Hg bioaccumulation in Arctic fish monitored by the NCP.

M-20
Spatial and temporal variations of Hg isotope ratios in ice cores across the Canadian Arctic

Project leader: Eva Kruemmel, Inuit Circumpolar Council Canada

PLAIN LANGUAGE SUMMARY

The Arctic is vulnerable to global mercury (Hg) pollution, and Hg levels in top marine predators (e.g., beluga, polar bears) are reported to have increased ~10-fold in the past 150 years, raising serious concerns about the safety of traditional foods in northern populations. While Hg emissions in North America and Europe have declined in recent years, emissions from Asia have been rising. However, the exact sources and pathways of Hg to the Arctic have yet to be determined. This information is needed to support current efforts to negotiate a legally-binding international agreement on Hg. This study proposes to provide clues about factors such as a changing climate and human-caused releases on Hg deposition in the Arctic by using Hg isotope measurements. Ice-cores spanning a northsouth gradient in the Eastern

Canadian Arctic will be examined for spatial differences of Hg isotope signals. Pre-industrial times with extremes in ice cover, and present (industrial) times will also be compared. First results show different Hg isotope signals in pre-industrial versus industrial ice-core samples from Penny ice-cap. The results may reflect post-depositional processes as well as changing mercury deposition that occurred over time, and it may be possible to differentiate source-specific signals.

M-23
Investigation of Mercury Toxicity in Landlocked Char in High Arctic Lakes

Project leader: Paul Drevnick, INRS---ETE, Université du Québec

PLAIN LANGUAGE SUMMARY

Mercury (Hg) degrades the ecosystem services that fish provide. Consumtion of contaminanted fish is the major source of Hg in humans and wildlife and is detrimental to their health. Hg also causes toxic effects in the fish themselves. In northern Canada and especially Nunavut, Hg concentrations can be high in predatory fish, including landlocked Arctic char (*Salvelinus alpinus*). An analysis of data from landlocked char in northern Canada and Greenland indicates that 30% of the populations surveyed exceed toxicity thresholds for Hg in fish. In 2011, with funding from NCP we collected landlocked char from "NCP focal ecosystem" lakes on Cornwallis Island to determine whether wild populations are indeed experiencing Hg toxicity. Collections were conducted in cooperation with the char "core" monitoring project led by Muir. The lakes sampled (Small, 9-mile, North, Char, Amituk) span a gradient of Hg concentration, allowing for the comparison of biological endpoints in char with low Hg concentrations to char with high Hg concentrations. Endpoints relate to the reproduction, liver anatomy/physiology, and general health. Data thus far indicate a possible subtle effect on reproduction, as the number of eggs per ripe female (relative fecundity) is lower at high Hg concentreations. Effects on the liver are more severe – at moderate Hg concentrations, injury to issues is monor because of repair mechanisms, but at high Hg concentrations (Amituk only), repair is inhibited and there is widespread cell death and tissue inflamation. In this proposal, we request a second year of funding from NCP in order to (1) complete lab analyses of samples from 2011 and (2) collect more char in 2012 and analyze the samples for selected endpoints. The research will yield unambiguous results about Hg toxicity, and the data will be used to estimate a toxicity threshold specific to landlocked char. Our work is novel in that it goes beyond documentiing Hg concentrations in fish and will provide critical knowledge concerning the status of fish health, and as stated in the NCP blueprint, "the health of northern Aboriginal populations is initmately linked to the health of Arctic ecosystems."

M-25
Quantifying contaminant loadings, water quality and climate change impacts in the world´s largest lake north of 74° latitude (Lake Hazen, Quttinirpaaq National Park, Northern Ellesmere Island, Nunavut)

Project leader: Vince St. Louis (University of Alberta), and Derek Muir (Environment Canada),

PLAIN LANGUAGE SUMMARY

Human activities have elevated global atmospheric concentrations of greenhouse gases to levels that have resulted in an unequivocal warming of the Earth's climate. This is especially true in the high Arctic, where in the past century average annual temperatures have increased at almost twice the global rate. Current climate models predict that in certain regions of the Canadian Arctic, by 2100, autumn/winter temperatures will increase by up to 9^{o}C, while annual precipitation will likely rise by 35%. Such warming and wetting is anticipated to result in permafrost degradation and glacial melt, increased surface runoff, pond formation and/or drying, increased productivity on landscapes, and enhance deposition of certain contaminants to the Arctic. Human activities have also resulted in unprecedented releases of contaminants to the environment, many of which make their way to the high Arctic via the atmosphere. Unfortunately in many regions of the high Arctic, it is largely unknown how much change has already occurred since the beginning of industrialization and what the current state of Arctic ecosystem health is in general. We are proposing to monitor contaminant loadings, water quality and climate change impacts (e.g., levels of productivity) in the world's largest lake north of 74° latitude (Lake Hazen, Quttinirpaaq National Park, Northern Ellesmere Island, Nunavut). From a socio-economic perspective, understanding contaminant loadings, water quality and climate change impacts is important for predicting how the abundances and quality of certain organisms used as Inuit traditional foods may be altered due to climate change.

M-26
Monitoring of Radioactivity in Caribou and Beluga in response to the Fukushima accident.

Project leaders: Trevor Stocki (Health Canada)

PLAIN LANGUAGE SUMMARY

This project will determine radioactive contaminant levels in Canadian Arctic caribou and beluga whale, in response to the Fukushima Daiichi nuclear accident, which began on March 11, 2011. These measurements will determine whether contaminant levels in these resources have changed since the accident.

Previous studies have shown increased levels of radioactivity in caribou and reindeer after the Chernobyl accident in 1986. Although these radioactivity levels in Porcupine caribou indicated that the caribou were safe to eat, it is important to verify this for the Fukushima nuclear accident to ensure food safety and address concerns by northerners.

It is equally important to ensure food safety and address the concerns raised by community members from the Inuvialuit Settlement Region regarding beluga. As such we will be measuring levels in the Beaufort Sea beluga population, this population winters in the Bering Sea. This project will work in cooperation with two other Northern Contaminant Program (NCP) projects to measure radioactivity in caribou and beluga. It will give scientists a better understanding of radioactive contaminants in the Arctic and find out whether the releases of radioactivity as result of the Fukushima accident have affected these important food sources in the north. Radioactivity measurements will be performed on samples of caribou and beluga from these two other NCP projects and will use samples obtained before and after the accident. This project will also use information from Health Canada's measurements of radioactivity in air and its analysis of the atmospheric transport of radioactivity from Japan.

An environmental pathway analysis will also be done for the case of caribou, using an estimation of the location and concentration of the plume of radioactivity from Fukushima and by measuring radioactivity in lichens and mushrooms sampled from the potentially affected area within the range of the Porcupine caribou.

Finally the possible human health impacts of the beluga and caribou measurements will be determined. The Radiation Protection Bureau has experience in this (Tracy et al. 1993, Tracy et al. 1992, Stocki et al. 2005).

M-27

Established and emerging contaminants in declining glaucous gull populations from the Canadian Arctic: Relationships with annual habitat-use, diet and biological effects

Project leaders: Johnathon Verreault (Université du Québec à Montréal (UQAM))

PLAIN LANGUAGE SUMMARY

Numbers of breeding glaucous gulls (*Larus hyperboreus*) have been declining dramatically during the last decades in several colonies in Nunavut, Canadian Arctic. Reasons for this marked breeding population decline are as yet unclear, although it has been suggested that high contaminant burden combined with several other potential ecological/physiological stressors (e.g., climate change, food scarcity, parasites, pathogens, etc.) may have played a determinant role. In this three-year project we propose to investigate, in two declining glaucous gull colonies from Nunavut, the influence of habitat-use strategy and diet on the bioaccumulation profiles of established and emerging contaminants (PBDEs and recently emerged and new halogenated and non-halogenated flame retardants (HFRs/FRs)), and their exposure-related health impact. Using a biomarker approach, contaminant exposure-related biological and ecological responses and effects will encompass measures of endocrine and immune status, parasite infection and demographic changes. This study will be among the first to combine contaminant profiles and effects, ecological tracers (stable isotopes) and a new geolocation technology to track the movements of birds during their annual life cycle. An additional novelty of this project is that it addresses current questions and knowledge gaps related to PBDEs and their currently-used replacement halogenated (or non-halogenated) flame retardant additives, for which little or no toxicological data exist in Canadian Arctic wildlife for most of these compounds. This new NCP project will offer the opportunity for university students (University of Quebec in Montreal and Acadia University) and young Aboriginal peoples to conduct or participate in research activities that span understudied aspects of ecotoxicology as well as other natural science fields (animal physiology, ecology and behaviour, telemetry, endocrinology, immunology, etc.)

M-28

Temporal trends of mercury levels of fish in lakes with out-dated health advisories in the Northwest Territories, Canada.

Project leaders: Kami Kandola (NWT Health and Social Services)

PLAIN LANGUAGE SUMMARY

While undertaking the phase II 2011-2012 project of “Building Capacity in Knowledge Translation of Northern Contaminants”, it was noted that a number of old public health advisories were in place from the mid-1990’s. A priority for this proposal is to update

these outdated public health advisories. We propose six lakes for testing of mercury levels in fish muscle for 2012-2013. (Three located in the Dehcho region and three in the Sahtu region). Five of these lakes were last tested around 15 years ago. There is interest from the communities that frequent the lakes to harvest fish as their traditional diet to test these lakes. These lakes will be posted to update the Government of the Northwest Territories (GNWT) Health and Social Services (HSS) website for fish consumption advisories. Recent testing of these lakes would make these advisories more concrete and give a better look at the mercury levels of fish in these lakes and allow for the monitoring of trends.

The final part of this project would be to provide community presentations in order to inform members within the surrounding regions of the study's findings. Efforts will be made to combine this with similar projects from separate funders in order to minimize travels costs. The project completion date would be at the end of the 2012-2013 fiscal year and the results will be presented at the 2013 NCP Results Workshop.

The funding requested in this proposal will help to ensure that the fish in the lakes which have advisories are safe to eat and will allow GNWT HSS to inform community members, as well as other people about levels of mercury in fish in the Northwest Territories (NWT). It will also provide a temporal analysis to monitor any changes over time. The main goal is the promotion of safe consumption of traditional foods.

M-29

Anticipating the effect of climate change on contaminant exposure in the Arctic

Project leaders: Frank Wania (University of Toronto)
PLAIN LANGUAGE SUMMARY

This project seeks continuing matching funds for the participation of Canadian researchers in a European research project on the effect of climate change on the contaminant exposure and resulting health effects in Arctic human populations. In particular, the research will use conceptual and numerical models to predict how and to what extent the exposure of human and wildlife populations in the North are likely to change as a result of the rapidly changing Arctic climate. The models and the results of simulations using these models will facilitate the interpretation of time trends of contamination in air, wildlife and humans, by identifying and quantifying the confounding influence of climate change on those time trends. In the fourth project year, we will synthesize what we have learned during the project so far in an attempt to predict how concentrations of persistent organic pollutants are likely to change in the Arctic over the next half century or so.

M-30

Community based seawater monitoring for legacy and current use organic contaminants in the Canadian, high Arctic Archipelago

Project leaders: Derek Muir (Environment Canada)

PLAIN LANGUAGE SUMMARY

Seawater sampling was conducted in May-June 2011 in Barrow Strait as part of a community based study of contaminants in ocean water. The goal was obtain samples at key time points (no melt, mid-melt, heavy melt, open water) to give insight into how ice cover/melt influence trace contaminant concentrations in seawater. The sampling was conducted by Peter and Jeffry Amarualik using equipment supplied by Environment Canada. Passive water samplers consisting of a polyethylene film (similar to "Saran Wrap") were deployed under the ice. Preliminary results show low (pictogram/litre) concentrations of PCBs and chlorinated pesticides in the polyethylene samplers. Sampling of seawater by passing it through an XAD column using a high volume pump was unsuccessful due to pump failure possibly due to blockage of the lines or flow meter due to freezing. With lessons learned from the sampling program in 2011 we propose to repeat the sampling in 2012 with a modified plan taking into account challenges of deploying samplers in under ice and during ice melt. The sampling will be led again by Peter Amarualik. By doing so, we hope to establish a community based seawater monitoring program that would reduce sampling costs and provide valuable training to members of this community.

CB-01

Mercury Levels in Food Fish Species in Lakes used by Dehcho Community Members with a focus on Choice and Risk Perception of eating Traditional Country Food.

Project leader: George Low, Dehcho First Nations

PLAIN LANGUAGE SUMMARY

The Dehcho First Nations (DFN) in collaboration with Environment Canada has been updating the data on mercury levels in fish from lakes in the Dehcho. Mercury levels in predatory fish in some lakes may be increasing due to climate change factors. New health advisories have been issued for certain fish in certain lakes by the GNWT, Health and Social Services. The Dehcho will continue to support GNWT, Health and other researchers by collecting fish for contaminant analysis.

Our emphasis is changing towards studying the apparent shift in diet from fish and other country food towards a market based diet. People in some communities are consuming less fish and other country food than previously. Part of the reason seems to be a perception that water and fish are no longer safe because of the presence of mercury and other contaminants. These perceptions need to be examined at the community level in order to encourage the return to a healthy traditional diet.

The Dehcho First Nations through its AAROM program intends to address risk perceptions about country foods over the next couple of years. This year initiation will lead into a full study once consultations are complete for the following fiscal year.

CB-02

Evaluation of hydro-climatic drivers of contaminant transfer in aquatic food webs in the Husky Lakes Watershed (Inuvialuit Settlement Region, Northwest Territories)

Project leader: Niklaus Gantner, University of Victoria

PLAIN LANGUAGE SUMMARY

We propose to investigate hydro-climatic effects on food webs and related contaminants transfer to top predators of lakes near the community Inuvik and Tuktoyaktuk using a mixed method approach. Sample collections for this project will be conducted following TK interviews and in conjunction with fall/spring fishing by residents of Tuk/Inuvik. We will hire local people for this work and provide training in relevant methods for future work. We will compare sites in the Husky Lakes Watershed (along a local salinity gradient) with Big Lake and Yaya Lake (NOTE: additional lakes may be added upon a recent request by FJMC, i.e., along the proposed Inuvik-Tuk road corridor). This 2-year project will allow us to investigate the effects of marine water entering Husky Lakes, controlled by changes in synoptic climatic conditions, while capturing TK on the system. The research will establish a baseline for future changes of climate and land use in the ISR, in particular the proposed Inuvik-Tuk all weather road. We expect to see differences in productivity related to ice cover, differences in food web structure, and subsequently contaminants transfer along those hydro-climatic/salinity gradients. We would also expect to see different contaminant concentrations in Lake Trout related to growth rates as a result of differences in diet in the freshwater and marine influenced basins. We will use the chemical makeup of the Lake Trout earbone (otolith) to determine how much trout move within the Husky Lakes. We will also use a method that could allow us to track the 'fingerprint' of mercury through the food web. We will compare how the mercury 'fingerprint' differs in Yaya, Big, Noell lakes, and the Husky Lakes. We will inform the community about the concentrations in the Lake Trout in all sites. This study will build on and utilize knowledge from previous fisheries work in tundra upland lakes, the Husky Lakes, Yaya, and Big Lake. This project could aid in the future design of a community-based monitoring of the fisheries in the area and can be linked to other environmental pre-assessment plans currently being developed in the light of the Inuvik-Tuk all weather road.

CB-03
Paulatuk Beluga whales: Health and Knowledge

Project leader: Diane Ruben, Paulatuk Hunters and Trappers Committee

PLAIN LANGUAGE SUMMARY

- The community of Paulatuk hunts beluga whales in the summer. The hunts are limited by sea ice conditions that have been changing over the years. More open water earlier in the summer has changed the beluga occurrence and the hunts. Hunters have had concerns and questions about the health and well being of the beluga whales and their supporting ecosystems. While these are whales from the same population as those harvested at Hendrickson Island, previous research from 2005 showed differences in mercury concentrations, diet markers and other biological measurements (Loseto et al., 2008).
- The differences in whales collected at Hendrickson Island and those collected in Paulatuk raises new questions about variability among beluga and how one monitoring site is reflective of a large population with a home range. The Hendrickson Island beluga program provides intensive health information in context with the ecosystem, adding

new information from beluga whales harvest at Paulatuk would strengthen the holistic knowledge on this beluga population.

- Previous work has shown whales collected at Hendrickson have similar mercury concentrations as those collected at other nearby monitoring sites (Kendall Island, East Whitefish) that are located in the Mackenzie Estuary. The habitat near Paulatuk is very different than the Mackenzie Estuary. How habitat is used differs and may reflect different diets and processes among the whales. Including this site as a satellite monitoring site to Hendrickson will not only address community questions on health but will also enhance our understanding of these beluga on a larger scale.
- A proposal was submitted to NCP for 2011/2012 to address the community questions on beluga health and contaminants that may not be well represented by samples collected at Hendrickson Island. The proposal was unsuccessful, however a small pot of funds were obtained by FJMC and DFO to run a short beluga monitoring program in 2011.
- The program was a success sampling nine harvested whales at Browns Harbour. Two monitors were trained (by F. Pokiak; lead sampler at Hendrickson Island) and demonstrated ability to properly collect samples and data for further analysis. Currently samples are in Winnipeg awaiting analysis.
- The community of Paulatuk is concerned about both contaminant levels as well as potential impacts of climate change to the whales. Expected future changes in the environment such as climate change and increased industrial activity may change this habitat used by the beluga whales. Changes have been observed in other marine mammals such as ringed seals, their diet and their health. Understanding beluga health in context with their supporting ecosystems will provide information on management of the area.
- Given the success of the 2011 community lead beluga program we feel we are ready to begin moving the pilot program into the next phase. This program will be part of a larger new regional coastal monitoring initiative partnered with FJMC and DFO (details on the program can be provided upon request).
- Currently DFO is search for funds to support a pilot fish program at Browns Harbour to assess ecosystem linkages and links to the offshore BREA fish program (not sure to mention or not?).
- Knowledge collected from such programs will aid the community in future decision making in relation to conservation and development. The program will partner with the ongoing beluga monitoring program at Hendrickson and further engage youth in learning about the hunt, beluga health and science.

