Aboriginal Affairs and
Northern Development Canada

Affaires autochtones et
Développement du Nord Canada

Synopsis of Research

Conducted under the 2011–2012 Northern Contaminants Program

Résumé de recherche

effectuées en 2011–2012 dans le cadre du Programme de lutte contre les contaminants dans le Nord

Canada

Synopsis of Research Conducted Under the 2010-2011 Northern Contaminants Program

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Table of Contents

Table des matières

Foreword

This report provides a summary of the progress to date of research and monitoring studies on contaminants in northern Canada, and related education, communications and policy activities that were conducted in 2011-2012 under the auspices of the Northern Contaminants Program (NCP). The projects cover all aspects of northern contaminants issues, as outlined in the NCP blueprints, including human health, monitoring the health of Arctic peoples and ecosystems and the effectiveness of international controls (abiotic monitoring and modeling, and biotic monitoring), education and communications, international policy and program management.

These projects were evaluated as proposals, by external peer reviewers, technical review teams, regional contaminants committees, and the NCP Management Committee to ensure that they support the overall Northern Contaminants Program objectives.

Further information about the Northern Contaminants Program is available on the NCP website at www.aadnc-aandc.gc.ca

Official Languages Disclaimer
These synopsis reports are published in the language chosen by the researchers. The full reports have not been translated. The Abstracts are available in English and French at the beginning of each report. Complete individual project synopses are available in either official language, upon request.
Requests for individual reports can be made to: PLCN-NCP@aadnc-aandc.gc.ca

Avant-propos

Le présent rapport comporte un résumé des progrès réalisés à ce jour dans le cadre des projets de recherche et des études de contrôle sur les contaminants dans le Nord canadien ainsi que des activités de sensibilisation, de communication et d'orientation menées en 2011-2012 sous l'égide du Programme de lutte contre les contaminants dans le Nord (PLCN). Les projets portent sur tous les aspects du dossier des contaminants dans le Nord, décrits dans les plans directeurs du PLCN, soit la santé humaine, la surveillance de la santé des résidants et des écosystèmes de l'Arctique et de l'efficacité des mécanismes internationaux de contrôle (surveillance abiotique et modélisation; surveillance biotique), l'éducation et les communications, la politique internationale et la gestion de programme.

Des pairs examinateurs de l'extérieur, des équipes d'examen technique, des comités territoriaux sur les contaminants, un comité régional sur les contaminants et le comité de gestion du PLCN ont évalué les propositions de projet, afin de s'assurer de la réalisation des objectifs du programme.

Pour obtenir d'autres renseignements, consultez le site Web du Programme de lutte contre les contaminants dans le Nord, à l'adresse www.aadnc-aandc.gc.ca

Avertissement lié aux langues officielles
Les chercheurs ont rédigé leurs rapports dans la langue de leur choix. Les rapports n'ont pas été traduits en entier, mais comportent un résumé en anglais et en français, au début. Il est possible d'obtenir sur demande le synopsis d'un projet dans l'une ou l'autre des langues officielles. Pour obtenir un rapport, envoyez un courriel à l'adresse PLCN-NCP@aadnc-aandc.gc.ca

Introduction

The Northern Contaminants Program (NCP) was established in 1991 in response to concerns about human exposure to elevated levels of contaminants in fish and wildlife species that are important to the traditional diets of northern Aboriginal peoples. Early studies indicated that there was a wide spectrum of substances – persistent organic pollutants, heavy metals, and radionuclides – many of which had no Arctic or Canadian sources, but which were, nevertheless, reaching unexpectedly high levels in the Arctic ecosystem.

The Program's key *objective is to reduce and, where possible, eliminate contaminants in northern traditional/country foods while providing information that assists informed decision making by individuals and communities in their food use.*

Under the first phase of the NCP (NCP-I), research was focussed on gathering the data required to determine the levels, geographic extent, and source of contaminants in the northern atmosphere, environment and its people, and the probable duration of the problem. The data enabled us to understand the spatial patterns and temporal trends of contaminants in the North, and confirmed our suspicions that the major sources of contaminants were other countries. The data, which included information on the benefits from continued consumption of traditional/country foods, was also used to carry out assessments of human health risks resulting from contaminants in those foods. Results generated through NCP-I are synthesized in the Canadian Arctic Contaminants Assessment Report.

Extensive consultations were conducted in 1997 - 1998 to find the common elements between the concerns and priorities of northern communities and the scientific needs identified as critical for addressing the issue of contamination in Canada's North. As a result, priorities for current and future research are

Le Programme de lutte contre les contaminants dans le Nord (PLCN) a été créé en 1991, en réaction aux inquiétudes que suscitait l'exposition des humains à des concentrations élevées de contaminants chez les espèces sauvages aquatiques et terrestres constituant une part importante du régime alimentaire traditionnel des populations autochtones du Nord. Les premières études ont mis en évidence une vaste gamme de substances – polluants organiques persistants (POP), métaux lourds et radionucléides –, substances qui dans de nombreux cas n'avaient pas de source dans l'Arctique, ni même au Canada, mais qui se retrouvaient néanmoins à des concentrations anormalement élevées dans l'écosystème de l'Arctique.