CB-04

Tlicho Aquatic Ecosystem Monitoring Project

Project leader: Jodi Snortland, Tlicho First Nations

PLAIN LANGUAGE SUMMARY

The proposed project builds on a community-driven aquatic ecosystem monitoring project carried out in 2010 and 2011 as a means of addressing community concerns related to observed changes in the environment. The project will engage local community members to collect samples and record a standard set of observations using both Tlicho and western scientific knowledge to address the question “are the fish and water safe to consume?”. As a

community- driven project, it will meaningfully involve community members in all aspects of conducting contaminants related research, including in the actual pursuit of monitoring and research objectives.

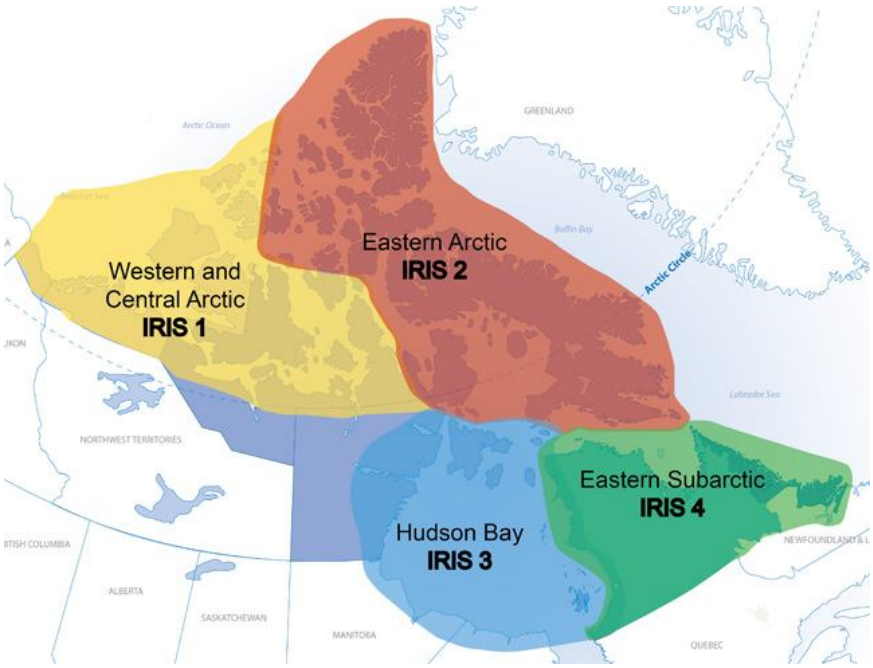
Community elders and youth in Wek'weètì will be informed through workshops discussing concepts such as monitoring, indicators of change as well as traditional and scientific knowledge relevant to water, sediments, fish, and potential contaminants. A key outcome of the workshops will be for advance planning of an on-the-land camp to take place at a location that supports a strong aboriginal subsistence fishery near the community of Wek'weètì. Guided by the "Tlicho Fisheries Health Datasheet" (developed through the project in 2011) Elders will be asked to provide assessments of fish health and to describe the indicators they use to identify fish health. Scientists will sample Lake Trout and Lake Whitefish tissues for analysis of mercury levels and will train Elders and youth to collect fish tissues for this purpose. Water and sediments will be sampled and analysed for metals as well as chemical and physical properties.

Results of the project will be communicated via a public meeting in Wek'weètì where the GNWT Health and Social Services, Chief Medical Officer, the NWT Regional Contaminants Committee along with the Tlicho Communications Advisor will take the lead in developing appropriate messaging and communication strategies.

Annex 2. Summary of ArcticNet projects related to AMAP

Broad Objective: The central objective of the Network is to translate our growing understanding of the changing Arctic into impact assessments, national policies and adaptation strategies.

In the context of a changing Arctic World, the research program of ArcticNet focuses on four main themes: coastal marine ecosystems, coastal terrestrial ecosystems, Inuit health and adaptation, and industrial development in the North. To address the identified knowledge gaps and research challenges, the core research program comprises 36 research projects grouped into four Integrated Regional Impact Studies (IRIS) that each underpin an Integrated Regional Impact Assessment (IRIA) to be re-edited at intervals of a few years. Each of the four IRIS corresponds to one of the main politico-physiographico-oceanographic region of the coastal Canadian Arctic. Although allocated to one IRIS for convenience, most projects operate in several of the regions and contributes to several of the four IRIA. Along with results of other arctic studies and assessments, and the expertise of our Inuit partners, the scientific conclusions and recommendations produced by the core research program of ArcticNet are compiled in the Integrated Regional Impact Assessment (IRIA) developed for each region.



Associations with AMAP: All of the projects described below are associated with AMAP and its climate change science related mandate. Some project are directly related to AMAP contaminants monitoring with links to the Northern Contaminants Program.

IRIS 1, Western and Central Arctic

The Western and Central Arctic IRIS focuses on the Inuvialuit Settlement Region and, for reasons of ecosystem continuity, extends into the SW sector of the Canadian Archipelago for the study of marine and terrestrial ecosystems. Demographically, the ISR Land-Claim Region is home to about 3000 Inuvialuit distributed in six communities. Among all regions of the Canadian Arctic, climate warming has been most intense in the Western High Arctic with temperature increases of 2 to 3°C in the last 50 years. The relatively productive ecosystem of the Mackenzie River Delta contrasts with the low-diversity coastal plain and islands which belong to the Southern Arctic ecozone (rolling uplands and lowland plains; long cold winters and short cool summers; dwarf shrub decreasing in size northward; musk ox, wolf, arctic fox, grizzly and polar bear, and caribou (Furgal et al. 2003). Throughout the region, the silty clays and organic terrain are rich in massive ice and the unlithified coast is subject to intense erosion as ground ice melts and the protection afforded against waves by landfast sea ice declines. The coastal ISR borders the south-west Beaufort Sea, including the shallow Mackenzie Shelf which is strongly influenced by the Mackenzie River plume, and the deeper Amundsen Gulf that connects to the Canadian Archipelago. The Beaufort sea is home to the largest stock of beluga whales in the world, a large population of bowhead whales in summer, polar bears and ringed and bearded seals. Marine diversity is generally low and productivity is weak to moderate except in a few biological hotspots such as the Cape Bathurst polynya on the eastern margin of the Mackenzie Shelf. Marine ecosystems north of the Amundsen Gulf remain largely unexplored.
Navigation on the Mackenzie River system, hard minerals mining (e.g. around Kugluktuk) and exploration for oil in the Delta region dominate the industrial sector. Exploration for oil was extended offshore in 2007 and 2008 with the sale of concessions at the continental margin of the Beaufort Sea.
Leader: Gary Stern
Coordinator: Ashley Gaden

Projects and Project Leader(s):

Smit, Barry (University of Guelph)
Project 1.1 Adaptation in a Changing Arctic: Ecosystem Services, Communities and Policy (Community Adaptation). Contributes to all 4 IRISes.

This project documents the changing physical, biological and socio-economic conditions that are affecting people in the Arctic and identifies policies and strategies to assist communities in dealing with these changes. The project builds on previous work on the vulnerabilities of Arctic communities, and it is feasible because of established collaborations with northern people and organizations. The project includes case studies in all four of the ArcticNet IRIS regions. One main focus of the project involves integrating scientific and traditional knowledge of ice, permafrost, coastal dynamics and wildlife with information about community use of these ecosystem services. The other main thrust is to identify the opportunities in existing policies and co-management

arrangements for adaptation strategies to help communities deal with changing conditions.

Stern, Gary; Macdonald, Robie and Wang, Feiyue (University of Manitoba/Fisheries and Ocean Canada)
Project 1.2 Effects of Climate Change on Contaminant Cycling in the Coastal and Marine Ecosystems (Contaminants). Contributes to all 4 IRISes.

Contaminants pose a potential hazard to Arctic fish and marine mammal health, and ultimately to northerners that consume the tissues of these animals as part of their traditional diets. It is therefore imperative that we strive to understand how climate variability in physical forcing and the biogeochemical response to this primary forcing will affect among others 1) contaminant transport processes and cycling; 2) biomagnification through Arctic marine food webs; 3) foraging behaviour of marine mammals (e.g. in response to changing sea ice regimes); 4) changes to hunting patterns and diets of northerners to reflect availability of traditional foods (e.g. less ice may lead to reduced reproductive success of ringed seals forcing northerners to consume more beluga tissues which typically have 10-fold higher contaminant concentrations). Overall, results from our research will help assess the vulnerability of coastal Inuit communities to climate change, document and project impacts of climate change on traditional food security and community health and provide the information required by communities, scientists and policy makers to help develop adaptation strategies. Our findings will help to test and shape the policy for the future management of contaminants emissions and long range transport to the Arctic and will support integrated ocean management programs such as Marine Protected and Large Ocean Management Areas (MPA & LOMA, respectively) such as zone 1(a)s in the Beaufort Sea.

Lamoureux, Scott and Lafrenière, Melissa (Queen's University)
Project 1.3 High Arctic hydrological, Landscape and Ecosystem Responses to Climate Change (Hydrology). Contributes to IRIS 2.

Water is crucial for northern communities and ecosystems and plays a vital role, in conjunction with climate and permafrost, in the morphology and stability of arctic landscapes. To determine the impacts of climate change on freshwater quality and availability in the High Arctic, we created a watershed and landscape ecosystem observatory. The research is conducted primarily at the Cape Bounty Arctic Watershed Observatory (CBAWO) on Melville Island, near the Nunavut/NWT border, with additional work at Polar Bear Pass on Bathurst Island. Research will investigate how climate change will affect rivers, permafrost, soils, vegetation, greenhouse gas emissions and the release of contaminants into High Arctic rivers, lakes and ponds.
Our integrated watershed network will provide an unprecedented understanding of the sensitivity and anticipated future effects of climate change to the High Arctic water, permafrost and ecosystem. By closely integrating related water and ecosystem process studies, this project will identify key environmental and societal vulnerabilities. Our goal

is to develop impact models to assess linkages between anticipated environmental change and possible adaptations by communities and government agencies (clean water supply and ecological integrity) and industry (resource extraction, infrastructure protection).

Wrona, Fred (University of Victoria)
Project 1.4 Hydro-Ecological Responses of Arctic Tundra Lakes to Climate Change and Landscape Perturbation (*Tundra Lakes*).

The Arctic Climate Impact Assessment (2005) concluded that the annual mean warming for the areas north of 60°N to be 3.7°C for the period 2070-2089. Hence, the Arctic is expected to display a warming that is more than twice the global average, show decreases in snow cover and ice extent, display further retreat/degradation of permafrost, and have increased inter-annual variability in extreme precipitation events. Such significant changes/shifts in climatic regimes are expected to have far-reaching cascading impacts on the hydrology and ecology of Arctic freshwater ecosystems, which are highly sensitive to climate variability and change (CVC). Large-scale permafrost degradation (i.e., increased depth of seasonal active layer and/or landscape slumping) is predicted to increase with the effects of climate warming, along with enhanced addition of geochemical loadings (e.g., carbon, nitrogen, phosphorus) to the freshwater environment. In addition, changes in the timing and duration of lake-ice characteristics in conjunction with altered geochemical loadings are projected to dramatically affect affecting freshwater ecosystem productivity levels, energy mobilization pathways and community structure. The goals of this research are to: 1) conduct three integrated landscape-lake process and modeling studies that will improve our regional understanding of the sensitivities/responses of upland tundra lakes to CVC; 2) to develop and validate an integrated landscape-geochemical, lake-ice, hydro-ecological model applicable to cold regions/Arctic systems; and, 3) to develop and test new and innovative automated water quality/hydrometric monitoring systems for application in the Arctic. The project is producing legacy data and products of direct benefit to the development of adaptation options for the conservation, protection and management of arctic freshwater ecosystems to present and future climate variability and change.

Hughes Clarke, John (University of New Brunswick)
Project 1.5 The Canadian Arctic Seabed: Navigation and Resource Mapping (Seabed Mapping). Contributes to all 4 IRISes.

This project undertakes the core seabed mapping component of the ArcticNet research program. Underway acoustic mapping of the seabed relief, sediment distribution and shallow subsurface sediments are the prime datasets used by researchers to understand the geological processes shaping the seafloor, to assess natural hazards and coastal habitats and to reconstruct the history of past climatic changes. These mapping results are applied to specific projects in this proposal including :
- **Marine geohazards to hydrocarbon development**: Canada has potentially huge economic benefits to gain by having access to the natural resources of the Arctic

Archipelago region. Exploitation in this manner however, can only proceed in a safe and responsible manner, by managing the potential detrimental impacts to the environment. A key requirement is to be able to assess potential natural hazards that might result in harmful affects both to persons and the environment. Natural hazards such as underwater landslides, collapse of offshore structures built on gassy seabeds and the impacts of glacial and sea ice must be known and their risk managed.
- **Opening new shipping lanes and improving navigational charting**: Despite previous focused mapping programs in the bottleneck regions, the Archipelago region remains sparsely mapped with shipping normally restricted to narrow singular corridors that may be ice covered. Because the Amundsen is operating a multipurpose mission throughout the region, there is a golden opportunity to simultaneously map uncharted regions to provide alternate pathways.
- **Past to present evolution of sea-ice regime**: Understanding past climatic history is the key to predicting potential future ramifications of a changing sea ice regime. To responsibly plan adaptation strategies, we need to be able to predict future climatic responses and their consequences. It is also the key to understanding the nature of these changes-i.e. are they part of a natural cycle or induced by present excess of greenhouse gases. The mapping is an essential precursor to designing seabed sampling strategies to recover undisturbed sediments.

Byers, Michael (University of British Columbia)
Project 1.6 The Law and Politics of Canadian Jurisdiction on Arctic Ocean Seabed (*International Law*). Contributes to IRIS 2.

The possibility that the Arctic Ocean seabed contains vast deposits of hydrocarbons is attracting considerable attention. Under the 1982 UN Convention on the Law of the Sea (UNCLOS), any state party may, within 10 years of ratifying, seek to extend certain sovereign rights over the seabed beyond its 200 nautical mile Exclusive Economic Zone. To do so, it must establish—through the collection and submission of information concerning topography and geology—that the area of seabed in question is a "natural prolongation" of the continental shelf within 200 miles. Canada, which ratified UNCLOS in 2003, is currently mapping the seabed along its northern coastline so that it can submit the necessary information to the UN Commission on the Limits of the Continental Shelf by 2013. The United States, Denmark and Russia are undertaking similar exercises, albeit with different timelines. This international, interdisciplinary research project focuses on several outstanding maritime boundary disputes—involving the United States, Denmark and potentially Russia—that must be resolved before Canada can submit a comprehensive package of information to the UN Commission. The resolution of these disputes is highly desirable because the Commission lacks authority to deal with information submitted by a state where it is possible that another state will have a claim to that same area. The project will analyze the legal and political differences involved in the different disputes, explore the various options for resolving them, and provide detailed recommendations. These recommendations will specify a series of considered options occupying progressive positions on the scale of political and technical acceptability. Then, the government of the day will be able freely to select the option that

best suits its priorities and objectives, or use the input from this project to craft a better option of its own.

Goodman, Karen (University of Alberta)
Project 1.7 Community-Driven Research on *H. pylori* Infection in the Inuvialuit Settlement Region (*H. pylori infection*).

Despite limited systematic data on its presence in northern Canada, Helicobacter pylori infection has been an emerging health concern in northern Aboriginal communities, where people are becoming aware of its health risks. In many such communities, people worry about the link between H. pylori and stomach cancer, a cancer that occurs more frequently in this region than on average across Canada. Physicians in the north view this infection as a major challenge because it is found in many patients with common stomach complaints and standard treatment is often ineffective in this setting. Health authorities have identified the need for research aimed at developing H. pylori control strategies appropriate for the north. This research program seeks to generate knowledge about how health care decision makers can effectively manage H. pylori infection in a manner that addresses community concerns. To achieve these goals, the applicants formed the Canadian North Helicobacter pylori (CANHelp) Working Group, a collaborative team that links the University of Alberta with northern health officials and community organizations. While the research goals require data from multiple northern settings, the team conducted a pilot project as a starting point in Aklavik, NWT, where they found that 62% of participants had H. pylori infection, and among those infected, there was a high prevalence of precancerous stomach conditions. This research program, developed at the request of the Inuvialuit Regional Corporation, aims to: 1) Expand the research to additional communities in the Inuvialuit Settlement Region to obtain representative data required for developing regional public health strategies pertaining to H. pylori infection; 2) Identify cost-effective and culturally appropriate H. pylori management strategies for northern communities; 3) Create knowledge exchange strategies to help community members understand H. pylori health risks and currently available solutions.

Fortier, Louis (Université Laval)
Project 1.8 The Arctic cod (*Boreogadus saida*) ecosystem under the double pressure of climate change and industrialization (*Arctic cod*).

The Arctic cod (*Boreogadus saida*), also known as the polar cod in Europe, is a key component of the Arctic Ocean pelagic ecosystem that effects up to 75% of the energy transfer between the plankton and the vertebrate fauna (fish, seals, whales and marine birds). Being an hyper-specialist adapted to life in ice-covered seas, Arctic cod is likely to be displaced by southern generalists such as the capelin and the sandlance as the ice regime becomes less severe. This project collaborates closely with "Hotspots", "Moorings" and "Sea-ice" to map the distribution of Arctic od in the Canadian Arctic, and to measure variations in its hatching season and early growth in relation to annual changes in ice regime, surface temperature, and zooplankton prey abundance. We also focus on numerical models of the early growth and survival of the juveniles. In partnership with the Oil Exploration sector and the Department of Aboriginal Affairs and

Northern Development (Beaufort Regional Environmental Assessment program), we assess the general distribution and reproduction of Arctic cod in the Beaufort Sea and the potential environmental risks of drilling on its ecology.

Babin, Marcel (Université Laval)
Project 1.9 Remote Sensing of Canada's New Arctic Frontier.

Rapid climate change and industrialization are unlocking the natural resources of the vast Canadian Arctic and increasingly impacting its ecosystems. The stewardship of these ecosystems, the environmentally sustainable development of arctic resources, and the adaptation of northern communities to their rapidly changing world require a massive intensification of scientific observations. Furthermore, these observations must be organized into geo-referenced data banks and models that will provide stakeholders in government, industry and communities with the knowledge needed to inform their decisions. The objectives of this project are aligned with the targeted achievements of the Canada Excellence Research Chair on "Remote Sensing of Canada's New Arctic Frontier" to: (1) Augment in time and space the observation of arctic marine ecosystems by implementing new algorithms for the remote-sensing of phytoplankton, particulate matter, dissolved organic carbon and seawater optical properties in the surface layer of the Canadian Arctic Ocean, from which primary production, bacterial growth, and organic matter photo-oxidation will be derived; (2) Develop, validate, and implement the urgently-needed ecosystem models that will help anticipate the impacts of climate change and industrialization on the resources and services (fisheries, navigation, minerals, energy, tourism) provided now and in the near future by the ecosystems of the Canadian Arctic Ocean; (3) Adapt existing and future new observing technologies to the extreme conditions of the Arctic Ocean, with emphasis on the field deployment of Profiling Floats, Autonomous Underwater Vehicles, and Ocean Gliders, and on the use of optical sensors; (4) In collaboration with the Canadian Cryospheric Information Network (CCIN), Centre d'études nordiques (CEN) and other national and international partners, mesh the respective expertise of ArcticNet and GEOIDE, two pan-Canadian NCE, into the development of state-of-the-art geo-referenced data archiving systems that can be accessed online by scientific, industrial and government stakeholders to produce maps and analyses of the transforming Canadian Arctic. The scientific broad objectives of this ambitious program are: (1) To understand the functioning of the arctic marine ecosystems. What is the composition of the microbial communities (biocenoses)? Who are the main players among phytoplankters and bacteria in terms of energy and biomass transfer to higher trophic levels? What are the main ecologically distinct environments (biotopes)? Where do critical biological processes really happen in this environment? What are the interactions between the biocenoses and biotopes? How does the ecosystem work? (2) To determine the carbon fluxes (rivers ? coastal environment ? ocean), with special emphasis on those affected by light. What is the impact of bacterial activity and photo-oxidation on mineralizing organic carbon? What is the extent of new organic carbon production by primary production? What are the chemical and physical factors controlling those three carbon fluxes affected by light: primary production, bacterial activity and photo-oxidation? What is the spatial and temporal variability of those three

processes? What large-scale physical phenomena control that variability? (3) To determine the impact of current and near-future changes in the Arctic environment on marine ecosystems and biogeochemical fluxes. How will CO2 production from the mineralization of old organic carbon be compensated by the new sequestration of carbon? Will the Arctic Ocean experience a major shift biotopes and biocenoses? What will be the impact on higher trophic levels? Briefly, the milestones are, for 2011-2014: (i) Develop the CERC technical team and implement the necessary land-base research facilities; (ii) adapt autonomous platforms and in situ sensors for operation in the Arctic Ocean; (iii) identify and isolate the key Arctic phytoplankton species during oceanographic cruises; (iv) characterize in the laboratory their optical and physiological properties, and derive relevant model parameters, (v) archive and process all available ocean color data and other relevant remote sensing data for the Arctic Ocean; (vi) conduct intensive sampling in key region of the Arctic Ocean with regard to biological production, using various platforms (ship, AUV, gliders and profiling floats) ; and (vii) analyze time series derived from remote sensing data and diagnostic models to identify the main drivers of biological production.

IRIS 2 Research (Eastern Arctic)

Nunavut ("our land" in Inuktitut) is the ancestral home of the Inuit of the Central and Eastern Arctic. It is the largest, least populous, and newest federal territory of Canada, having been separated officially from the Northwest Territories on April 1, 1999 (Nunavut Act and the Nunavut Land Claims Agreement Act). Nunavut comprises the greater part of the Canadian Arctic Archipelago and the islands of Ungava, Hudson and James Bay. The territory covers 1,932,255 km2 of land and 160,935 km2 of water. Several islands in the Archipelago are divided between Nunavut and the Inuvialuit Land Claim Settlement, notably Victoria, and Melville Islands. The landscape has been shaped by ice sheets and glaciers, which carved out deep valleys and fjords. Today, it is being altered by climate-related changes such as rising temperatures, retreating sea ice, and thawing permafrost. Ecosystems vary widely, from the flat tundra west of Hudson Bay to the rich North Water polynya in northern Baffin Bay. Of great scientific interest is the south-north gradient in terrestrial coastal arctic ecosystems from the northern limit of the taiga to the arctic desert of Ellesmere Island.
Nunavut is currently home to approximately 30 000 residents, 85 percent of whom are Inuit (Nunavummiut), distributed in 26 coastal communities. The population is young (35% under 18 years of age) and is projected to increase from 32 183 in 2009 to 44 581 by 2036. The economy is a mix of wage-based economy (mining, exploration, tourism, fisheries, art) and land-based economy, an integral part of the Inuit cultural and social way of life. Activities such as harvesting caribou, seals and Arctic char provide a healthy diet, education, community cohesion, and cultural identity. Nunavut's economy is still highly dependent on employment in the public sector (Government of Nunavut, municipal, education, health and security). Vast distances, a small but growing population, the high cost of materials, energy, transport and labour, and extreme and changing climate challenge the Nunavut's government and people.
Government in Nunavut co-exists with a number of public bodies directly and indirectly related to the Nunavut Land Claims Agreement. Nunavut Tunngavik Incorporated (NTI) represents Inuit beneficiaries, manages federal funding resulting from the claim, offers services and programs, and oversees co-management bodies such as the Nunavut Planning Commission, the Nunavut Wildlife Management Board and the Nunavut Water Board.

Leader: Trevor Bell
Coordinator: Philippe Leblanc

Projects and Project Leaders:

Vincent, Warwick (Université Laval)
Project 2.1 Freshwater Resources of the Eastern Canadian Arctic *(Freshwater Resources)*. Contributes to IRIS 4.

Lakes and wetlands are major ecological features of the circumpolar Arctic, and they provide many essential services including habitats for aquatic wildlife, drinking water supplies for northern residents, and water for industrial activities. Inuit communities and

northern scientists have increasingly observed that these resources are highly vulnerable to ongoing climate change. The project proposed here will extend our observations on lakes and wetlands at key sites in the eastern Canadian Arctic, to identify and measure aquatic indicators of environmental change in the past and present. These studies will allow us to make assessments of future changes in northern freshwater ecosystems to help guide the formulation of environmental management policies. We will continue our research on lakes, ice shelves and contaminants along the northern Ellesmere Island coastline based out of Ward Hunt Island Observatory, where we will work with Parks Canada to develop facilities, indicators and protocols for long term monitoring. This coastline lies at latitude 83oN, at the northern limit of Nunavut and thus North America, and it is characterized by many climate-sensitive aquatic ecosystems that are highly dependent on ice. We will extend our research to wetlands by assessing the snow storage and melt patterns in Polar Bear Pass on Bathurst Island (75oN). This Wildlife Sanctuary is composed of a mosaic of lakes and ponds, and seasonal snowmelt is considered the most important source of water to this wetland. The resultant models and understanding should be of broad application to arctic wetland wildlife habitats that have begun to respond strongly to climate change. Permafrost thaw lakes are a prominent component of northern wetland ecosystems, and we will work at several sites including Bylot Island (73oN) and Kuujjuarapik (55oN), to determine the environmental factors that control their ecosystem metabolism and net production of greenhouse gases in the present and future. We will analyze sediment cores from northern waters in the Foxe Basin region (65-70°N) to assess the natural climate variability in arctic and subarctic Canada, and to identify regional variations in climate sensitivity. Finally we will develop and apply new DNA-based techniques to assess the diversity and function of microscopic life in lakes and wetlands and to develop state-of-the-art molecular indicators of climate responses by northern aquatic ecosystems. We will contribute our findings and expertise on Canadian arctic water resources to the ArcticNet IRISs and panArctic climate impact assessments (e.g. the SWIPA report). Enfin, nous documenterons les changements climatiques passés de l'est du Subarctique canadien au moyen d'un vaste résera de séries dendroclimatiques millénaires. Finally, past climate changes will be documented in the eastern Canadian subarctic by means of a vast network of millennial tree-ring network.

Tremblay, Jean-Éric (Université Laval); Gosselin, Michel (Université du Québec à Rimouski); Archambault, Philippe (Université du Québec à Rimouski)
Project 2.2 Marine Biological Hotspots: Ecosystem Services and Susceptibility to Climate Change *(Marine Ecosystem Services)*. Contributes to all 4 IRISes.

Living, harvestable resources in the upper Arctic Ocean ultimately depend on the production of marine microalgae. Microalgal production also mitigates global warming by fixing the greenhouse gas CO2 into biomass, of which a portion sinks to the seafloor. This process, called the “biological CO2 pump”, supplies food to the benthic organisms living at the bottom. Ongoing alterations of the physical environment will have profound impacts on the growth conditions of primary producers, affecting the timing, productivity and spatial extent of biological hotspots (i.e. areas of elevated food web productivity against the low background typical of the Canadian Arctic). This project investigates how

changes in the dynamics of sea-ice and glacial ice (icebergs and ice islands), water temperature, ocean circulation and wind forcing affect primary production in the upper water column and the benthic ecosystem underneath. Specific objectives are to 1) locate biological hotspots (and coldspots) of pelagic and benthic activity, 2) assess how they function and interact, and 3) assess how their productivity and biodiversity is likely to respond to further perturbations of the environment. To do so, we are and have been developing and implementing cutting-edge observational and experimental approaches that exploit remote sensing from space, autonomous underwater vehicles as well as the sampling and laboratory facilities of the CCGS Amundsen. Our work is done in very close collaboration with several ArcticNet projects, collaborators and partners from government and the industry.

Henry, Greg (University of British-Columbia)
Project 2.3 Impacts of Vegetation Change in the Canadian Arctic: Local and Regional Assessments *(Arctic Vegetation)*. Contributes to IRISes 1 & 4.

The tundra across the Canadian Arctic is already reacting to climate change. Northerners and scientists are observing changes, such as shrubs getting taller and more numerous. The taller shrubs catch more snow, and change the depth and pattern of snow drifting, which could affect travel and caribou migration. Increases in the cover of shrubs will also result in more sunlight being absorbed by the leaves and this will increase the temperature even further. We will study these changes near Arctic communities across the North. Community members are involved in designing the studies and in conducting measurements on tundra vegetation. An important focus of the project is the measurement of changes in amounts of berries produced each year in traditional berry picking areas near the communities. Experimental studies including warming with small open-top greenhouses and altering snow deposition with snow fences have been established to determine effects on vegetation, especially berry shrubs. These studies have been incorporated into science studies in the local schools and used to show students how traditional ecological knowledge and scientific studies can be used together. The results will be used in the communities and will contribute to national and international efforts to understand the responses of tundra ecosystems to climate variability and change.

Bell, Trevor (Memorial University of Newfoundland); Forbes, Don (Memorial University of Newfoundland / Geological Survey of Canada)
Project 2.4 Instability of Coastal Landscapes in Arctic Communities and Regions *(Coastal Landscape)*. Contributes to IRISes 1 & 4.

Future climate scenarios and impacts modeling predict changes in climate variables that may increase coastal landscape instability and hazard risk. Projecting the future response of the coastal land system to these changes in climate forcing is a prerequisite for an effective adaptation strategy and forms the core of this ArcticNet project. Through improved understanding of changes in climate, sea-level, sea ice, storms and wave

climate, seasonal thaw depths, and other aspects of environmental forcing we will assess integrated impacts on coastal landscape stability, including flooding, erosion, habitat integrity, and community vulnerability. Together with northern communities and partners we plan to integrate local and external research and knowledge on climate-change trends and impacts in order to provide a common basis for decision-making at all levels, thereby enhancing community adaptive capacity. Ultimately the goal is to promote informed choices of adaptation measures and enhanced resilience in northern coastal communities.

Huebert, Rob (University of Calgary)
Project 2.5 The Emerging Arctic Security Environment *(Arctic Security)*. Contributes to all 4 IRISes.

Climate change is fundamentally reshaping the Arctic region. Boundary disputes, newly viable transportation routes, access to resources, and governance issues have generated significant questions about Arctic security and circumpolar geopolitics in the twenty-first century. Anticipating future prospects for competition, conflict and cooperation in the region requires a systematic examination of the new forces at play, both internationally and domestically. Our project examines the fundamental questions: what is Arctic security? What should policy makers anticipate that the circumpolar world will look like in the future, given the various forces that are now transforming this region? These questions will be posed at the international and national levels to discern what senior government officials, indigenous groups, corporate interests, scientists, academics, and Northern residents perceive to be the most significant security and safety challenges in the Arctic, and to determine what unilateral, bilateral and multilateral mechanisms should be in place to address them. This project will make two primary contributions: one policy focused and the other academic. First it will add to the public policy debate about the evolving Arctic security environment. Our research team will critically assess the interplay between traditional, state-based military security and environmental, health, and societal security concerns. Our development of future scenarios – based upon a robust knowledge of past decision-making processes and practices, Northerner's experiences and priorities, and scientific modelling about climate change in the region – will facilitate responsible policy development. In linking international and domestic security practices to human impacts, we will generate more integrated tools to anticipate the consequences of security action/inaction on Northern ecosystems and peoples. This will improve Canada's capacity to deal with external challenges in a way that is sensitive to, and better integrates, Northerners' concerns and priorities. Second this project will advance the academic debates about how best to understand the relationship between environmental, political, and socio-economic processes that are changing ideas about Arctic security. Community consultations will ground our analyses of how the changing geopolitics of the Arctic will impact Northerners' culture, well-being, and economies. We will refine existing frameworks and models to incorporate the complexity of these new forces, better explain the actions that are now being taken, and generate appropriate lessons for future relationship-building.

Rodon, Thierry (Université Laval)
Project 2.6 Improving Access to University Education in the Canadian Arctic *(University Education)*. Contributes to all 4 IRISes.

Increased participation in postsecondary education is of primary concern for Inuit. The goal of this project is to provide evidence-based research on Inuit participation in University education throughout Inuit Nunangat and to promote a national discussion amongst provider of university program in Inuit Nunangat, Northern institutions and Inuit organizations in order to develop a more coordinated effort in program delivery, curriculum development. More specifically this research has three objectives: 1) Make an inventory and evaluation of past and present university initiatives in Inuit Nunangat or for Inuit in term of curriculum, delivery methods and success, 2) Evaluate the Inuit Peoples needs and experiences with postsecondary programs or courses in order to better understand educational paths and university successes from the point of view of the Inuit 3) Develop different scenarios to improve access to university education for Inuit and Northerners in Inuit Nunangat. The data is being collected through surveys, in-depth interviews and workshops. This research provides evidence-based data on the Inuit students' university experience: Inuit participation in university programs; definition of university and educative success from a point of view of Inuit that will help university program providers deliver programs better adapted to the needs of Inuit students; monitoring of Inuit student success according to this definition; inventory and evaluation of the university program delivered in Inuit Nunangat and for Inuit students; and development of scenarios to improve access to University program for Inuit students.

Walton, Fiona (University of Prince Edward Island)
Project 2.7 *Inuit Qaujimajatuqangit* and the Transformation of High School Education in Nunavut *(High School Education)*.

The *National Strategy on Inuit Education* (NCIE) argues, "there is almost no data or evidence supporting any of the major policy shifts in Inuit education" (2011, p. 90). This research, conducted with partners at the Nunavut Department of Education and the Coalition of Nunavut District Education Authorities (CNDEA) in Nunavut, begins to create evidence of performance measures and factors that influence high school graduation in Nunavut, one of the highest priorities of the Nunavut Government and the NCIE. It establishes an approach to gathering longitudinal information on high school education and reveals practices that contribute to students' ability to graduate. The research offers support for legislative and policy changes within high school education in Nunavut. The research also documents the leadership of Inuit principals and District Education Authority (DEA) members in Pangnirtung and Clyde River, providing much-needed, research-based examples of community-school collaborations, parental engagement and efforts to transform education by catalyzing change at the high school level in Nunavut. Data was used to create a documentary video in Inuktitut with English subtitles. *Going Places: Preparing Inuit High School Students for a Changing, Wider World* (Sandiford, Walton, Metuq, Hainnu, Pitsiulak, Flaherty, Wheatley & O'Leary,

2011), captures the views and opinions of students, Elders, Inuit staff and parents as they implement new curriculum initiatives based on *Inuit Qaujimajatuqangit* (IQ), Inuit ways of knowing and being. The involvement of Inuit graduates of the UPEI Master of Education (MEd) Nunavut continues to build research and leadership capacity within Nunavut. Findings from dialogue with young people in Rankin Inlet and Pangnirtung during the 2011/2012 year reveal specific approaches in high school education that promote student engagement. The ten-year historical and statistical profiles of the high schools in Pangnirtung, Clyde River and Rankin Inlet are starting to reveal patterns and challenges related to educational outcomes and indicators at the high school level across Nunavut (McGregor, 2011, 2012).

Rysgaard, Soren (University of Manitoba)
Project 2.8 Arctic Geomicrobiology and Climate Change.