Le Programme a comme principal objectif *de travailler à réduire et, dans la mesure du possible, à éliminer les contaminants présents dans les aliments traditionnels, tout en fournissant de l'information pour aider les individus et les collectivités à prendre des décisions éclairées au sujet de leur alimentation.*

Le premier volet du PLCN (PLCN-I) visait principalement à réunir les données nécessaires pour déterminer les concentrations, l'étendue géographique et la source des contaminants dans l'atmosphère, l'environnement et les habitants du Nord ainsi que la durée probable du problème. L'information recueillie a permis de comprendre les tendances spatiotemporelles de la contamination dans le Nord et de confirmer les soupçons à savoir que les principales sources de contaminants se situent à l'étranger. De plus, ces données, qui portaient notamment sur les bienfaits de la consommation régulière de tels aliments, ont servi à évaluer les risques pour la santé humaine de la présence de contaminants dans les aliments traditionnels. Dans le Rapport de l'évaluation des contaminants dans l'Arctique canadien, on présente les résultats obtenus dans le cadre du PLCN-I.

based on an understanding of the species that are most relevant for human exposure to contaminants in the North, and geographic locations and populations that are most at risk.

In 1998 - 1999, the NCP began its second phase (NCP-II), which continued until 2002-2003. Results of this phase are synthesized in the Canadian Arctic Contaminants Assessment Report II (CACAR II). NCP-II supported research designed to answer questions about the impacts and risks to human health that may result from current levels of contamination in key Arctic food species. To ensure a balanced assessment of the risks, an emphasis is placed on characterizing and quantifying the benefits associated with traditional diets. Communications activities are also emphasized and supported under NCP-II. Under the leadership of the northern Aboriginal organizations, the dialogue between northerners and the scientific community, which was initiated in NCP-I, continued to build awareness and an understanding of contaminants issues, and helped to support the ability to deal with specific contaminant issues at the local level.

In addition, the NCP effort to achieve international controls of contaminants remained strong in NCP-II. The legally binding POPs protocol, under the United Nations Economic Commission for Europe (UN ECE) Convention on Long-range Transboundary Air Pollution, has been successfully negotiated and was signed by 34 countries (including Canada) at the UN ECE Ministerial Conference in Arhus, Denmark in June 1998. Canada ratified this agreement in December 1998. A legally binding global instrument on POPs under the United Nations Environment Programme was completed with the signing of the POPs Convention in Stockholm, Sweden, May 23, 2001. The Convention has been signed by more than 160 countries; Canada has signed and ratified the Convention. Cooperative actions under the Arctic Council, including the circumpolar Arctic Monitoring and Assessment Programme (AMAP), are continuing. NCP continues to generate the data that allows Canada to play a leading role in these initiatives.

De vastes consultations ont été menées en 1997-1998 en vue de concilier les préoccupations et priorités des collectivités du Nord et les activités scientifiques nécessaires pour traiter la question des contaminants dans le Nord canadien. Ainsi, on a établi, pour les travaux actuels et à venir, des priorités fondées sur la définition des espèces principales par lesquelles les habitants du Nord se trouvent exposés aux contaminants ainsi que des régions et des populations les plus à risque.

Dans le deuxième Rapport de l'évaluation des contaminants dans l'Arctique canadien, on trouve une synthèse des résultats du second volet du Programme (PLCN-II), mis en oeuvre de 1998-1999 à 2002-2003. Les recherches menées au cours de ce volet visaient à déterminer les risques et conséquences pour la santé humaine associés au degré actuel de contamination d'aliments clés dans l'Arctique. Pour que l'évaluation des risques soit juste, on a aussi défini et quantifié les avantages des régimes traditionnels. On a aussi mis l'accent sur les activités de communication dans le cadre du PLCN-II. Sous la conduite des organisations autochtones du Nord, le dialogue entre les habitants de la région et la communauté scientifique, amorcé lors du PLCN-I, a continué d'accroître la sensibilisation aux questions liées aux contaminants et la compréhension de celles-ci et a permis d'améliorer la prise en charge de certains problèmes associés aux contaminants à l'échelle locale. En outre, les efforts déployés dans le cadre du PLCN afin d'assurer l'établissement de mécanismes internationaux de contrôle des contaminants sont demeurés un objectif privilégié du second volet. À l'occasion de la Conférence ministérielle de la Commission économique des Nations Unies pour l'Europe, ayant eu lieu à Aarhus, au Danemark, en juin 1998, trente-quatre pays (dont le Canada) ont signé le protocole sur les POP, ayant force obligatoire, dans le cadre de la Convention sur la pollution atmosphérique transfrontalière à longue distance. Le Canada a ratifié l'entente en décembre 1998. Les négociations visant la conclusion d'un accord global sur les POP, ayant force obligatoire, dans le cadre du Programme des Nations Unies pour l'environnement, ont

The NCP is directed by a management committeethat is chaired by Aboriginal Affairs and Northern Development Canada (AANDC), and which includes representatives from four northern Aboriginal organizations (Council of Yukon First Nations, Dene Nation, Inuit Tapiriit

Kanatami, and Inuit Circumpolar Council), the Yukon, Northwest Territories and Nunavut Territorial Governments, Nunavik, and four federal departments (Environment, Fisheries and Oceans, Health, and Aboriginal Affairs and Northern Development). The management committee is responsible for establishing NCP policy and research priorities and for final decisions on the allocation of funds. Three territorial contaminants committees in the Yukon, Northwest Territories and Nunavut, and a regional contaminants committee in Nunavik support this national committee. Funding for the NCP's $4.5 million annual research budget comes from AANDC and Health Canada.