Anthropocene is a time of extraordinary change in the Arctic. It has experienced unprecedented variability in both the rates and magnitudes of change in the cryosphere, atmosphere and lithosphere, dependent ecosystem function variability, increased industrial development, and concomitant globalization of local economies. These changes are challenging our ability to respond and to develop a coordinated and scientifically informed policy for the Arctic. The objectives of this project are aligned with the targeted achievements of the Canada Excellence Research Chair on "Arctic Geomicrobiology and Climate Change" to increase understanding on geomicrobial transformations as they occur in Arctic sea ice and sediments, including the regeneration of nutrients required by primary producers and thus the health of all other inhabitants of the Arctic marine system. The project will address 4 key research questions and 2 objectives: (1) What are the relative contributions of dynamic and thermodynamic forcing to the observed change in sea ice areal extent and thickness and how is this related to intra- and extra-Arctic climate processes, variability, and change? (2) What are the consequences of change in Question 1 on biogeochemical cycling, including carbon, nitrogen, sulphur, phosphorous, oxygen, and their stable isotopes? (3) What are the consequences of changes in Questions 1 and 2 on ecosystem function, examined throughout the complete trophic structure: beginning with microbial processes, primary and secondary production, through to apex predators; and on habitat structure: benthic, pelagic, epontic, and within the ocean–sea-ice–atmosphere (OSA) interface? (4) What are the consequences of change on release, transport, and biological impact of chemical contaminants, including both organic and inorganic contaminants, across Arctic biotic and abiotic environmental interfaces? Objective 1: To produce models of coupled physical-biological processes examined in Questions 1 through 4 as a means of making the project science predictive and able to inform future environmental conditions. Objective 2: To provide and communicate a knowledge base upon which public policy development can build to address the key issues facing the Canadian Arctic (e.g., sustainable development, globalization, socioeconomic stability, and environmental stewardship). Recent evidence suggests that microbial activity and chemical transformations within sea ice greatly influence inorganic carbonate chemistry, playing a far more important role in regulating carbon dioxide (CO_2) uptake by Arctic seas than previously anticipated. The objective of the program is

to investigate and quantify the importance of these fundamental microbial activities using state-of-the-art assessment techniques in a comprehensive three-pronged approach of ice tank, in situ, and modelling studies. Combining experimental ice tank and in situ studies will provide important new insight into the regulation of these processes, their seasonal and geographical distribution, and how they are coupled between surface ocean and seafloor. Modelling activities will range from small-scale studies within the sea ice and sediment compartments to local coastal regions of strategic importance and the large-scale systems of the Arctic Ocean and neighbouring seas.

Berteaux, Dominique (Université du Québec à Rimouski)
Project 2.9 Effects of Climate Change on the Canadian Arctic Wildlife *(Arctic Wildlife).*
Contributes to IRIS 3.

Many northern ecosystems are undergoing major shifts related to climate change. An understanding of this transformation and of the significance of its consequences is critical to anticipating ways in which potential negative and positive effects to wildlife populations (and ultimately humans) may be mitigated or used through sound management. Our overall goal is to provide the wildlife-related knowledge necessary to conduct the integrated regional impact studies of the “Eastern Arctic” and “Hudson Bay”, two of the four regions identified by ArcticNet to conduct regional impact studies. We work through 4 specific objectives. First, we identify the main vulnerabilities of Arctic wildlife with regards to climate change. Second, we monitor more than 30 wildlife populations (mostly tundra wildlife and marine birds) at 6 main study sites located in the Eastern Canadian Arctic (from South to North: Belcher Islands, Rankin Inlet, Coats Island, East Bay-Southampton Island, Bylot Island, and St.Helena Island). Third, we use data from our own field work and from the literature to analyze past and present responses of wildlife to climatic variability in order to develop Impact Models. Finally, we project some wildlife patterns into the future by forcing these Impact Models with regional climate change scenarios. This project is a collaboration between ArcticNet researchers and a number of partners including the Canadian Wildlife Service (Environment Canada), Parks Canada Agency, Wildlife Conservation Society Canada, Nunavut Tunngavik Inc., Nunavut Wildlife Management Board, Baffinland Iron Mine, Department of Environment of Goverment of Nunavut, and many Northern communities, especially members of their Hunting and Trapping Organizations. Our project helps ArcticNet impact studies to provide decision makers in the wildlife sector with a sound basis for working at adaptation strategies in a changing climate.

IRIS 3 Research (Hudson Bay)

The Hudson Bay marine ecosystem encompasses Hudson Bay, Foxe Basin and Hudson Strait and, at 1 240 000 km2, is the largest inland sea in the world. It connects to the Arctic Ocean through Fury and Hecla Strait and to the Atlantic Ocean through Hudson Strait. The surrounding Hudson Bay Lowlands are low, permafrost-laden plain characterized by marshes, peat and ponds. The land surrounding the Bay is slowly rising due to isostatic rebound, slowly exposing more and more coast. Its relatively southern location supports the most southern Arctic marine ecosystem in the world. This leaves the Hudson Bay system highly susceptible to climate change. The Bay experiences complete annual sea ice cover in the winter, and becomes ice-free each summer. Ice cover starts in late October in the northern parts of the Bay, while the maximum ice coverage occurs in April. Several polynyas recur in the Bay predominantly along the north-west and east coasts. The Bay is fed by numerous large rivers on its western, southern and eastern shores. This freshwater influx strongly affects the general counter-clockwise coastal circulation. The Hudson Bay watershed covers over a third of the Canadian landmass, from southern Alberta to central Ontario to Baffin Island, as well as parts of North Dakota and Minnesota.
The Bay is home to several species of fish, seals, whales, migratory birds, sea birds, as well as mammals such as the polar bear and caribou. The bioregion has been traditionally inhabited by Cree in the south, occupying parts of Manitoba, Ontario and Quebec, while Inuit have long inhabited the north, including the eastern shores of Hudson Bay, north Nunavik, and the Nunavut, including the island communities of Coral Harbour and Sanikiluaq. As part of their traditional subsistence hunting, Cree harvest waterfowl and terrestrial mammals like moose. Inuit traditional subsistence includes the harvesting of fish, seals, whales, while caribou are also important in some communities. The shores of Hudson Bay are shared by the provinces of Quebec, Ontario and Manitoba, and the territory of Nunavut. The islands within Hudson Bay are part of Nunavut, including the Belcher Islands in the south, while the waters of the Bay are under exclusive federal jurisdiction. Hydroelectric development is extent in the Hudson Bay watershed, and plays a significant role in the water flow and timing of several of the large rivers draining into the Bay. Other commercial activities in Hudson Bay include mining and shipping in summer via the Port of Churchill, the only deep water port of the Canadian Arctic.
Leader: David Barber
Coordinator: Dan Leitch

Projects and Project Leader(s):

Papakyriakou, Tim (University of Manitoba)
Project 3.1 Carbon Exchange Dynamics in Coastal and Marine Ecosystems *(Carbon Dynamics)*. Contributes to all 4 IRISes.

Our overarching objective is to understand the effects of climate change on the air-sea exchange and associated exchange budgets of climate active gases (carbon dioxide-CO_2 ,

dimethylsulfide-DMS, and nitrous oxide-N_2O) in the Canadian coastal Arctic environment.
Oceans exert considerable influence on climate through their role on the global cycling of climatic active gases. For example, the world's oceans are nature's largest sink for CO_2 and they globally account for a significant proportion of the natural emissions of the greenhouse gas nitrous oxide (N_2O), and the vast majority of dimethyl sulfide (DMS) production. DMS is the largest source of sulfate in the marine environment, and once in the atmosphere the compound can trigger the formation of aerosols that serve as cloud condensation nuclei. While greenhouse gases (CO_2 and N_2O) act to warm the atmosphere, the increased production of DMS may have a cooling effect on climate by increasing back-scattered solar radiation. Our understanding of the effect that a changing Arctic climate and sea ice regime will have on the air-sea (and sea ice) exchange of these trace gases is currently somewhere between partially understood and mostly unknown, and hence important feedbacks that involve sea ice and the cycles of climate-active gases are currently not represented in general circulation models.
A requirement of this project is to parameterize both those processes affecting the distribution of dissolved CO_2, N_2O, and DMS in surface waters of the Arctic, and their exchange with the atmosphere. Newly developed parameterizations are being implemented into a coupled atmosphere-sea ice-ocean biogeochemistry models to learn how the ocean's response (physical, biogeochemical and biological) to climate change and variability will affect the atmosphere-ocean cycling of these climate active gases within the Arctic, and in turn how these regional processes may affect the global budgets of these gases.

Barber, David (University of Manitoba); Sydor, Kevin (Manitoba Hydro)
Project 3.2 Freshwater-Marine Coupling in the Hudson Bay IRIS *(Freshwater-Marine Coupling)*. Contributes to IRISes 2 & 4.

Climate models predict warming in the Hudson Bay watershed that may alter the amount and timing of runoff and hence, of the load of suspended solids, dissolved organic matter and other major nutrients, and heat delivered to the Bay. In the Churchill and Nelson estuaries, such changes will be superimposed on earlier changes in the hydrological regime – diversion of Churchill River flows into the Nelson River and a shift of a third of total discharge from summer to winter. Our study of transfer pathways through river estuaries into Hudson Bay will improve our understanding of the effects of these changes. The overarching objective of this project is to describe the impact of freshwater quality and quantity on marine processes within Hudson Bay. In particular we are interested in understanding the principal processes which couple the freshwater and marine systems in Hudson Bay and to examine the cumulative impacts of climate change and hydroelectric development on Hudson Bay. Our key industry partner (Manitoba Hydro) will use this information to examine aspects of environmental impacts due to development of dams along the Nelson River, including the planned development of Conawapa in 2010. More specifically our team will determine the fluxes, pathways and fate of suspended solids and dissolved organic matter transferred through the Churchill and Nelson estuaries during the open water season when mixing in the estuary is determined by wind-driven

waves, tides and fluvial and marine currents, and under ice, when mixing is determined by tides and fluvial and marine currents alone. We will also investigate the relative significance of fluvial loading and littoral resuspension to concentrations of suspended solids in the estuaries and Hudson Bay and to study the effect of suspended solids and dissolved organic matter on radiative transfer in the estuary and nearby Hudson Bay. This team will also investigate historical effects of climate on Hudson Bay by interpretation of data stored in bottom sediments within our three supersites – the estuaries of the Nelson and Churchill Rivers, and of the Grande Rivière de la Baleine – and also in sediments deposited at the Bay-wide scale.

Ferguson, Steven (University of Manitoba/Fisheries and Oceans Canada)
Project 3.3 Impacts of Global Warming on Arctic Marine Mammals *(Marine Mammals)*. Contributes to all 4 IRISes

This project examines various aspects of Arctic marine mammal (seals, whales, and polar bears) ecology to try to determine the impacts of global warming on their abundance and distribution. Research will answer: •How will marine mammals adapt to global warming – and what are the possibilities for future survival? •What is the relationship between warming temperatures and the habitats of seals, whales, and polar bears? •What are the potential effects of global warming on reproduction and survival? •What will be the effects of changes on northern communities and Inuit lifestyle? •How can we reduce the impacts of these changes on Arctic peoples and marine mammals? Satellite tracking, analysis of tissue samples collected by local hunters, and genetics and population modeling are methods that will be used to understand how these animal populations may respond to environmental change. Several areas of Arctic marine mammal health are also being studied, including diet, diseases, contaminants, and stress. Knowing how polar ecosystems may change with global warming will help to develop strategies for conservation and species management. Northerners depend on these species as a food source and as an integral part of their unique culture, and results will help Inuit communities adapt to changes in marine mammal distribution and abundance.

Hik, David (University of Alberta); Furgal, Christopher (Trent University)
Project 3.4 Integrating and Translating ArcticNet Science for Sustainable Communities and National and Global Policy and Decision-Making *(Science to Policy)*. Contributes to all 4 IRISes.

Ecological changes, economic strains, cultural transformations and other factors are causing multiple stresses for the indigenous peoples of the Arctic. The best available information, based on contemporary science and community and traditional knowledge (TK), must be used to ensure that Canadian Inuit, circumpolar Inuit and all Canadians make policy decisions that will contribute to sustainable development in the Arctic and the well-being of Arctic peoples. This research project's objective is to investigate the Arctic policy landscape and how ArcticNet science contributes to informing policy. A

series of activities will contribute to a strategic analysis of the Arctic policy landscape and how the ArcticNet program science program contributes to informed policy decisions in Canada and globally. This will be accomplished through a quantitative and qualitative analysis of the influence of ArcticNet science on Arctic policy development and other forms of science impact. The conclusions from this project will allow ArcticNet to address the most effective ways to use and translate ArcticNet research results on urgent issues such as climate change into 'action' or decision-making at the local, region, national or international levels. Further, recommendations will be made to address the changing physical, political, social, economic, and cultural reality of the Arctic, and identify information decision-makers in Canada and the international community need to make the most informed decisions. The project will also identify gaps and needs to access to the best available scientific research and an innovative methodology to translate research results into sound policy and other decisions. This project will contribute to our present knowledge on how to improve the use, translation and transfer of research results into sound policy.

Gratton, Yves (INRS-ETE)
Project 3.5 Long-Term Observatories in Canadian Arctic Waters *(Marine Observatories)*. Contributes to all 4 IRISes.

In the past decade, we have witnessed records of Arctic sea ice minimal extent (Maslanik et al. 2011) and it appears that 2011 will be another record low. The ice cover is the insulation between the atmosphere and the ocean. A shrinking ice cover means that more light and more heat are going to penetrate in the Arctic Ocean and totally change the Arctic environment. The objective of this project is to monitor these changes in physical, biological and geochemical properties of the Canadian Arctic waters. In the past, we have deployed ocean observatories in Hudson Bay, Hudson Strait, Baffin Bay, Beaufort Sea and the Eastern Arctic Ocean. These observatories are the oceanic equivalent of atmospheric meteorological stations. They are deployed every fall and recuperated one year later. While in the water, they record temperature, salinity, water velocity, dissolved oxygen, nutrients, light intensity, fluorescence (an indicator of micro-algae biomass) and ice motion. Hydrophones also record the vocalization of whales and other marine mammals. The data is used to describe the seasonal and annual variations in the Arctic environment and its local ecosystems. This, in turn, enables us to understand how global warming is affecting the Arctic and how fast.

Barber, David (University of Manitoba)
Project 3.6 The Role of Sea-Ice in ArcticNet IRISes *(Sea-Ice)*. Contributes to all 4 IRISes.

The observed decline in the summer sea ice, in terms of both magnitude and trend, is alarming. We are changing the arctic from one that has been dominated by multiyear sea ice to one that will now be dominated by first-year sea-icerelated processes. We can expect a seasonally ice free arctic early in this century. It is important to note that our

planet has not had a seasonally ice-free Arctic for at least the past 1.1 million years. This reduction in sea ice is of critical importance to all peoples of the world because of the role that the Arctic plays in the ventilation of the Atlantic and Pacific (Carmack et al. 2006) and because of the large effect that the sea ice albedo-feedback mechanism has on acceleration of warming and increased fluxes of green house gases to the atmosphere (due to permafrost melt). Both flora and fauna have evolved over millions of years to take advantage of the presence and timing of the seasonal sea ice life cycle. Now, northern peoples increasingly are finding their traditional way of life under pressure from these changes as they struggle to adapt. Global warming changes both dynamic and thermodynamic processes of snowcovered sea ice and these changes have an impact throughout both the physical and biogeochemical cycling in the Arctic marine system. The next few decades will proceed with significant challenges for the Arctic. Marine ecosystems will come under increasing pressure; industrial activity will increase as more exploration and development occurs; and the Inuit people will increasingly find it a challenge to use sea ice for cultural and subsistence purposes. This project will provide sea ice expertise to the coordinated ArcticNet IRISs of the coastal Canadian Arctic, supplying the required information for sound management of these challenges.

Ford, James (McGill University)
Project 3.7 Climate Change and Food Security in Regional Inuit Centers *(Food Security)*. Contributes to all 4 IRISes.

Food insecurity is a chronic problem affecting many Inuit communities and is likely to predispose Inuit food systems to the negative effects of climate change. Using in-depth case studies, this project will identify and characterize the vulnerability of food systems in four regional Inuit centers (RIC) (Iqaluit, Arviat, Inuvik and Kuujuuak) to climate change as a basis for identifying adaptation entry points. Thus far, the majority of work on this issue has focused on more 'traditional' or isolated northern communities thought to have a larger dependence on country/traditional food items. Largely unexamined, but critically important in the public health context, is the vulnerability of RICs, which is a major research gap given their rapid economic and population growth and increasing size of their food insecure population. The work will focus specifically on the food security of at-risk populations within RICs in a changing climate, defined to include individuals who use community food programs on a regular basis and who by definition experience chronic food insecurity. No research to-date has explicitly examined the vulnerability of this at-risk population in a northern Canadian context. To this end, the project has five primary objectives: 1) document and describe the nature of food insecurity among at-risk populations in RICs 2) characterize the environmental, biological and socio-economic determinants of their food insecurity 3) document coping strategies to manage food shortages 4) examine the pathways through which climate change might affect food insecurity for at-risk peoples in RICs 5) identify opportunities and priorities for adaptation intervention in the context of rapid current and future change. The project will work closely with community members, has established partnerships with a number of regional and community organizations, will link research to policy making at multiple

levels, and contribute towards an enhanced understanding of climate vulnerability in all Inuit regions of Canada.

Keeling, Arn (Memorial University of Newfoundland)
Project 3.8 Adaptation, Industrial Development and Arctic Communities *(Industrial Development)*. Contributes to IRIS 1.

This project is engaging in community-based, historical and comparative research into industrial development as a driver of social, cultural and environmental change in the Arctic. In particular, researchers are exploring the cultural, economic and environmental impacts of mineral exploration and development on three Arctic communities, Kugluktuk (Coppermine) in the Kitikmeot region, Qamani' tuaq (Baker Lake) and Kangiqiniq (Rankin Inlet) in the Kivalliq region. A fourth community, Arctic Bay, site of the Nanisiviq mine, has recently been added to the project. Working with community researchers, this project intends to identify issues of importance in relation to mining development and community change, and to explore community adaptations to the changes brought by industry. Researchers have collected extensive archival records relating to the history of industrial development in the Arctic, and will relate this history to changing government social and economic policies in the region, such as Inuit resettlement.
This research seeks to understand how current debates and controversies over mining development reflect Inuit experiences and traditional knowledge of previous developments. This project will also contribute to the building of both northern and southern research capacity, by providing research experiences for graduate students, postdoctoral researchers and community members. In addition, through conferences, workshops and and joint publications with European researchers and other Canadian research networks, this project is developing an international network of scholars interested in environmental, economic and cultural change in the circumpolar Arctic. The result will be a locally relevant, community record of this knowledge and history, as well as information useful for communities and policy makers in assessing the potential benefits and impacts of current development proposals.

Lasserre, Frédéric (Université Laval)
Project 3.9 Climate Change and Commercial Shipping Development in the Arctic *(Commercial Shipping)*. Contributes to all 4 IRISes.

The Arctic ice is receding, as ice extent in the summer is decreasing fast, faster than models predicted. The perspective of an ice-free Arctic in the summer is looming, with talks of riches to be exploited (oil, gas, minerals) and seaways developing across it between Europe and Asia. The perspective of a dramatic development in Arctic shipping triggered the debate in Canada as to how to assert Canada's sovereignty so as to protect the environment. But is shipping really going to develop this fast ? What segments of the shipping industry could be interested in plying a seasonal, poorly mapped, unserviced northern route ? Will containerized cargo liners between Europe and Asia rush to the

route ? The weak development of shipping in the region, despite several years of talks about the perspective of the opening of the Northwest and Northeast Passages, attest to the complexity of the question. Although some segments of the shipping industry might be interested in developing new routes across the Arctic, not all will be: what will then be the speed and shape of shipping development in the region ?

IRIS 4 Research (Eastern sub-Arctic)

The Eastern Subarctic IRIS encompasses the Inuit territories of Nunavik (northern Quebec) and Nunatsiavut (northern Labrador). Both territories have a form of self-government that is evolving towards greater autonomy. Population size is about 10800 residents in Nunavik and 10550 in Nunatsiavut. Demographic growth from 2001 to 2006 was very high in Nunavik at 10.4 % while the population of Nunatsiavut was decreasing at a rate of -6.0 %.
The region is bounded by seas on three sides (Hudson Bay to the west, Hudson Strait and Ungava Bay to the north, and the Labrador Sea to the east). This geography results in a continental-type climate with higher precipitation, particularly snow, than at similar latitudes west of Hudson Bay. The region lies totally within the Canadian Shield. Highest elevations are in the Torngat mountains along the boundary between Nunavik and Nunatsiavut, where the only glaciers east of the Rockies are found in continental Canada. Both transitions from forest to tundra and from discontinuous to continuous permafrost occur across the region.
The climate of the region has been warming rapidly since the early 1990s and models project an increase of temperatures by 3-4°C and precipitations by 10 to 25% for the middle of the century relative to the 1960-1990 period. Current climate change already impacts the thermal regime of permafrost and the dynamics of the active layer. A 2°C temperature increase 4 m deep over the whole territory, affects transportation infrastructures and communities. Stakeholders support ongoing research targeted at improved land planning and technical solutions for adaptation. Thaw lakes are forming in great numbers in areas of ice-rich, fine-grained soils and wetlands, with a feedback on the generation of greenhouses gases. Changes in vegetation cover are reported both by Inuit and researchers. Shrubs, particularly, are expanding in the forest-tundra. Trees, mostly larch in the eastern Ungava bay region, are extending the tree-line upwards on hillsides. Expected impacts on key animal resources such as the large caribou herds and the Arctic charr populations will likely be through a series of complex interactions between climate factors, food availability, vegetation dynamics, water temperature, ice cover duration and thickness on lakes, population dynamics, herbivory and predator-prey relationships. Therefore, adaptation processes for humans living on these resources will require multiple approaches over the geographical domain.

Leader: Michel Allard
Coordinator: Mickaël Lemay

Projects and Project Leader(s):

Chan, Laurie (University of Northern British Columbia); Furgal, Chris (Trent University)
Project 4.1 Food Security, Ice, Climate and Community Health: Climate Change Impacts on Traditional Food Security in Canadian Inuit Communities *(Community Health)*.
Contributes to IRISes 1 & 2.

The importance of traditional/country food as a critical resource for the health and well-being of northern populations is well documented. Traditional/country foods are critical

resources for physical, as well as mental, social and economic health of individuals and communities across the Arctic. Despite this, shifts in traditional/country food consumption have been taking place over the past 15 – 20 years related to a variety of changes in northern ecological, social, political and economic systems. Those related to ecological shifts have been in part previously associated with reduced confidence in food safety due to identified threats from environmental contaminants such as mercury and PCBs, and more recently the changes in species availability and accessibility due to shifting climatic conditions. Specifically, climate related changes and variability in the North have been associated with changes in animal, fish and plant population health and distribution, while changes in ice, snow, precipitation regimes, and other environmental factors have the potential to influence human travel and transportation in the North, and thus Inuit access to these wildlife resources. As such, climate change and variability has the potential to influence nutrition and health status among Inuit via impacts on aspects (availability, accessibility and quality) of traditional/country food security. Earlier phases of this project both positive and negative changes in the traditional/country food harvest of five Inuit communities were reported in relation to changes and variability in climatic conditions. It was documented that environmental changes are already having impacts on both the availability of wildlife species and hunters' access to them in all regions studied (Nunavik and Nunavut). Additionally, during the Nunavik Regional Inuit Health survey, respondents reported some influence of climate and environmental change on wildlife access and availability in comparison with the same hunting season in previous years. However, the impacts are not homogenous among all hunters and communities and both individuals and households show differential ability to adapt successfully. Factors such as access to economic resources and equipment, experience, and the nature of the adaptive strategy used appear to influence the success of hunter adaptations. This project studies these factors among individuals and households in Inuit communities influencing climate change impacts on nutritionalal and food security status. Further, through the analyses of harvest and local consumption data in Nunavut we determined that it is feasible to relate wildlife harvest data to traditional/country food use at both community and regional levels. Thus, it is possible to begin to model the relationship between climate projections, impacts on key environmental variables influencing availability of wildlife and/or Inuit access to traditional/country food species (e.g. ice conditions), and the level of viable consumption of those species in the community. These two pieces of information are critical for furthering our understanding of the major determinants of traditional/country food consumption in Arctic communities and of the current and future impacts of climate variability and change on traditional/country food consumption.

Power, Michael (University of Waterloo); Furgal, Chris (Trent University)
Project 4.2 Growth Variability and Mercury Tissue Concentration in Anadromous Arctic Charr *(Arctic Charr)*. Contributes to IRISes 1 & 2.

The project was designed to build on prior work that examined probable climate change related growth and contaminant impacts on land-locked populations of Arctic charr by extending the analysis to include important migratory and land-locked populations of Dolly Varden Charr in the Yukon Territory. There is a notable lack of data dor Dolly

Varden charr, despite the importance of the species as a country food resource. Here we plan to use existing archival tissue samples to construct an historical spatial baseline for THg levels in Dolly Varden charr against which contemporary data can be compared to examine the impacts of climate change and development activities on current THg levels. Work will also be extended to include comparative examination of Dolly Varden charr in the Beaufort and a determination of where and how they function in Beaufort Sea foodwebs likely to be affected by oil and gas exploration activities. The project will also continue important partnering work begun with Nunavik Research to examine the marine life-history phase of Ungava Arctic charr introduced into a previously unoccupied river system. Previously PIT-tagged fish have begun to return in numbers and we are now able to estimate annualized marine growth and compare that growth to monitored water temperatures as a means of estimating site-specific growth temperature relationships. Results to date have shown Arctic charr growth rates in Ungava exceed those obtained from monitoring of Arctic charr populations along the Labrador coast. Increased nearshore productivity associated with the large freshwater discharges from the Koksoak River is believed to account for the differences, with Labrador populations being more food limited than Ungava populations. Results are critical data for assessing the possible impacts of climate change Nunavik Arctic charr and understanding how overall availability of Arctic charr will respond to predicted climate changes. In concert with growth studies, the project has been monitoring the ecological impacts of Arctic charr introductions and found them to be negligible. This effort represents the first attempt to scientifically evaluate the consequences of northern ecosystem manipulation and has provided important data and insights for management purposes by showing it is possible to proactively manage Arctic charr stocks with minimal ecological consequences. Finally work continues on genetic typing of Arctic charr populations to improve our understanding of how climate change may impact the immunological capabilities of Arctic charr and their abilities to deal with new diseases and pathogens likely to be introduced into northern environments as a result of changing environmental conditions. All study generated information will contribute to the improvement of management abilities to make informed decisions about the risks associated with continued country food consumption in the face of changing conditions in the Arctic.

This project also identifies key environmental indicators of changes in Arctic Char (Salvelinus alpinus) growth using both quantitative (ecological) and qualitative (Indigenous Knowledge) data by linking community-based monitoring, local expert Indigenous and ecological knowledge. Arctic Char is a staple subsistence resource for Inuvialuit on Banks and Victoria islands in the Northwest Territories, Canada. In recent years, significant climate variability and change has been observed in the area, raising local concerns about how this variability will affect subsistence resources. Residents in local communities are the first to directly observe these changes and variability in local the climate and the effects on their land, water and animals. Centuries of knowledge and observations about the environment and natural resources exist among Inuvialuit hunters and fishers. Indigenous Knowledge (IK) can complement our scientific understanding of environmental variability and change and its effects on Arctic species. Community-based monitoring provides an opportunity to better understand the current status of Arctic species and can form the basis for understanding and preparing for future changes in Arctic species in light of climate variability and change effects. Using a mixed-methods

approach to research is one way in which ecological scientific and Indigenous Knowledge can be brought together to complement one another and provide a more thorough understanding of northern fish species in a changing environment.

Dewailly, Éric (Université Laval)
Project 4.3 Country Foods *Health* Benefits in a Changing Canadian Arctic *(Health Benefits)*. Contributes to all 4 IRISes.

To survive in the Arctic, Inuit had for centuries to rely on fish, mammals and some plants such as wild berries and seaweeds. However, since the 1990's, the consumption of country food has decreased markedly, and the rapid food transition towards a western diet has led to excessive intake of carbohydrate, salt and trans-fatty acids. The obesity prevalence is increasing, and cardiovascular diseases and risk factors have become major health issues. Global environmental changes also affect Inuit dietary patterns in many ways including the availability of local animal and plant species and/or environmental contaminants concentrations. Their country food diet in Nunavik is very rich in key protective nutrients such as omega-3 polyunsaturated fatty acids and selenium. Wild berries and seaweeds found in Nunavik may provide plant-derived nutrients and secondary metabolites that also offer unique potential for the prevention or management of metabolic disease and associated cardiovascular complications and to offset some deleterious effects of environmental contaminants exposures. With a better understanding the overall benefits of nutrients present in the different country foods consumed in Nunavik, we will be able to orient public policies aiming to improve country food consumption and food security, promote Inuit culture, minimize the risks from environmental contaminant exposure and the emergence of obesity, diabetes and cardiovas¬cular diseases in this population and the Arctic.

Allard, Michel (Université Laval); Pollard, Wayne (McGill University)
Project 4.4 Permafrost and Climate Change in Northern Coastal Canada *(Permafrost)*. Contributes to all 4 IRISes.

This project analyzes how permafrost, or permanently frozen ground, responds to the changing climate. Permafrost is the foundation upon which northern ecosystems and communities rest and upon which new industrial infrastructures are built. So determining its fate is important to a number of different disciplines and users. Remote sensing is used to map surface temperatures across northern Canada as they regulate the thermal regime of permafrost and regional climate models are used to predict coming changes in permafrost thermal regime under projected climate changes. The impact of thawing permafrost is often a function of how much ice is found below the ground surface, so an important component of the project is to map where this ground ice is located, particularly in sensitive areas such as Inuit communities or in regions targeted for industrial projects. Other factors that have a bearing on the impact of warming permafrost are the types of soil, the vegetation cover, snow depths, and soil moisture, so these are elements that are also considered by our multi-disciplinary team. Changes to the

landscape as a result of the changing permafrost temperatures are monitored, including the development of landforms such as landslides, changes in vegetation patterns, modification of drainage patterns, coastal erosion, release of carbon and production of greenhouse gases. The tools and methods used by the team include remote sensing, drilling, geophysics, thermal analyses, vegetation studies, numerical simulations, site monitoring and GIS applications. Permafrost mapping and predictions of ground temperature changes in Arctic communities are used to formulate adaptation strategies and planning land management.

Côté, Steeve (Université Laval)
Project 4.5 Population Dynamics of Migratory Caribou in Nunavik/Nunatsiavut *(Caribou)*.

Despite much media attention in 2011, migratory caribou are still abundant in northern Québec and Labrador, where they are central to the economy and traditional life of northern people. They are also economically important for a major outfitting industry, much of it involving Aboriginals. Scientific and Aboriginal Traditional Knowledge, however, indicate that populations of migratory caribou undergo drastic changes over several decades. Caribou herds are declining almost everywhere in Canada, and the factors responsible for those declines are poorly known. Caribou also face threats from expanding resource-extraction industries, and this will continue to increase with the up-coming Plan Nord, and from climate change. A major preoccupation is that warmer weather may delay the freeze-up of hydroelectric reservoirs, possibly disrupting migration routes or inducing mass drownings if caribou attempt to cross on thin ice. Through the cooperation of government agencies, Aboriginal groups and industry partners we are combining existing long-term data, population genetics studies, monitoring of known-age caribou with satellite collars, satellite-derived information on plant productivity and small-scale climate manipulations to establish how climate and population density affect the food resources of caribou, their habitat use, choice of calving site, body growth and condition, recruitment and age-specific survival. These are the most important factors currently thought to affect caribou abundance and distribution in the Arctic. We are also addressing the effects of industrial activities on caribou ecology and quantifying the impact of caribou on vegetation in key seasonal ranges. In addition to identifying the factors responsible for changes in population density and distribution, our work will provide managers and Aboriginal Peoples with new tools to monitor the demography of caribou and therefore improve their conservation in the face of climate change.

Bell, Trevor (Memorial University of Newfoundland); Sheldon, Tom (Nunatsiavut Department of Lands and Natural Resources)
Project 4.6 Understanding and Responding to the Effects of Climate Change and Modernization in Nunatsiavut *(Nunatsiavut Nuluak)*

Nunatsiavut Nuluak is addressing Inuit concerns about the impacts of climate change, modernization and contaminants on the health of marine ecosystems and communities of Northern Labrador. The overarching goal of NN is to involve Inuit and Inuit knowledge in all aspects of the project to ensure the results are meaningful to local communities and industries and to help build scientific capacity in the region. The project co-leads (Nunatsiavut Government, NG, and the Environmental Sciences Group, ESG) have developed core partnerships with organizations such as Parks Canada, the Department of National Defence, Vale Inco (Voisey's Bay Nickel Company), Sikumiut Environmental Management Ltd., the Canadian Wildlife Service, and the Department of Fisheries and Oceans. Together these research partnerships are providing important insights into how the environment of Northern Labrador is changing, what this means for the long term health of marine ecosystems and how Northern communities will access and manage their land and freshwater resources in the future. The involvement of the Inuit, the Nunatsiavut Government and federal agencies in all aspects of the project will ensure that new scientific understandings are used to develop adaptation strategies and polices that have direct relevance for the people, industries and environment of Northern Labrador.

Dewailly, Éric (Université Laval)
Project 4.7 International Inuit Cohort Study: Developing the Next Phase *(Inuit Health Cohort)*. Contributes to all 4 IRISes.

The International Inuit Cohort was born from an international collaborative effort to gather pertinent data from
Inuit circumpolar populations in order to show differences and trends in this population. This cohort study will address long-standing questions with respect to Inuit health research. Many studies among Inuit populations are limited by a lack of statistical power, weak external validity and absence of temporal links and causality between disease and potential aetiologic factors. Indeed, the small size of communities (between 50 and 5000) living in different regions of the Arctic limits the use of epidemiological studies to determine rates of health outcomes. This initiative is based on three different companion studies conducted among Inuit adults in Canada and Greenland. Each study has a cross-sectional and a longitudinal component. The protocols used were developed in close collaboration and are nearly identical. To date, all three baselines surveys and measurements
have been completed and results have been delivered to communities. The baseline survey was carried out among adults (≥18 years) with Inuit/Yupik ancestry from across each circumpolar region. From 2003 to 2009, a total of 6223 participants (929 from Nunavik; 2835 from Greenland; 2459 from Nunavut, Inuvialuit and Nunatsiavut) participated in a 3-4 hours session with an English/Inuktittut questionnaire to ascertain a range of various lifestyle habits and health outcomes. All subjects participated in a medical and para-clinical examination and had a blood
sample drawn. This project deals with all aspects of the Cohort, including its constitution as a databank and all activities to further gather data to augment the databank.