The NCP Operational Management Guide, available on the NCP website (http://www.aadnc-aandc.gc.ca), provides a summary of the management structures and review processes used to effectively implement the NCP. The Guide explains the overall management structures currently used, the proposal review process and outlines a protocol to be used to publicly disseminate health and harvest information generated by the NCP. Background information on all NCP committees and review teams is also provided.

In 1998, the NCP Management Committee redesigned the NCP-Phase II for application under the 1999-2000 funding year. The two main initiatives undertaken were: 1) the development of blueprints that represent the long-term vision and strategic direction for NCP-II; and 2) the implementation of a more open and transparent proposal review process. This new management structure is designed to ensure that the NCP remains scientifically defensible and socio-culturally aware, while at the same time, achieving real progress in terms of the Program's broad policy objectives.

abouti à la signature de la Convention sur les polluants organiques persistants, à Stockholm, en Suède, le 23 mai 2001, par plus de cent soixante pays. Le Canada a signé et ratifié la Convention. Les efforts concertés déployés dans le cadre des travaux du Conseil de l'Arctique, ce qui comprend le Programme de surveillance et d'évaluation de l'Arctique et le Plan d'action du Conseil de l'Arctique, se poursuivent. Les données recueillies dans le cadre du PLCN permettent au Canada de jouer un rôle de premier plan dans ces initiatives.

Le PLCN est dirigé par un comité de gestion, présidé par Affaires autochtones et Développement du Nord Canada (AADNC), qui compte des représentants de quatre organisations autochtones du Nord (soit le Conseil des Premières nations du Yukon, la Nation dénée, Inuit Tapiriit Kanatami et la Conseil circumpolaire inuite), des gouvernements du Yukon, des Territoires du Nord-Ouest et du Nunavut, du Nunavik et de quatre ministères fédéraux (Environnement Canada, Pêches et Océans Canada, Santé Canada et Affaires autochtones et Développement du Nord Canada). Le comité de gestion est chargé de l'établissement des priorités du PLCN en matière de politique et de recherche et de la prise des décisions définitives en matière de financement. Trois comités territoriaux sur les contaminants (Yukon, Territoires du Nord-Ouest et Nunavut), et un comité régional sur les contaminants (Nunavik) appuient les travaux du comité national. Les fonds pour le budget annuel de recherche de 4,5 millions de dollars du PLCN-II proviennent d'AADNC et de Santé Canada.

Le Guide de gestion des opérations du Programme de lutte contre les contaminants dans le Nord, que l'on peut consulter sur le site Web du Programme (www.aadnc-aandc.gc.ca), comprend un résumé des structures de gestion et des processus d'examen utilisés pour assurer la mise en oeuvre efficace du PLCN. On y présente les structures globales de gestion actuelles, le processus d'examen des projets et la marche à suivre pour la diffusion publique d'informations sur la santé et la

Blueprints were developed for each of the four main NCP subprograms: i) Human Health, ii) Environmental Monitoring and Research, iii) Community Based Monitoring, and iv) Education and Communications. The blueprints are used to provide the necessary guidance to project proponents for the development of proposals as well as to peer reviewers, review teams and the NCP Management Committee for evaluating proposals. They are evolving documents that are reviewed at least annually.

The proposal review process involves an external peer review process facilitated by review teams. The review of proposals is a two pronged approach involving a scientific review by external peer reviewers, facilitated by technical review teams, and a socio-cultural review facilitated by the Regional Contaminants Committees (RCCs). Both sets of recommendations are considered by the management committee in making final funding decisions. Proposals submitted under the Education and Communications subprogram are evaluated by a technical review team. All peer reviewers, review teams and RCCs use evaluation criteria and the blueprints to review and rate proposals. Written consent from the appropriate northern community authority or national-level Aboriginal organization is required for all projects involving field work in the North and/or analyses of samples as a condition of approval for funding.

This report provides a summary of the progress to date of research and activities funded by the Northern Contaminants Program in 2011-2012. It is a compilation of reports submitted by project teams, emphasizing the results of research and related activities that took place during the 2011-2012 fiscal years. The report is divided into chapters that reflect the broad scope of the NCP: Human Health; Environmental Monitoring and Research, Community Based Monitoring, and Education and Communications.

récolte recueillies dans le cadre du Programme. Le Guide comporte aussi des renseignements généraux sur tous les comités et équipes d'examen du PLCN.