Furgal, Chris (Trent University); Sheldon, Tom (Nunatsiavut Government)
Project 4.9 Inuit Knowledge and Geospatial Ontologies in Nunatsiavut *(Inuit Knowledge).*

In a context of changing natural, social, political and economic environments in the Arctic, there is an urgent need to document and share the extensive and valuable knowledge held by Elders and other experts with local decision makers, younger generations, and with members of the scientific community trying better to understand pressures on northern systems. Geographic Information Systems (GIS) and other spatial data organization and representation technologies have been used for a variety of applications for, with, and by Indigenous groups in recent decades (e.g. land use planning, natural resource management, land claims negotiations, documentation and transmission of Traditional Knowledge to younger generations). Through processes such as Participatory GIS (PGIS) and geospatial ontology research methods of capturing and representing Indigenous conceptualizations of spatial phenomenon, initiatives such as the current project can be empowering and create useful tools to illustrate and communicate Indigenous Knowledge (IK) and concepts of the environments which local people understand exceptionally well. Efforts of this nature have the potential to create tools with which to make local decisions about the environment and its resources, and which better reflect local understandings and cultures. Using literature review, expert interviews and participatory mapping, this project is conducting a geospatial ontology exercise with expert knowledge holders in the Nunatsiavut Settlement Area. The long term goal is the development of a geospatial ontology application and interface (newly conceptualized land classification system with GIS representation) that complements existing GIS for use in land use planning, environment and development decision-making as well as Nunatsiavut Inuit Knowledge representation and transmission to a variety of audiences. This is a unique project that is aimed at influencing and supporting Inuit decision making on land and development issues in the future. This sort of work is at the interface between Inuit Knowledge and computing technologies such as GIS and is an emerging new field of study. Here we present preliminary concept maps, a subset of a formal ontology based on the knowledge of local experts, and a conceptual architecture indicating how the project results will be used to support applications. This project is a partnership between university-based researchers and the Nunatsiavut Government (NG). The results are expected to provide evidence for a different and potentially more culturally-specific way of viewing and making decisions about land and landscape in Inuit regions.

Annex 3. Summary of Northern Oil and Gas Science Research Projects

Beaufort Regional Environmental Assessment Research Projects

In August 2010, the Government of Canada announced the Beaufort Regional Environmental Assessment (BREA), a $21.8 million dollar investment in support of increased research to inform regulatory decisions for potential offshore exploration and development activities in the Beaufort Sea.

BREA is a multi-stakeholder initiative led by Aboriginal Affairs and Northern Development Canada that provides an opportunity for Inuvialuit communities, industry, federal and territorial governments, academia and regulators to prepare for oil and gas activity in the Beaufort Sea by building a regional socio-economic and scientific knowledge base that will: fill regional information and data gaps related to offshore oil and gas activities; and support efficient and effective regulatory decision-making.

BREA's foundation stems from recommendations from the Beaufort Sea Strategic Regional Plan of Action, a multi-stakeholder initiative that was developed in response to concerns raised by the Inuvialuit Game Council (IGC) about Government preparedness for offshore oil and gas development in the Beaufort Sea. BREA has since developed to ensure a coordinated and integrated approach to addressing the challenges of oil and gas activity in the Beaufort Sea and to incorporate lessons learned from the 2010 Gulf of Mexico Deepwater Horizon tragedy.

BREA consists of a research program and working group activities to address priority issues in the region. Seventeen research projects have been funded to-date, based on priorities identified in earlier analyses (Environmental Studies Research Fund Report #163 and a 2011 Data Mining Report prepared by ArcticNet for Aboriginal Affairs and Northern Development Canada) and subsequently refined collaboratively through multi-stakeholder committees. All projects were selected based on their relevance to the priority research areas, as well as their contribution to regulatory efficiency and community preparedness, the two primary goals of BREA.

Separate working groups are addressing issues related to climate change, cumulative effects, information management, oil spill preparedness and response, social, cultural and economic indicators, and waste management.

The following covers BREA research projects from the period between April 1, 2011 and March 31, 2012.

Active Acoustic Mapping of Fish in the Beaufort Sea, 2011-2013

Louis Fortier (Laval University)

This cutting-edge project, led by ArcticNet, will use state-of-the-art fisheries sonar technology to map the distribution and abundance of Arctic cod and other fish in the offshore Beaufort Sea during the summer months. Arctic cod is the main food source for seals, whales and birds in the Beaufort Sea Region and this study will be important to supplement existing research into the winter distribution patterns of Arctic cod.

Impacts of Development in the Beaufort Sea on Fish, their Habitats and Ecosystems, 2011-2015

Jim Reist (Department of Fisheries and Oceans)

Fisheries and Oceans Canada, in collaboration with six Inuvialuit communities, will conduct a four-year (2011-2015) study that will include a fishing survey in deeper waters (100 to 1000m) of the outer continental shelf as well as slope areas of the Beaufort Sea. Researchers will study both bottom-dwelling and mid-water fish species, documenting the size of their populations, habitats, diets, roles in the food chain and migratory patterns – something which has never been done before. Increased understanding of the ecosystems on which fish species depend will support environmental assessments and sound decision making regarding fish habitat and offshore oil and gas activities.

Coastal and Marine Bird Usage of the Beaufort Sea Region, 2011-2013

Myra Robertson (Environment Canada)

The Beaufort Sea Region provides marine and coastal habitat for hundreds of thousands of migrating and breeding birds. Environment Canada will lead this project to identify important nearshore and coastal nesting, feeding and migration areas. The study will compile existing information on coastal bird usage and will identify species, numbers and distribution of birds. A digitized Geographic Information System will be used to identify bird sensitivity areas in the Beaufort Sea based on available information. The information will be valuable to oil and gas developers and regulators through the environmental assessment process to ensure that negative impacts of development on birds are minimized.

Database and Atlas of the Birds of the Canadian Beaufort Sea, 2011-2012

Ross Harris (Upun-LGL)

This project will synthesize existing information on offshore bird populations in the Beaufort Sea into a geo-referenced database. The database will include information on the offshore occurrence of birds, species, gender, age, date, location, movement and the data source. This work will complement the coastal bird population project being led by Environment Canada.

Polar Bears in the Deep Offshore Regions of the Beaufort Sea: A Preliminary Study to Estimate Distribution and Density in Previously Under-Surveyed Areas, 2011-2012

Norm Snow (Joint Secretariat)

The potential presence of polar bears in the deep waters of the offshore region of the Beaufort Sea has been a longstanding interest of Inuvialuit communities, but scientific surveys for bears in this region have never been undertaken. This study, being led by the Joint Secretariat, will involve an aerial survey in early March 2012 to document the distribution and density of polar bears in the deep offshore region of the Beaufort Sea. Preliminary estimates of bear density in the offshore region will enable regulators to better understand the potential effects of offshore oil and gas development activities on these marine mammals. At the same time, results from this study will help guide further studies into population structure in this part of the Beaufort Sea, eventually leading to a longer-term understanding of polar bears in the region.

Biological Data to Assess the Net Environmental Benefits and Costs of Dispersants and In-Situ Burning in Oil Spill Response, 2011-2013

Ken Trudel (SL Ross)

An important part of oil spill response planning is to develop tools to assist in assessing the risks from oil spills and the benefits of countermeasures (e.g., dispersants, burning) used to fight them. This project will examine traditional knowledge to identify Inuvialuit environmental protection priorities in the Canadian Beaufort Sea. Traditional knowledge will be combined with scientific data to:
a. describe Inuvialuit harvesting and other activities;
b. describe the fish, bird and marine mammal populations upon which these activities depend; and
c. assess the vulnerability of all of these to effects of spills and countermeasures.
Using realistic spill scenarios, this information will be used to illustrate the use of net environmental benefit analysis to assess the merits dispersant and in-situ burning in responding to oil spills in the Beaufort Sea.

Overwintering in the Beaufort – Assessing Damage Potential to Vessels, 2011-2013

Anne Barker (National Research Council)

Vessels containing and/or storing fuel are frozen into ice that is anchored to the shoreline (land-fast ice) throughout the Beaufort region over the winter months. The practice, called over-wintering, has raised concerns in some northern communities about the potential for fuel spills. This project will assess whether vessels or barges experience any significant damage when overwintering in land-fast ice. The information will be used to make recommendations to Inuvialuit communities and regulators on the best ways to reduce the likelihood of damage to vessels overwintering in ice in the nearshore region of the Beaufort Sea that could pose environmental risks.

Southern and Northeastern Beaufort Sea Marine Observatories, 2011-2014

Martin Fortier (ArcticNet)

This initiative will see three oceanographic observatories, each composed of two moorings, established to collect year-round marine observations of the Beaufort Sea using state-of-the-art instruments, including Doppler current meters, sediment traps, ice-profiling sonars, conductivity-temperature sensors and turbidity meters. Researchers will monitor and interpret the information generated on sea ice, ocean circulation and biogeochemical fluctuations throughout the region. The four-year project, led by ArcticNet and IMG-Golder, an Inuit-owned environmental and engineering company, will collect data to gauge the physical conditions and variability of the Canadian Beaufort Sea year over year. This information will provide previously unavailable scientific evidence of oceanic and sea ice conditions, enabling regulators to make informed decisions about potential environmental effects of exploration drilling in the Beaufort Sea.

CanICE – A Sea Ice Information Database and Web-Based Portal, 2011-2014

Leah Braithwaite (Environment Canada)

Sea ice exerts important seasonal effects on weather and climate, marine ecosystems, the safety of marine transportation, northern communities and offshore resource development and exploitation. Whether preparing policy or regulations, assessing the impacts of activities on ecosystems, designing sustainable infrastructure, or planning and conducting safe and secure shipping, information about sea ice conditions is vital given the variable and harsh Arctic marine environment. Environment Canada, in partnership with several universities, will create a publically accessible database that captures existing information on sea ice features including coverage, concentration, type, characteristics and extreme ice hazards. Access to the database will be through the Polar Data Catalogue. The interoperable database will enable online, open access to historical and current sea ice information and will allow others with sea ice information to add data to this central information source.

Beaufort Sea Environmental Database, 2011-2013

Ivana Kubat (National Research Council)

Over the years, a significant amount of environmental data has been collected in the Beaufort Sea, but it is widely scattered. Searching for the best available datasets is often difficult. Downloading, extracting and visualizing the information from various sources and file formats is even more challenging and time consuming. The National Research

Council of Canada will develop an integrated database for the storage, query and visualization of all key relevant environmental data for the Beaufort Sea. This single-window information source will give regulators access to definitive regional environmental information. The database will be used to determine design ice loads for offshore platforms and marine operations.

Delineation of Extreme Ridges in High Resolution Satellite-Based Radar Imagery, 2011-2012

Desmond Powers (C-Core)

This project, led by C-Core, will demonstrate the feasibility of using satellite-based imagery to delineate extreme ridge features in sea ice of the Beaufort Sea. Data collected from ice profiling sonar maintained by the Institute of Ocean Sciences (Department of Fisheries and Oceans) will be compared to high resolution satellite radar images for the detection of these extreme ice features. Knowledge of the spatio-temporal frequency of ice ridges will provide valuable information for engineering design and transportation issues related to oil and gas activities in the Beaufort.

Deep Water Seabed Geohazards, 2011-2015

Steve Blasco (Natural Resources Canada)

Oil and gas exploration in the deep waters of the Beaufort Sea requires knowledge of seabed stability conditions to ensure safe drilling practices. Under this initiative, the Geological Survey of Canada will conduct a regional assessment of seabed instability conditions, such as mud volcanoes, gas vents and faults, subsea permafrost and the severity of these geohazards. Seabed geohazard research provides baseline knowledge in support of spill prevention and contributes to the preservation of the marine ecosystem and protection of renewable resources. Research findings from this regional assessment will be essential for environmental impact assessments and will support informed decision making in the development of an effective regulatory regime.

Integrated Sea Ice Projects

The following three projects, led by the National Research Council, the University of Manitoba and the University of Alberta are part of an integrated sea ice project that will examine the characteristics of multi-year sea ice. The result will be measurements at the small, medium, and large scale that are brought together to improve our understanding of the properties and behavior of sea ice in the Canadian Beaufort Sea.

Measuring the Thickness and Strength of Deformed Multi-Year Ice in the Beaufort Sea, 2011-2015

Michelle Johnston (National Research Council)

Although there is growing evidence that the polar pack is decreasing in extent and thickness, icebergs, ice islands and thick, deformed multi-year ice continue to pose a hazard. This project, led by the National Research Council of Canada, will describe the thickness and strength of extreme ice features in the Beaufort Sea at ice depths (up to 12 m) where no information currently exists. The research will provide information needed to better engineer structures to withstand the impacts of deformed multi-year ice. Increased knowledge of dangerous ice features will also enhance the decision-making capacity of regulators and industry.

Understanding Extreme Ice Features in the Beaufort Sea, 2011-2015

Christian Haas (University of Alberta)

Among the most serious challenges to operating in the Beaufort Sea are widely varying sea ice types and severe ice conditions. This project, led by the University of Alberta, will use electromagnetic surveys and drift beacons to perform large-scale, airborne ice thickness surveys to quantify the thickness and regional distribution of multiyear ice and extreme ice features in the Southern Beaufort Sea. The results of this research will improve understanding of how sea ice moves in response to winds and currents, and will contribute to the development of tools to predict ice drift. Being prepared for any and all eventualities is one of the realities facing regulators and industry contemplating offshore oil and gas exploration and drilling.

Radarsat Mapping of Extreme Ice Features in the Southern Beaufort Sea, 2011-2015

David Barber (University of Manitoba)

There is growing global interest in marine shipping and oil and gas development in the Southern Beaufort Sea as ice cover in Arctic waters diminishes over the summer months. However, hazardous ice remains a risk to industrial operations in the region. This research will provide regionally relevant information on extreme ice features along the northwestern flank of the Canadian Arctic Archipelago. The University of Manitoba is leading a team of investigators that will use Radarsat technology to detect, monitor and eventually model the distribution and motion of hazardous ice features and their movement over significant oil and gas exploration licenses in the area. This scientific knowledge will be married with information collected by local residents participating in a new community-based pilot program to monitor sea ice thickness.

Integrated Modeling Projects

The following two projects led by Fisheries and Oceans Canada and Environment Canada are part of an integrated project on coupled ocean-ice-atmosphere modeling. The researchers are working together to improve forecasting capabilities of ocean and ice behaviour in the Canadian Beaufort Sea.

Forecasting Extreme Weather and Ocean Conditions in the Beaufort Sea, 2011-2015

Fraser Davidson (Fisheries and Oceans Canada)

Drilling operations in the Beaufort Sea are increasingly focused on the shelf break between the deep and shallow parts of the Sea – an area characterized by extreme weather events, ocean currents and waves. This research will develop and implement an integrated ocean-wave-ice-atmosphere prediction system to forecast the changing marine weather, sea ice and ocean conditions. This invaluable information will support the Global Maritime Distress Safety System's warnings and information services for the Arctic. It will be equally vital to oil and gas exploration and development by providing forecasts that will inform operations in the Beaufort Sea.

Seasonal Forecasting of Ocean and Ice Conditions in the Beaufort Sea, 2011-2015

Gregory Flato (Environment Canada)

Predicting the weather days in advance is standard fare in most parts of the country. But for oil and gas companies considering exploration and drilling activities in the Arctic, anticipating what the weather will be like over the coming year is extremely important. This project, led by Environment Canada, will create a high-resolution forecasting system capable of predicting ocean and sea-ice conditions in the Beaufort Sea region from one to twelve months in advance. The research will provide enhanced regional detail in operational seasonal predictions and contribute directly to the development of improved climate prediction products. This will serve both regulators' and industry's operational needs, now and in the future.

Annex 4. Summary of Projects Conducted under the Cumulative Impact Monitoring Program

A multi-scale assessment of cumulative impacts in the Northern Mackenzie basin
Claire Marchildon (AANDC)

The Northern Mackenzie Basin is an area of enormous ecological and cultural significance that is changing in response to more frequent disturbances (natural and human-caused), and regional temperature increases. These changes are impacting priority valued ecosystem components (VCs). Disturbances like fire, seismic activity, and road construction affect vegetation structure, altering the quality and distribution of caribou habitat. Permafrost disturbances like thaw slumping can increase nutrient and sediment fluxes to lakes and streams, impacting water quality and fish habitat. At present, the cumulative effect of all of these disturbances is extremely poorly understood. For planners and decisions makers to deal with this uncertainty, research on the impacts of disturbance needs to be combined with regional-scale data on their extent and location.

In this project, we will combine remote sensing data with field observations to document the extent and ause of changes occurring between 1985 and 2012. Examples of these changes that will be examined include: drained lakes, thaw slumps, tundra fires, tall shrub expansion, ice wedge degradation, mud sumps, seismic trails, road, gravel pads, airstrips, etc.). In the long-term (2014-2015) our goal is to used this data to develop predictive models that can be used to explore how ongoing changes will impact the ecosystems of the northern Mackenzie.

A watershed approach to monitoring cumulative impacts of landscape change
Steve Kokelj (AANDC)

The Peel Plateau is a physiographic region extending from the Beaufort Sea in the Inuvialuit Settlement Region, through Gwich'in lands into the Sahtu (Figure 1) and it contains hundreds of fish bearing tributaries of the Peel and Mackenzie Rivers. This is an area of cultural and ecological significance that hosts important transportation infrastructure and significant oil and gas reserves. It is also one of the most rapidly changing landscapes in Canada (Figure 2). Through bringing together numerous community, research and land management partners, this collaborative study is able to take a holistic approach to monitoring and understanding cumulative impacts. The proposed project addresses community and land management concerns related to the impacts of terrain disturbance on water quality and fisheries, and aims to develop a watershed framework for tracking the cumulative impacts of disturbance on water resources. A remote sensing component in this year's work will increase the spatial extent of our permafrost disturbance mapping and develop products that will allow watershed impacts to be monitored and sensitivity to be modeled over broad areas. In the future, these tools may be applied to monitor cumulative impacts on aquatic environments in other parts of the NWT.
This is a multidisciplinary project stimulated by community and land management concerns. The project involves communities, governments and academic researchers. Our goals are to:

1) inventory and track broad scale changes in landscape disturbances;

2) determine the impacts of natural and anthropogenic disturbances on the physical, chemical and biological characteristics and ecology of streams and rivers;
3) establish disturbance thresholds relevant to the health of streams and fish;
4) compile geospatial disturbance layers and portray this information on a watershed basis as a platform for evaluating cumulative impacts to aquatic systems; and
5) design a Gwich'in based monitoring program utilizing Traditional Knowledge to describe environmental conditions in the Peel Plateau.

The research questions address the distribution and drivers of permafrost disturbance and examine how physical and ecological impacts to terrestrial and aquatic ecosystems compare with natural variability, and with those resulting from anthropogenic disturbance (What are the cumulative impacts?). Research questions also relate to identifying water quality thresholds for stream and fish health which may be broadly applicable. To determine the distribution of critical habitat and sensitive watersheds, we will integrate our datasets on a watershed basis. The monitoring and research questions will be addressed using field based techniques and remote sensing techniques over both impacted and unimpacted aquatic and terrestrial environments. Lake cores will be obtained to understand current change to aquatic systems in the context of long-term trends. This project will lead to better collaboration between government, researchers and communities on monitoring of cumulative impacts. Our multidisciplinary approach will facilitate a holistic view of landscape and environmental change and bridge scientific and traditional knowledge approaches. It will also provide information on thresholds for terrain disturbance, stream and fish health. Watershed disturbance maps will provide a common platform to integrate information on sensitive fishes, critical habitat, and natural and anthropogenic disturbances. This output will be of use to environmental managers, regulators and industry. Community involvement in long-term monitoring will increase capacity and knowledge transfer to local decision makers. Team members will provide information to northern decision makers via reports, GIS.

Changing hydrology in the Taiga Shield: Geochemical and resource management implications

Shawne Kokelj (AANDC)

The principle goal of this project is to understand the cumulative impacts of changes in streamflow and geochemical regimes in the North Slave Taiga Shield. The project will generate information relevant to water resource decision making and information will be communicated directly to decision makers and the community of Yellowknife. Specific examples where this information will be useful are management of contaminated sites (e.g., GIANT Mine) and management and maintenance of NWT road infrastructure (via the GNWT Department of Transportation).

This project combines the monitoring and research efforts of several partners, including government agencies, academics and a community-based monitoring initiative to address: A) The changes in winter stream flow on the North Slave Taiga Shield; B) the drivers of these recent changes; C) the impacts of these changes on the environment; and D) the implications to water quality. The team will utilize field and remote sensing methods to monitor water levels in streams and rivers, examine the geochemistry of streams, lakes and groundwater, determine the thickness and duration of lake ice cover, assess lake bottom and permafrost temperatures and track the development of terrestrial and river icings. The cumulative impacts of multiple climatic, environmental and anthropogenic stressors are impacting the behaviour of streams and their geochemical characteristics. Coordinating monitoring and research efforts and pulling together

multiple sources of information is necessary to understand the drivers of these changes, which in turn is required to make informed planning decisions and assess cumulative impacts on aquatic ecosystems in the region.

This project will develop a knowledge base to inform decision makers and to assess cumulative effects. The hydrological changes investigated in this study will continue to influence water resources and terrain stability as northern environments adjust to climate change. Understanding the nature and drivers of these hydrological changes, and the relationships with stream geochemistry and permafrost stability are critical to making informed water management decisions and plan adaptation in an uncertain and changing future. More frequent autumn runoff events and higher winter stream flows have implications for water management at the GIANT Mine site and will have to be considered in future development proposals throughout this region. Winter streamflow can result in the development of large icings which can complicate care and maintenance operations at contaminated sites and along road infrastructure. Water movement through deeply thawed soils in winter can inhibit ground freezing and complicate winter construction operations. Enhanced interaction of water and deep soil layers can also impact aquatic chemistry regimes, so that under these changing baseline conditions, water quality criteria and license limits may need to be reevaluated. The project team regularly communicates with GIANT Mine team, transportation infrastructure planners and the engineering design community. Input from these groups has been central to the design of a monitoring program relevant to water resource related decision making in the North Slave Taiga Shield. The project team regularly communicates new information and study results to Aboriginal groups and land and water boards.

Arctic Borderlands Co-op: Community based ecological and cumulative impacts and monitoring program

Michael Svoboda (Arctic Borderlands Ecological Knowledge Coop)

Summary

- The Arctic Borderlands Coop provides an opportunity for the Cumulative Impact research and monitoring data to be turned into information. In addition to providing the cumulative impact results (indicators) that are reported to the Coop, other explanatory data help understand what is happening and why.
- The Arctic Borderlands Co-op has been conducting community based ecological monitoring and analyses since 1996 with particular focus on the impacts of development, climate change, and contaminants. This year in addition to the annual monitoring work, the Coop will focus attention to accelerating to data analysis to influence decision makers. The new automated analysis portal will allow for rapid primary analyses targeting/ informing resource management decision making boards and debates when it matters. Most notably is the Co-op caribou related results being formally incorporated into the management board annual herd analyses since demonstrating the strong role it plays in understanding the cumulative impacts to caribou.
- Each year, Co-op partners meet to review and assess current findings at an Annual Gathering held in a community in the Borderlands region. These activities are important to help create linkages from land users to land managers/ management bodies (turning data into information).
- This proposal seeks funding for our community-based monitoring and related activities in the Northwest Territories communities of Aklavik, Fort McPherson, Inuvik, Tuktoyaktuk and Tsiigehtchic, Monitors follow the format of specially

prepared questionnaires seeking detailed information about over 65 indicators, including: human activities, temperature, precipitation, extreme weather events, water, berries, and numerous fish and animals. Specifically, funding will be directed to support training, data collection of monitoring priority valued components and communication of monitoring and baseline data that are collected (see budget).

Methods

- Monitors are trained and complete structured survey interviews of 15-20 local people who spend a significant amount of time on the land. The questions focus on over 65 indicators of environmental change in several categories, including weather, berries, fish and animals.
- The results of the questionnaires are entered into a database, and the database is periodically reviewed to ensure the data is readily accessible. In 2011-12 the data entry system was upgraded to be accessible online, thus significantly improving data quality assurance, reducing analysis time, and increasing the role of community monitors in the data to analysis phase of the program.

Baseline monitoring of Arctic vegetation and snow changes over the Bathurst caribou habitat using satellite remote sensing and community-based field observations

Wenjun Chen (Canadian Centre for Remote Sensing)

Caribou are one of the most important natural resources in Canada's North. Fluctuations in caribou abundance have long concerned northern aboriginal people, many of whom identify themselves as "caribou people". The abundance of caribou is influenced by complex and interacting factors, including habitat, harvest, predators, diseases/parasites, extreme weather and climate change, forest fires, and industrial developments. For example, summer range foliage availability could affect caribou body mass, survival rate, and calf:cow ratio. Winter range and calving ground lichen availability may influence winter weight loss and survival rate, cow milk production, and calf survival rate. Deep snow and delayed melting could hinder caribou spring migration, delay calving, and increase calf mortality.

The cumulative impacts of climate change and forest fires result in changes to northern vegetation and snow. Satellite remote sensing is arguably the most effective technology for monitoring vegetation and snow changes over a large area such as the range of a migratory tundra caribou herd. The proposed study will develop and improve satellite-based methods and products that will enable the systematic monitoring of vegetation and snow changes over the Bathurst caribou habitat. The satellite-based products will be validated, interpreted and improved by the integration of community-based field measurements and knowledge.

Over the study period, the study will create geospatial products that identify and characterize the seasonal and long-term foliage availability over the calving grounds and the summer range, the percent cover of lichen in the calving ground, the extent of snow

cover along the migratory route, and the area of lichen abundant upland mature forest in the winter range.

These study results will be delivered to the local caribou co-management boards and the Wildlife Division of GNWT, contributing to their knowledge base for informed decision-making on caribou habitat management. Furthermore, caribou biologists and managers can relate these habitat conditions to indicators of caribou productivity, to improve their understanding of and management decision-making on changes in caribou population and health conditions. Finally, the remote sensing techniques can form the basis of continual, systematic monitoring of the habitat of the Bathurst Caribou.

Winter ecosystem and fish habitat in the nearshore Beaufort Sea
Christine Michel (Fisheries and Oceans Canada)

This project will characterize winter-spring habitat and ecosystem linkages in the nearshore Beaufort, to address community priorities of habitat use by fishes and marine mammals including polar bears and potential impacts of Oil and Gas activities. Key goals will be to:

- Acquire baseline data on the winter-spring sea ice ecosystem and fish habitat, establish baseline for on-going and long-term monitoring and for regulatory advice.
- Build capacity for community monitoring to identify critical winter-spring ecosystem components (including fish habitat) and key measureable parameters that can serve as indicators for monitoring and assessment of impacts of oil and gas activities in the presence of ice.
- Establish habitat linkages from lower trophic levels to top predators, to support ecosystem modelling.

Methods will include community coastal surveys for winter fish habitat and local and regional sampling from an ice camp located in Summer Harbour or Wise Bay. These areas were identifed by the communitiy of Paulatuk as priority areas of concern due to the potential for overwintering of oil and gas equipment.

This study will contribute to two key components of cumulative impacts, a) climate change and b) industrial development, specifically proposed oil and gas activities. Outcomes will include a) recommendations and training for monitoring of ecosystem and fish habitat during winter, b) increased capacity to understand food web and habitat linkages for ecosystem modelling/analyses in the context of cumulative impacts and c) baseline winter datasets of water quality and fish habitat to begin evaluating environmental trends.

Community coastal based monitoring: A regional approach for the ISR
Lisa Loseto (Fisheries and Oceans Canada)

Many fish and marine mammal coastal monitoring programs have taken place throughout the ISR to address questions raised by science and communities. These programs are often carried out as partnership programs among Fisheries and Oceans Canada, Fisheries Joint Management Committee and local communities. While these programs are often designed to address key questions or issues many of them monitor key indicators of ecosystem structure, function and health, and thus provide a baseline of system functioning. To characterize the ecosystem and its natural variability (and response to

stressors), there is need for long term research and monitoring. The timely factors such as: a) the rise in oil and gas interests and need for knowledge for regulatory decision making, b) changes in the physical environment (e.g. loss of sea ice) in response to climate change that will have cascading impacts on the ecosystem and c) the start of the offshore fish project (DFO/ BREA) in 2012, together have provided the impetuous to carry out regional approach to coastal monitoring in the ISR. Thus this summer a co-ordinated approach to monitoring key VEC's (fish, beluga, habitat) will be implemented. This will involve tailoring already established programs (e.g. Hendrickson Island, ACES) and establishing new ones (e.g. Paulatuk beluga and fish project).
Goal: While the field and laboratory analytical aspects of the program are underway we would like to direct focus on a) complete a framework for an ISR coastal regional monitoring program; b) synthesizing the existing indicator data for the region, c) testing the robustness of some of the indicators and d) ensure the indicators used are ideal for long term monitoring – specifically cumulative impact monitoring.
Methods: Analytical statistics on indicator data that will include power analyses, temporal and spatial trend analyses, and define baseline trophic level interactions.
Significance: The finalized framework for long term cumulative impact monitoring can be adopted and used for ecosystem management where significant activity is expected in the next 5-10yrs.
Anticipated outcomes: A robust framework for long term cumulative impact monitoring at a regional scale.

Monitoring Pacific salmon to understand cumulative impacts of climate change in the Arctic
Karen Dunmall (Fisheries and Oceans Canada)

The overall goal of the project is to assess the cumulative impacts of climate change on the Mackenzie River ecosystem by monitoring the distribution of colonizing Pacific salmon, a biological indicator of ecosystem change, and addressing potential competition between Pacific salmon and native salmonids for spawning habitat. Pacific salmon may be responding to climate-induced changes in the freshwater or marine ecosystem, which manifests as a greater distribution and abundance of Pacific salmon in the Northwest Territories. Therefore, the distribution of Pacific salmon may indicate cumulative impacts of climate warming in the arctic. Identifying potential geographic and temporal overlap in spawning locations and activity between Pacific salmon and native salmonids (Dolly Varden and Bull Trout) will address the hypothesis that climate warming is affecting local natives salmonids through competition and interaction with colonizing fish species. Pacific salmon distribution will be monitored in the subsistence fisheries throughout the Northwest Territories through community participation in a reward-based collection program. Potential geographic overlap of spawning habitat will be assessed by comparing the distribution and maturity level of Pacific salmon to known spawning locations of other salmonids. The potential temporal overlap in spawning activity will be assessed by monitoring groundwater temperature in the gravel (the hyporheic zone) in known spawning locations for Dolly Varden and Bull Trout that are also suspected spawning locations for Pacific salmon. These activities will be done in collaboration with communities throughout the Northwest Territories to develop local capacity to

continue long-term monitoring using Pacific salmon as a proxy for ecosystem change. This research is directly applicable to the priority VCs "Fish and fish habitat" and "water quality and quantify" and it addresses the understanding of the cumulative impacts of climate change on the Arctic through the tangible connection between colonizing Pacific salmon and competition with local fisheries resources. This information can be used to assist in the effective management of fisheries resources in the Northwest Territories in the context of ecosystem change due to climate warming, and provides information that can be used in the management of Pacific salmon as a potential emergent fishery. This project builds on partnerships between communities, government agencies and academia and empowers communities through the connection of subsistence to science.

Impacts of climate change on contaminants in consumed fish
Gary Stern (Fisheries and Oceans Canada)

Climate change has been shown to affect contaminant (e.g., mercury, persistent organic pollutants) uptake over time in burbot from Fort Good Hope, as warming increases the number of contaminant-scavenging algae which, in turn, changes food web dynamics leading to increasingly higher contaminant levels in burbot (see Carrie et al., 2010). We would like to see if these processes apply to burbot caught in Mackenzie River tributaries and trout from lakes farther south (near Tulita and Trout Lake). Temporal increases in mercury have been observed in several fish species from lakes in this region (Evans and Muir, 2010) some of which now exceed Health Canada safe consumption guidelines (0.5 ug/g), prompting the need for consumption advisories (NWT Health). Our analysis of fish collected from Kelly Lake and Trout Lake during 2011-12 (CIMP-funded) show that mercury concentrations are increasing at both sites relative to earlier samples (1.2x and 1.5x, respectively). As these regions possess similar characteristics to those found near Fort Good Hope, these locations are ideal to test our hypothesis of climate change affecting fish mercury concentrations. Collected sediment cores from these lakes (Kelly Lake and Trout Lake) will be analysed to compare any temporal increases in mercury deposition in the core with algal proxies and with mercury levels seen in burbot and trout over time. Local communities will be hired to catch burbot and trout from these sites. Our hope is that this will develop into ongoing Community Based Monitoring (CBM) programs. Long-term fish data coupled with sediment data provide an excellent tool to determine any cumulative impacts climate change is having on fish contaminant levels, and consequently, on the health of those who consume them.

Community and scientific monitoring of the Great Slave Lake ecosystem
Marlene Evans (Environment Canada)

Our study has scientific and capacity building goals. It is designed to complement our contaminant monitoring of fish under the Northern Contaminant Program (NCP) and our investigations of the influence of the Slave River on contaminant loading to the lake.

Our capacity building studies, primarily with Fort Resolution but also Lutsel K'e and Hay River, have been providing various forms of training with an initial focus on simple measurements of water temperature, conductivity, pH (YSI instrument) and clarity. In

2012 we propose to expand this monitoring to include simple demonstrations of water, sediment, benthos, plankton and forage fish collections in early summer. At Hay River, this may form the basis of an assessment of the health of harbor benthic communities while at Fort Resolution some sampling will contribute to an assessment of factors affecting mercury trends of increase (see below). The YSI and water clarity monitoring could then be expanded to include plankton collections. Training will continue through fall and winter through other means, e.g., recording and working with data generated from the water intake data, climate data and domestic fish surveys.

Our scientific studies have determined that mercury concentrations are increasing in burbot and lake trout in Great Slave Lake with pike showing less evidence of change. This mercury increase has been attributed to: 1) a warming trend which is causing the area to become more productive and the mercury that is present to be taken up more readily and 2) increased mercury emissions reaching North America from Asia. In order to investigate the first hypothesis, we will collect a series of plankton and benthos samples in the area offshore of the Slave River (Lutsel K'e will also provide samples) and assess whether their features have changed since our studies conducted in the mid 1990s, i.e., is there evidence of increased productivity? We also will examine mercury biomagnification rates in the food web and compare with earlier rate measurements. Finally a series of sediment samples will be collected to assess whether contaminant levels have changed since our studies in the mid 1990s. Of particular interest are contaminants associated with the oil sands industry.

Furbearer contaminants, population and harvest on the Slave River and Slave River Delta: historical and current conditions

Erin Kelly (Government of the Northwest Territories – Environment and Natural Resources)

Northern Voices, Northern Waters: The NWT Water Stewardship Strategy (2010) and *NWT Water Stewardship: A Plan for Action* (2011) promote federal, territorial, Aboriginal and municipal governments, boards, agencies and communities working together toward the vision "the waters of the Northwest Territories will remain clean, abundant and productive for all time". The Strategy was developed collaboratively with input from all water partners in the NWT, and reflects that Aboriginal governments and communities want to actively participate in water stewardship initiatives, particularly community-based monitoring.

The transboundary (NWT-AB) Slave River and the Slave River Delta are culturally and spiritually significant, support northern subsistence harvesting and lifestyles, are a direct source of drinking water, and provide habitat for a range of wildlife species including fish and furbearers. There are several potential sources of cumulative impacts to the Slave River and the Delta including hydroelectric development, historic transport of uranium and hydrocarbons, upstream development (oil sands, pulp mills, agriculture, etc.) and climate change

Community concerns related to cumulative environmental impacts along the Slave River

and Delta led several Aboriginal organizations, the territorial and federal governments, academics, ENGOs, the Aurora Research Institute and Aurora College to form the Slave River and Delta Partnership (SRDP) to work together on aquatic monitoring and research, with a focus on aquatic community-based monitoring. The SRDP recently completed a State of the Knowledge Report, Vulnerability Assessment and prioritization of research and monitoring goals.

The project presented in this proposal was developed based on community concerns related to cumulative impacts and the results of the Vulnerability Assessment and prioritization exercise. Communities are concerned about changes in contaminants concentrations of fish and wildlife over time, about changes to muskrat and beaver populations due to altered winter flow and ice regimes, and differences in harvesting over time.