En 1998, le comité de gestion du PLCN a réorienté le second volet du Programme en vue de l'exercice financier 1999-2000. Deux initiatives clés ont été mises en oeuvre, soit : 1) l'élaboration de plans directeurs représentant la vision à long terme et l'orientation stratégique du second volet; 2) la mise en oeuvre d'un processus ouvert et transparent d'examen des propositions. Cette nouvelle structure de gestion visait à assurer le caractère défendable du Programme du point de vue scientifique et la prise en compte des aspects socioculturels, tout en assurant la réalisation de progrès réels en ce qui a trait aux objectifs stratégiques généraux du PLCN. On a créé un plan directeur pour chacun des quatre sous-programmes principaux : i) santé humaine; ii) les tendances environnementales surveillance et de recherche; iii) surveillance communautaire ; et iv) éducation et communications. Ces plans fournissent les directives nécessaires aux promoteurs de projet, pour l'élaboration de leurs propositions, ainsi qu'aux pairs examinateurs, aux équipes d'examen et au comité de gestion du PLCN, pour l'évaluation des projets. Il s'agit de documents évolutifs, examinés au moins une fois par année.

Par suite de changements apportés au processus d'examen, un processus d'examen externe par les pairs, facilité par des équipes d'examen, a remplacé le comité technique du PLCN. L'évaluation des projets se fonde sur une approche à deux volets comprenant un examen scientifique par des pairs examinateurs de l'extérieur (facilité par des équipes d'examen technique) ainsi qu'un examen des aspects socioculturels, mené par les comités sur les contaminants. Le comité de gestion se penche sur les deux types de recommandation en vue de la prise de décisions définitives en matière de financement. Un comité d'examen technique évalue les projets soumis dans le cadre du sous-programme sur l'éducation et les communications. Les pairs examinateurs, les équipes d'examen et les comités sur les contaminants se servent des critères d'évaluation et des plans directeurs pour évaluer et noter les projets. Le consentement écrit d'une autorité compétente de la collectivité nordique ou d'une organisation autochtone nationale est requis pour tous les projets comportant des travaux sur le terrain dans le Nord ou des analyses d'échantillons, comme condition d'approbation du financement.

Le présent rapport comporte un résumé des progrès accomplis à ce jour relativement aux travaux de recherche et aux activités financés par le Programme de lutte contre les contaminants dans le Nord, en 2011-2012. Il s'agit d'une compilation des données provenant des rapports soumis par les équipes de projet. On met l'accent sur les résultats des travaux de recherche et des activités connexes menés au cours de l'exercice 2011-2012. Les chapitres du rapport rendent compte de la portée étendue du programme: soit la santé humaine; les tendances environnementales surveillance et de recherche, surveillance communautaire; et l'éducation et les communications.

Human Health

Santé humaine

Nunavik Child Cohort Study (NCCS): Communication of Study Results from the 11-year Follow-up

Étude de la cohorte du Nunavik : communication des résultats d'une étude concernant le suivi d'enfants de 11 ans

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Abstract

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 (5 years). In 2010, we completed the follow-up of 294 school-age (11 years) children and, during the year 2010/2011, we analyzed most of the 11-year data, presented the results to a working group (WG) involving the Public Health Director of Nunavik (PHD), members of the Nunavik Nutrition and Health

Résumé

L'exposition prénatale aux biphényles polychlorés (BPC) et au mercure a été associée à des effets sur le développement cognitif et la croissance des enfants. Les Inuit du Nunavik comptent parmi les populations les plus exposées à ces polluants environnementaux, qui s'accumulent dans les poissons et les mammifères marins. Toutefois, la consommation de poissons et de mammifères marins permet également d'absorber des substances nutritives, par exemple des acides gras oméga 3, qui accélèrent le développement du cerveau en bas âge. Nous avons procédé à trois études au Nunavik au cours des 18 dernières années pour examiner l'exposition prénatale à partir d'échantillons de sang ombilical, les effets sur des nourrissons jusqu'à l'âge de 12 mois et les effets sur des enfants d'âge préscolaire (5 ans). En 2010, nous avons complété un suivi auprès de 294 enfants d'âge scolaire (11 ans). Au cours de 2010 2011, nous avons analysé la plupart des données relatives à ce groupe d'âge, et avons

Committee (NNHC) and the researchers, and developed the messages and a communication plan for dissemination of study results in Nunavik. During the year 2011/2012 we completed the knowledge transfer activities, communicated the study results to the Nunavik population and stakeholders and completed the analyses of the 11-year data.

présenté les résultats à un groupe de travail dont faisaient partie le directeur de la santé publique du Nunavik, des membres du Comité de la nutrition et de la santé du Nunavik et des chercheurs. De plus, nous avons élaboré des messages et un plan de communication pour faire connaître les résultats de l'étude au Nunavik. Durant l'année 2011 2012, nous avons terminé les activités de transfert des connaissances, communiqué les résultats de l'étude à la population et aux parties intéressées du Nunavik et terminé l'analyse des données relatives au groupe des 11 ans.

Key Messages

- After one year of intensive knowledge transfert activities, the communication campaign aimed to provide results from the NCCS took place in Nunavik the week of October 3rd, 2011.
- Dissemination of study results and public health recommendation to the Nunavik population was accomplished through public meetings, radio shows, web sites, letter to each study participant, project poster, vulgarized fact sheet, press release and five YouTube video capsules.
- The follow-up at age 11 years successfully advanced our understanding of the domains affected by exposure to PCBs, mercury and lead, and provided new insights on the long-term beneficial effects of omega-3 fatty acids.

Messages clés

- Après un an d'activités intensives de transfert des connaissances, la compagne de communication, qui visait à présenter les résultats de l'étude de la cohorte du Nunavik, s'est tenue la semaine du 3 octobre 2011.
- La diffusion des résultats de l'étude et des recommandations de santé publique auprès de la population du Nunavik s'est effectuée de diverses façons : assemblées publiques, émissions de radio, sites Web, lettre postée à chaque participant de l'étude, affiches, feuillets de documentation en langage clair, communiqué de presse et enregistrement de cinq vidéos YouTube.
- Le suivi effectué à l'âge de 11 ans a fait progresser notre compréhension des domaines touchés par l'exposition aux BPC, au mercure et au plomb, en plus d'avoir apporté un nouvel éclairage sur les effets bénéfiques à long terme des acides gras oméga 3.

Objectives

- To communicate the study results of the 11-year follow-up to the Nunavik population and stakeholders, using a format that respects the communication plan developed during the year 2010/2011 within our WG which is composed of the Nunavik Public Health Director, NNHC members, other Inuit representatives and study-r elated researchers.
- To complete the analyses of the 11-year data set and write-up of results for publications.

Introduction

A recent review of evidence from several Canadian studies underlines an alarming burden of illness resulting from environmental exposures (Boyd and Genuis 2008). The reviewers conclude that environmental contaminants (ECs) are associated with an increased prevalence of low birthweight, respiratory diseases, asthma, cardiovascular illness and congenital anomalies. These results give rise to a plethora of important research questions including the cumulative effects of low-dose, long-term and mixed exposures, the nature and the prevalence of such effects. Past studies have demonstrated the vulnerability of foetal brain development to environmental exposures. The US National Academy of Sciences has estimated that as many as 25% of learning disabilities are due to either known toxic substances or the interactions between environmental factors and genetic predispositions. This is of particular concern when one considers that approximately 6.4% of children have a developmental or behavioural problem, 10% have a learning disability and 3.6% have a diagnosed speech problem. It is of primordial importance that the associations between ECs, health and development be elucidated. As noted by an expert committee of the World Health Organization (World Health Organization 2006), addressing such knowledge gaps requires the design and implementation of longitudinal prospective cohort studies of pregnant women, infants and children with exposure assessments at critical windows and with sensitive health end-points along the continuum of human development.

During the last 25 years, environmental monitoring and research activities have provided evidence that Inuit traditional food, whose nutritional benefits are well documented, is also the primary source of exposure to environmental contaminants (polychlorinated biphenyls (PCBs), mercury, and lead) for Northerners. With the exception of lead, these contaminants are transported by atmospheric and oceanic currents from industrial regions in the South, accumulate in the Arctic food chain, putting the population at risk for greater exposure. The primary source of lead has been the use of lead-containing ammunitions.

In 1994, we met with the PHD of the Nunavik Regional Board of Health and Social Services, the NNHC and several municipal councils to discuss a plan to study effects of pre- and postnatal exposure to contaminants on infant and child development. These actors expressed their support for such a study if it would also focus on a broad range of factors that influence child development, including nutrients from traditional food (omega-3 fatty acids), life habits during pregnancy (smoking, alcohol and drug use), and other influences (e.g., maternal stimulation, food insecurity), in addition to environmental contaminants (PCBs and pesticides, mercury and lead). The researchers readily agreed to this proposal and subsequently obtained funding from many sources, particularly the U.S. National Institute of Environmental Health Sciences and the Northern Contaminants Program (NCP) from Indian and Northern Affairs Canada. The first phase of the study was initiated in 1996. We investigated the role that nutrients from traditional food, life habits during pregnancy, environmental contaminants and other factors have on infant development. Almost 300 mothers and their infants from Puvirnituq, Inukjuak and Kuujjuaraapik participated in the study between 1996 and 2002. Results and implications from the first phase of this study, when infants were examined at 6 and 11 months of age, were communicated to the Nunavik population by the researchers and public health officials in 2003 and 2004. Public health recommendations were provided at that time to the population by the PHD. However it was not clear if adverse effects found during infancy would impact on child development at school age. It was therefore decided to continue to follow children to monitor their development and its influencing factors.

Between September 2005 and February 2010, 294 children and their mothers from all 14 Nunavik communities participated to the last follow-up of the cohort. The participants were 11 year old children who participated at birth to the Cord Blood Monitoring Program (1993-1998). Participants met with the research staff about half a day in the three larger Nunavik villages (Puvirnituq, Kuujjuaq, Inukjuaq). Participants who resided in other communities were transported by plane with their mother to one of the larger villages for testing. Mothers were contacted by phone, were provided with information about the study protocol, and invited to participate with their 11 year old children. Exposure to ECs and measures of nutrients were measured in cord blood samples (for prenatal exposure) and from a blood sample taken from the child at time of testing (for current/childhood exposure).