Mink are top trophic level carnivorous species that often prey on fish and readily bioaccumulate environmental pollutants such as PCBs, DDT-related compounds, and methyl mercury. Mink are a sensitive indicator of ecosystem health as even low levels of PCBs can affect reproduction. A previous study of mink along the Slave River in 1991-1995 documented a number of metals and organochlorine compounds, including mercury, PCBs and toxaphene at low concentrations. This project will provide an update on current concentrations of metal and organochlorine contaminants in mink and several of their main diet species, including two important subsistence species (muskrat and hare). Fish contaminant data were also collected in the early 1990s on the Slave River, and recently through a SRDP project. Thus, a temporal comparison of mink, muskrat, hare, fish and sediment contaminant concentrations will be conducted. These can all be considered water quality and ecosystem health indicators.

Hunters and trappers along the Slave River and Delta have indicated that changing winter flow (water quantity) and ice regimes are affecting muskrat and beaver populations. Muskrat and beaver are of ecological, economic and subsistence value to community members. Current muskrat population densities will be assessed based on protocols developed for muskrat surveys in the Peace Athabasca Delta (Parks Canada). The surveys will take place in early winter (November) and replicated again mid-winter (January) to determine population densities and mortality rates. Bank beaver populations will also be assessed. Historical furbearer harvest records will be compiled and analyzed for trends over time.

Landscape scale flooding in the Great Slave Lake Plain: Expansion of lakes, flooding of wetlands and implications for bison habitat and local land users
Terry Armstrong (Government of the Northwest Territories – Environment and Natural Resources)

The goal of this project is to bring together local land users, researchers and resource managers to evaluate and understand the cumulative effects of environmental stressors that are driving abrupt ecosystem change in the Great Slave Lake Plain area north of Fort Providence. Water levels in large shallow lakes and wetlands throughout this important but

understudied ecoregion have increased dramatically since the mid-1990's. Consequently, hundreds of km^2 of moose and critical bison habitat have flooded, drowning vast forested areas and affecting both summer and winter travel safety and land-use access. The study will incorporate western scientific and traditional knowledge methods to describe recent ecosystem change and to test competing hypotheses regarding the drivers of change, which include increasing precipitation patterns, permafrost degradation and a beaver population boom. Project partners will evaluate remote sensing imagery and historical aerial photographs to determine the timing and aerial extent of recent flooding, and quantify habitat lost or modified due to increases in lake levels and flooding. These mapping products can also provide a focal point around which to stimulate discussion between land users and scientists. Tree ring samples from flooded and undisturbed spruce, larch and jack pine forests will be used to examine long term patterns of precipitation and the timing of recent and past flooding. Tree ring/climate studies will indicate if broad scale climatic changes are influencing water level fluctuations and whether the phenomena are cyclical. Fort Providence elders and land users, who have intimate, long-standing relationships with the local environment, will be engaged in a collaborative Traditional Knowledge study. Semi-structured interviews will be used to document knowledge about the drivers and occurrences of past water level fluctuations and both direct and indirect impacts on wildlife and traditional practices. This collaborative, multi-disciplinary project will enable an exchange of information between scientists and land users and assist in determining long-term objectives and indicators for community-based monitoring. Results will inform management of the land and bison, and support climate change adaptation strategies required for planning infrastructure (Department of Transportation) and traditional harvesting practices (Fort Providence).

Succession and regeneration response on seismic lines with respect to ecology, disturbance factors and time

Lisa Smith (Government of the Northwest Territories – Environment and Natural Resources)

The goal of this study is to collect and analyze data on the vegetation, forest and soil conditions on seismic lines in each of the four eco-climatic regions in the NWT with the aim of defining ecological and physical parameters that will assist in determining the long term recovery pathways of oil and gas disturbances.

Very little work has been done in the north to quantify and qualify the recovery and regeneration of seismic lines. We know that many lines that are decades old are visible from the air and the ground, but there is no information on the status of regeneration.

Understanding the natural processes involved in recovery of seismic lines provides a foundation for improving best management practices to minimize the impacts of seismic activities and ensure regeneration. Since many of the recovery processes evident on seismic disturbances are common to other types of disturbance, understanding the ecology of recovery processes allows other disturbances to be developed in such a way that recovery is enhanced.

Oil and gas disturbances, and particularly seismic lines have been identified as a primary concern for boreal caribou because of fragmenting the landscape and increased ability for predators to travel throughout the range. There is no empirical information to quantify the recovery of these sites and therefore predict the long term impact to boreal caribou habitat.

The results of this project will be available to all land and resource managers, and the information will benefit management of cumulative effects throughout the NWT. The outcome of the project is to have information that shows the range of recovery patterns on seismic lines to better inform management related to oil and gas disturbance, other land use disturbance, boreal caribou habitat management and forest management.

Visual analysis of predictors for increased mercury levels in predatory fish in NWT lakes

Kami Kandola (Government of the Northwest Territories – Health and Social Services)

Since 2007, there have been 12 consumption advisories issued in the Northwest Territories due to mercury levels in the fish muscle of predatory fish above Health Canada recommendations for retail fish. Although increased mercury levels in predatory fish in the Northwest Territories is not a new issue, the public concern over contaminants in general has been steadily increasing. However, it is not feasible to test every lake for mean mercury levels in fish. Nonetheless, a common question that arises often is how can one tell or predict which lake or river would have elevated levels of mercury.
The goal of this project is to use GIS tools to provide a visual analysis of predictors for increased mercury levels in lakes. It is our hypothesis that a number of factors would increase this probability such as drainage patterns to water bodies with existing elevated mercury levels, proximity to contaminated mines or sites, water basin shallowness or geological formation, forest fire history, warmer temperature changes and history of prior elevated levels of mercury. Our proposed work is to incorporate previously collected data on these postulated predictors into a GIS web-based map (web-map) which will allow us to manipulate the data with layers of secondary data and formulate an overall visual analysis of possible associations. This will allow us to determine potential "hotspots" for new sampling locations for future testing. It will also divert limited monitoring resources away from waterbodies or regions not perceived to be at risk. This proposed project is primarily a descriptive analysis. Currently, we have webmapped the following data using ArcGIS.
530 mean concentrations of mercury (Hg) representing a sample size of 7,348 fish in 114 study locations, of which 83 sample groups of fish (1,189 fish) were over 0.5 ug/g of Hg.

Simple bivariate analysis would be used to look for associations. Future studies would involve spatial regression analysis to test the significance of these associations. Nonetheless, the current visual analytic overview would impart valuable information to impacted communities, aboriginal organizations and the NWT regional contaminants committee since it will provide some level of risk assessment.

Investigating the cumulative effects of environmental change and human activity in the Tathlina watershed

Shawn Laidlaw (Ka'a'gee Tu First Nation)

The Tathlina Lake area is a culturally and economically significant area for the Ka'a'gee Tu First Nation, as Band members and their ancestors have lived, hunted, trapped and fished in the area for thousands of years. The lake supports a small commercial fishery, which employs KTFN members and contributes significantly to the economy of the community. The area is also downstream of one of the only producing oil and gas fields in the NWT, in the Cameron Hills. Multiple resource pressures and environmental change in the region have led the KTFN to question the cumulative effects of these influences on the current and future health of the aquatic system of the Tathlina watershed.

This is a multidisciplinary research project coordinated by the Ka'a'gee Tu First Nation, involving communities, universities, and government. The primary goal of this program is to understand the current health of the aquatic system in the Tathlina watershed and how this system has changed over time. Understanding the drivers of change in the aquatic system requires the determination of individual influences on the system, including the effect of climate change, upstream development, fire history and commercial fishing and of their cumulative effects.

A variety of techniques will be used to assess the current health of the aquatic system, including broad scale water quality and macroinvertebrate sampling using Environment Canada's CABIN protocol, investigating health and contaminants in aquatic furbearers, and detailed fish health studies. Specific research questions regarding historic contamination from upstream development and tracking environmental change in the region will be addressed using lake sediment cores.

This program is designed to address the cumulative impacts of upstream development, commercial fishing pressures and environmental change on water quality and fish health in the Tathlina watershed. Outcomes of this project include integration of government, university and community research in the area, and ultimately an understanding of how environmental change and multiple anthropogenic activities influence the health of the aquatic system in the watershed.

Quantifying the cumulative effects of industrial activities on the health of fish in rivers in the Northwest Territories
Gary Scrimgeour (Parks Canada)

Understanding the cumulative effects of aerial deposition and mining activities on the health of stream fish in the Northwest Territories is of central importance to northern communities members who continue to express concerns about: i) the effects of industrial activities on water quality and fish health and ii) whether fish are safe to eat. Determining whether contaminant levels in fish in the Northwest Territories are changing through time requires repeated collections of fish and chemical analyses of their tissues. Monitoring of contaminants in adult fish in northern rivers can be problematic because population densities are low and contaminant burdens are typically determined by killing the fish and removing a large fillet for analysis. Thus, repeated sampling of fish, which is crucial

to determining cumulative effects, can seriously deplete fish populations and compromise the ability to assess fish health. The goal of our work is to develop a new non-lethal method to assess levels of contaminants in fish by comparing concentrations of metals, including mercury, in muscle and three types of fins (e.g., adipose, caudal, and anal) of adult Arctic grayling and bull trout. Our hypothesis is that levels of metals in the muscle tissue will be strongly and positively related to at least one of the three fin types, and that this fin type can be used as a non-lethal surrogate to monitor levels of metals. We will also apply the method to quantify oncentrations of metals in adult: Arctic grayling and bull trout in Prairie Creek and up to four adjacent watersheds; and Arctic grayling, whitefish, and northern pike near the community of Nahanni Butte.
This newly developed method can form the core of northern cumulative effects programs whose objectives are to quantify the effects of aerial deposition, natural enrichment and enrichment by mining on metals loadings in adult fish. The data can also be used to assess if fish are safe to eat.
Once the method has been developed, we plan to complete a series of technical training sessions with local community members to demonstrate non-lethal methods and to facilitate community involvement with fish monitoring programs. We will hold information exchange sessions in 2013-2014 at multiple locations including Fort Simpson, Nahanni Butte, Wrigley, Yellowknife, and Hay River. The proposed work supports important northern initiatives including the Aboriginal
Aquatic Resource and Oceans Management Program (AAROM).

Understanding impacts of environmental change on char in the ISR: Science and Inuit knowledge for community monitoring
Chris Furgal (Trent University)

Residents of Sachs Harbour and Uluhaktok, NT have seen unprecedented variation in their local environment and Arctic Char populations in recent years (Riedlinger et. al., 2001, Nickels et al., 2002, Sachs Harbour and Ulukhaktok community residents, pers. comm., 2009-2011). Currently there is a lack of understanding of the effects of climate change on key natural resources for Arctic communities such as fish (Reist et al.,2006a,b). This research project is examining the influence of environmental variables, including those related to climate, on Arctic Char (*Salvelinus alpinus)* in these two ISR communities in the western Canadian Arctic. We aim to develop novel ways of monitoring local Arctic Char populations (priority VC) by utilizing the resources and knowledge of local residents in the creation of effective, long-term community-based monitoring plans. The goal of this project is to develop a novel ways to monitor the cumulative impacts of environmental and climate change on local char utilizing local expert knowledge and scientific understanding to create effective the char CBMP. The hypothesis is that there are environmental indicators that can forecast changes in char growth that can be used in CBMPs. Indicators to be used in CBMPs will be identified from both scientific and Inuvialuit Traditional Knowledge (TK). As a result, this research provides a unique 'mixed methods' research approach bringing together science (quantitative data and research methods) and TK (qualitative data and social research methods) for investigation methods that can be used for other research and monitoring plans in the future. Methods of data and knowledge analyses include thematic coding of TK interviews conducted with local fish experts and otolith (fish "earbone") age-specific growth back-calculation determining anomalous years of fish growth to determine potential correlation between fish growth and environmental conditions. Lake habitat characteristics, including water quality (priority VC), are also studied in relation to fish growth.

Expected outcomes are TK-determined environmental indicators with the potential to forecast changes in Arctic Char growth and that patterns of char growth in response to climate change will be different between the two communities demonstrating the need for the use of local knowledge and custom-tailored designs in char CBMPs in ISR communities.

Monitoring environmental change in the Mackenzie Delta Region: Inuvialuit observations and participatory-multimedia mapping
Trevor Lantz (University of Victoria)

The Mackenzie Delta Region is an area of ecological and cultural significance that is being impacted by larger and more frequent natural disturbances, increased air and ground temperatures, and renewed industrial activity (Alunik *et al.* 2003; Burn and Kokelj; 2009; Pearce *et al.* 2011). In the decades to come, the cumulative impacts of these changes will alter ecosystem structure and function, profoundly affecting northern communities and their ability to manage the impacts of industrial activity (Holroyd and Retzer 2005; Ford and Pearce 2010). In some areas, changes in land cover are occurring so rapidly that maintaining an accurate inventory is an ongoing challenge (Kokelj et al. In press). In this context of environmental change and uncertainty, there is critical need to draw on local knowledge and observations to track changes and provide planners and decision makers with up-to date information (Armitage 2005; Chapin 2011; Kokelj *et al.*, In Press; Bennett and Lantz, In Review).

In this research project we will use participatory multimedia mapping (PMM) to record Inuvialuit environmental observations. PMM combines 'on the land' interviews with videos and photographs captured by program monitors. Many of the observations recorded by local experts focus on disturbances (drained lakes, thaw slumps, storm surges, etc.), threats to infrastructure (winter icings, coastal erosion, failed culverts, etc.), and the locations of critical fish and wildlife habitat. Participant observations are combined with photo, video and audio recordings that are organized in a web-based map maintained by the University of Victoria. Ultimately this work provides a dynamic regional atlas describing the state of the environment. This information will make an enormous contribution to regional planning and decision-making that seeks to manage priority VCs. Using the PMM to record Inuvialuit observations and Traditional Ecological Knowledge will also enhance our ability to detect regional environmental change, understand cumulative impacts, and pursue environmental research of relevance to northern communities.

Snowpack accumulation: influence on caribou distribution, surface water chemistry and lake productivity
Michael English (Wilfrid Laurier University)

This project has two objectives: 1) retrieve spatial and temporal information on snow cover of the northern boreal forest from satellite passive microwave radiation and 2) long term evolution of lake productivity related to changes in climate.

The snowpack impacts climate and plays a significant role in boreal forest hydrology and surface water chemistry. Mammals have adapted to survive in snow but excessive depth and/or density can profoundly affect their physiology. Soil moisture, and active layer formation are influenced by the snowpack. Research illustrates how the snowpack determines if tundra is a net sink or source of CO_2 during winter and in controlling the fire regime the following summer.

Water quality and quantity concerns NWT communities. Climate-driven changes to the snowpack will affect export of nutrients from landscapes, partly controlled by volume of water runoff and passage through shallow soils. Increased snowpack depth will increase soil temperatures and microbial decomposition, affecting nutrients exported from soils. Permafrost degradation releases organic matter from frozen soils providing additional nutrients to nutrient limited northern lakes. Changes in nutrient provision to lakes will impact water quality and productivity, which, dictates energy flow through foodwebs, and therefore the abundance of fish that a particular lake can sustain.

Goals include: 1) quantifying temporal and spatial development and metamorphosis of the snowpack over the course of three years in order to quantify expected annual variability and how this influences retrievals of snow water equivalent (SWE) from satellite passive microwave data (from the SSM/I sensor); 2) relating patterns of SWE to spatial and temporal distribution of radio-collared caribou; 3) quantifying seasonal changes in surface water chemistry discharging from boreal forest catchments and 4) quantifying long term changes in lake productivity by measuring Carbon:Nitrogen ratios and carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope ratios in dated sediment cores collected from lakes. Changes will be examined in context of climate change and human disturbances (e.g., nutrient inputs from local and global sources) to i) determine baseline data on productivity pre-impacts and ii) understand which stressors (warming, hydrologic changes or human disturbances) are resulting in the greatest cumulative impacts on water quality and fish habitat.

Tlicho aquatic ecosystem monitoring project

Jody Snortland (Wek'eezhii Renewable Resources Board)

The purpose of the proposed project is to implement an aquatic ecosystem monitoring program based on Tlîchô and scientific knowledge to determine whether fish health, water and sediment quality is changing over time at locations near the four Tlîchô communities. There are many historic and proposed developments in the region and there is concern in Tlîchô communities that contamination of downstream aquatic ecosystems may occur or has already occurred. Thus, there is need to update baseline information and have ongoing monitoring of the aquatic ecosystem in this region in anticipation of continuing industrial pressures on the watershed.

Our community-driven project is led by Tlîchô elders supported by staff from the Tlîchô Government and Wek'èezhìi Renewable Resources Board (WRRB) and builds on a successfully implemented collaborative project conducted in 2010 and 2011 in water bodies near Behchokö. The project focuses on two priority VCs; water quality and quantity as well as fish and fish habitat and will be guided by the CIMP Pathways Project.

The project consists of five main phases: 1) planning workshop in the community; 2) a monitoring camp at a traditional fishery near the community in the summer ; 3) data review,

analysis and management; 4) reporting back to the community; and, 5) project conclusion. The planning workshop provides a forum to discuss indicators relevant to water quality, sediments and fish health from both a traditional knowledge and scientific perspective. Monitoring camps (near the community of Wek'weètì in year one, followed by Gamètì and Whatì in years two and three) will allow for the testing and refinement of Tlîchô and scientific based monitoring protocols developed in earlier phases of the project.

Elders and scientists will share with the youth their knowledge and methods for assessing, measuring and sampling fish health, water and sediment quality. In this way the two knowledge systems will provide the foundation for two sets of monitoring protocols (referred to as "Tlîchô Protocols") for long-term use and contribute to the overall Marian Lake Watershed Stewardship program as it is developed and implemented. In addition, the monitoring protocols developed and tested may contribute to CIMP's suite of standardized protocols for use across regions.