Activities in 2011/2012

Many **knowledge transfert and public communication activities** were conducted during years 2010/2011 and 2011/2012. First of all, the main results of the 11 year follow-up were presented to a working group (WG) composed of the PHD of Nunavik, NNHC members and representatives from other Nunavik agencies. Knowledge transfert activities completed during year 2011/2012 are summarized in the table below.

After completion of the knowledge transfert activities, the **communication campaign** aimed to provide results from the NCCS took place in Nunavik the week of October 3rd, 2011. The target audiences for this communication campaign were study participants (parents & children), the Nunavik population, employees of the regional health and social services network, midwives, regional organizations/ partners, national organizations/partners (regional contaminants committees (RCCs),

Meeting	Activities
June 9, 2011 Meeting of the NNHC, Kuujjuaq (1/2 day)	Presentation of public health messages, communication plan and communication tools by the PHD to the NNHC
June 22, 2011 Working group meeting, Quebec (1/2 day)	Revision of public health messages Revision of communication tools Planning of communication activities for fall 2011
Sept 7, 2011 Working session – G Muckle & S Déry – Quebec (1/2 day)	Revision of public health messages Revision of communication tools
Sept 22, 2011 Meeting with NCP representatives, Public health authorities of northern regions, delegate from contaminant committee (3 hours)	Presentation of study results and public health recommendations of the NCDS by G Muckle and S Déry
Sept 28, 2011 Working session – G Muckle & S Déry – in Quebec (1/2 day)	Revision of material for communication campaign to be held in Nunavik

health officials of other northern regions, NCP professionals supporting the RCCs and the general public.

Written **communication tools** were developped: personalized letter to each participant, project poster, vulgarized fact sheet and press release. As a communication mean aimed to reach the younger within the Nunavik population, five YouTube video capsules were developed.

Dissemination of study results and public health recommendation to the Nunavik population was accomplished through web sites, press relases, public meetings and radio shows:

- Written material presenting the history of the NCCS, its main results and public health recommendations was posted on web sites of the Nunavik Regional Board of Health and Social Services (NRBHSS) and the Nasivvik center: http://www.rrsss17.gouv.qc.ca; http://www.nasivvik.ulaval.ca/research/funded-research/nunavik-child-development/
- Five YouTube video capsules were made available on web sites of the NRBHSS and the Nasivvik center: http://www.rrsss17.gouv.qc.ca http://www.nasivvik.ulaval.ca/research/funded-research/nunavik-child-development/
- Coordinators of NCP funded RCCs from other northern regions and representatives from the NCP and Health Canada were met by G Muckle and S Déry during the 2011 Results Workshop (Victoria, September 21 2011). Detailed results and public health recommendations were provided at that time. Written documents presenting study results and recommendations were provided to the RCCs and public health authorities of other Northern regions the day they were made public in Nunavik (October 5, 2011).
- Meetings were held with regional stakeholders (October 4, 2011) and the board of directors of the NRBHSS (October 5, 2011).
- The NRBHSS board of directors meeting was simultaneously broadcasted on radio in all Nunavik communities.
- A phone-in show was broadcasted in all Nunavik houses on October 7, 2011.
- Press coverage of the communication campaign in can be seen at: http://www.nunatsiaqonline.ca/stories/article/65674eat_more_country_foods_nunavik_health_officials/
- The NCCS also provided information supporting public health interventions focussing on alcohol use and smoking during pregnancy that were made public: http://www.nunatsiaqonline.ca/stories/article/65674krg_wants_health_board_to_adopt_a_zero-tolerance_for_drinking_by_pregn/).

Finally, results were **disseminated to the scientific community and the general population** with the help of the Canadian Institute of Health Research (CIHR): The CIHR facebook is designed to made public results from health research conducted in Canada.

- http://www.facebook.com/HealthResearchInCanada.

Results

Below we summarize the results from the 11-yr follow-up on the outcomes that are the most clinically relevant: growth, intellectual function, and behavior. The manuscript reporting effects on intellectual function has been completed and the reporting effects on child behavior was recently accepted for publication. Multivariate analyses on each set of outcomes were performed and results are presented after controlling for confounders.

Effects on Growth. Weight, height and head circumference were measured in both the mother and the child, and body mass index (BMI) was computed. Multiple regression analysis indicated that the strongest determinants of child growth are, as expected, maternal height and weight, as well as height and weight at birth. Blood Hg levels, whether assessed in umbilical cord or at the time of testing, were not related to growth parameters. Cord plasma concentrations of PCB 153, the congener that was selected to represent the Arctic mixture and was detected in 100% of biological specimens, and cord plasma chlorinated pesticides were not related to child growth. However, after controlling for confounders, 11-yr plasma PCB levels were significantly related to smaller height, weight, BMI and head circumference ($p \leq .0001$). Comparisons conducted by quartile of PCB 153 indicated that significant differences were first seen in quartile 2, and the effects followed a dose-response pattern. In the highest exposed group, we observed a decrease of 5.2 cm for height, 3.2 kg for weight, 2.6 points for BMI, and 8.3 mm for head circumference at 11 yr of age, when compared with the least exposure group. Results for BMI and weight are likely to overestimate the PCB effect due to the intercorrelation between PCB levels and lipid mass, but the child PCB associations with decreased height and head circumference clearly indicate a negative effect of childhood PCB exposure on body size. There is a need to replicate these associations at a later age to determine whether they are persistent. The child PCB effects are most likely due to a long period of breastfeeding and frequent intake of PCB-contaminated country food during childhood, making this cohort by far the most heavily exposed to PCBs postnatally when compared with the other cohorts studied to date.

Effects on Cognitive Function. We administered the Wechsler Intelligence Scales for Children (WISC-IV) to 282 children. It includes 10 subtests, which focus on verbal ability, visuo-spatial reasoning, working memory, and information processing speed. Only the verbal subtests include questions about things that may be unfamiliar to Inuit children. Instead of the three verbal subtests usually included in the WISC-IV, we substituted two verbal tests (the Boston Naming Test and the Delis-Kaplan Verbal Fluency test) that include only items familiar to Inuit. Because the standard verbal subtests were not used, we consider our scores as estimates of IQ. As expected, the estimated IQ scores were related to the quality of the social environment ($p \leq .05$), as measured by socioeconomic status, mother's education, and mother's performance on verbal and nonverbal tests. IQ performance was not affected by whether the child had to travel by plane from a smaller village for testing. Although all exposures were related to IQ, statistical analysis showed that only prenatal Hg, Pb and DHA exposures were significantly ($p \leq .05$) associated with the estimated IQ scores once all other relevant factors were included in the analysis. The apparent correlation of prenatal PCBs with estimated IQ was due to the effect of prenatal Hg. Our results with regard to the prenatal Hg effects on cognitive function corroborate those reported in the Faroe Islands and New Zealand cohorts. We have also provided evidence for long-term benefits of prenatal -3 PUFA on cognitive development and memory processing at school age.

Effects on Behaviors. The child's classroom teacher was asked to complete the Teacher Report Form (TRF), a well-validated test. After controlling for confounders, cord blood Hg concentrations were significantly associated ($p \leq .05$) with higher TRF symptom scores of attention problems (Boucher et al. accepted). Consistent results were obtained on the Disruptive Behavior Disorders Rating Scale: children from the 3rd cord Hg tertile were 4.6-fold more likely to be identified by their teachers as exhibiting behaviors characteristic of the inattentive type of Attention-Deficit-Hyperavtivity-Disorder (ADHD). The increased risk of attention deficit observable in classroom is consistent with findings from a neuropsychological assessment of sustained attention in the Faroe Islands and our ERP findings in the NCCS. This study is the first to identify prenatal Hg exposure as a risk factor for ADHD–inattentive type. Whether these effects continue to be evident in adolescence needs to be documented.

NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project	7	7 (4 of them are Inuit)
Number of meetings/workshops in the North	3	3 meetings and 1 radio show
number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	3	three PhD students, three postdoctoral researchers
number of citable publications	9	publications in international peer-reviewed journals and 8 communications in international and national conferences as presented below

Discussion and Conclusions

Activities planned for the current year were successfully conducted, without significant changes, and there was no significant modification to the expected timeline and deliverables. The follow-up at age 11 years successfully advanced our understanding of the domains affected by exposure to PCBs, mercury and lead, and provided new insights on the long-term beneficial effects of omega-3 fatty acids. The next phase of this prospective longitudinal mother-child cohort will start during year 2013 with the follow-up of the cohort at the adolescence period.

Publications in Peer-reviewed Journals

Boucher, O., Muckle, G., Dewailly, É., Ayotte, P., Jacobson, J.L. and S.W. Jacobson. Domain specific effects of prenatal exposure to PCBs, mercury, and lead on infant cognition: Results from the environmental contaminants and child development study in Nunavik *(submitted)*.

Fortin, S., Jacobson, S.W., Gagnon, J., Forget-Dubois, N., Dionne, G., Jacobson, J.L., Muckle, G. Socioeconomic and psychosocial adversity in Inuit mothers during the first postpartum year *(submitted)*.

Valera, B., Muckle, G., Poirier, P., Jacobson, S.W., Jacobson, J.L., Dewailly, É. Cardiac autonomic activity and blood pressure among Inuit children exposed to mercury. Neurotoxicology *(accepted)*.

Boucher, O., Jacobson, S.W., Plusquellec, P., Dewailly, E., Ayotte, P., Forget-Dubois, N., Jacobson, J.L., & Muckle, G. Prenatal methylmercury and postnatal lead exposure: risk factors for attention deficit hyperactivity disorder among Inuit children in Arctic Quebec. *Environmental Health Perspectives (accepted)*.

Fraser, S.L., Muckle, G., Abdous, B.B., Jacobson, J.L., Jacobson, S.W. (2011) Effects of binge drinking on infant growth and development in an Inuit sample. Alcohol *(accepted)*.

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Communication in International and National Conferences

Dallaire, R., Muckle, G., Rouget, F., Seurin, S., Monfort, C., Multigner, L., Bataille, H., Kadhel, P., Thomé, J.-P., Jacobson, S.W., Boucher, O., Cordier, S. (2011/09). Effects of prenatal and postnatal exposure to chlordecone on infant neurodevelopment. 23rd International Society for Environmental Epidemiology. Barcelona, Espagne.

Dallaire, R., Dewailly, É., Ayotte, P., Forget-Dubois, N., Jacobson, S.W., Jacobson, J.L., Muckle, G. (2011/09). Effects of prenatal exposure to organochlorines and mercury on growth parameters in Inuit newborns from the Canadian Arctic. 23rd International Society for Environmental Epidemiology. Barcelona, Espagne.

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Poliakova, N., Muckle, G., Dewailly, É., Ayotte, P., Poirier, P., Valera, B., Jacobson, S.W., Jacobson, J.L. (2011/09). Persistent effect of prenatal docosahexaenoic acid on heart rate variability in Canadian Inuit children. 23rd International Society for Environmental Epidemiology. Barcelona, Espagne.

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Expected Project Completion Date

03/2012

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Assessment of Contaminant and Dietary Nutrient Interactions in the Inuit Health Survey: Nunavut, Nunatsiavut and Inuvialuit

Évaluation des interactions entre les contaminants et les nutriments alimentaires dans l'enquête sur la santé des Inuits : Nunavut, Nunatsiavut et Inuvialuit

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Abstract

The Assessment of contaminant and dietary nutrient interactions in the Inuit Health Survey seeks to incorporate contaminants research within the context of a broader health research study conducted in Nunavut, Nunatsiavut and Inuvialuit in 2007-8. This report presented key results on (1) the country food sources of contaminant exposure, (2) the percentage of participants that meet nutrient Dietary Reference Intake (DRI) and contaminant Toxicological Reference Values (TRV), and (3) options that maximize nutrient intake while minimizing contaminant exposure. Estimated dietary intake of mercury (Hg), selenium (Se), polysatuarated fatty acids (PUFA) including eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) were significantly correlated with their respective concentrations in blood collected from study participants. Average Hg exposure (7.9 μg/kg/wk) exceeded

Résumé

L'évaluation des interactions entre les contaminants et les nutriments alimentaires effectuée dans le cadre de l'Enquête sur la santé des Inuits vise à intégrer la recherche sur les contaminants dans le contexte plus large d'une étude scientifique sur la santé menée au Nunavut, au Nunatsiavut et dans la région désignée des Inuvialuit en 2007 et 2008. Ce rapport présente les principaux résultats en ce qui concerne : 1) les aliments traditionnels qui constituent des sources d'exposition aux contaminants; 2) le pourcentage de participants chez qui les valeurs de l'apport nutritionnel de référence (ANR) et les valeurs toxicologiques de référence (VTR) ont été atteintes; 3) les mesures permettant de maximiser l'absorption de nutriments tout en réduisant au minimum l'exposition aux contaminants. L'apport nutritionnel estimé en mercure (Hg), en sélénium (Se) et en acides gras polyinsaturés

the TRV of 5.0 μg/kg/wk with 35% of the population above this guideline. Average intakes for EPA and DHA met suggested dietary targets and average Se intakes fell within its Acceptable Range of Oral Intake (AROI). Since the estimated intakes of each of these nutrients were strongly correlated with estimated mercury exposure, efforts to decrease Hg exposure must emphasize the overall healthfulness of country foods and be designed to prevent concomitant harm to the nutrient status of Inuit.

Keys Messages

- The types of country foods consumed varied between the three participating regions
- Exposure levels and the major Hg and nutrient contributors also differed between regions
- Blood concentrations of Hg, Se, EPA and DHA were correlated with the estimated dietary intake
- Dietary advice to lower contaminant intake must consider impacts on nutrient intake
- Substitution of ringed seal liver with ringed seal meat is one possible strategy that decreases Hg intake without adversely affecting the nutrient status

(AGPI), y compris l'acide eicosapentanoïque (AEP) et l'acide docosahexanoïque (ADH), a été corrélé de manière significative aux concentrations respectives de ces substances observées dans les échantillons de sang recueillis chez les participants à l'étude. L'exposition moyenne au mercure (7,9 μg/kg/semaine) dépasse la VTR de 5,0 μg/kg/semaine, et 35 % de la population se trouve au delà de ce seuil. Les apports moyens d'AEP et d'ADH correspondaient aux cibles recommandées par le régime alimentaire, et l'apport moyen de sélénium était situé à l'intérieur de la fourchette acceptable d'apports par voie orale. Comme les apports estimés de chacun de ces nutriments sont fortement corrélés à l'exposition au mercure estimée, les efforts visant à réduire l'exposition au mercure doivent tenir compte des bienfaits généraux des aliments traditionnels et être conçus de façon à prévenir les effets néfastes concomitants sur l'état nutritionnel des Inuit.

Messages clés

- Les types d'aliments traditionnels consommés varient entre les trois régions participantes.
- Les degrés d'exposition et les principaux facteurs contributifs aux apports en mercure et en nutriments diffèrent aussi entre les régions.
- Les concentrations de mercure, de sélénium, d'AEP et d'ADH dans le sang ont été corrélées à l'apport alimentaire estimé.
- Les conseils en matière d'alimentation visant à réduire l'apport en contaminants doivent tenir compte des répercussions sur l'apport en nutriments.
- La substitution du foie de phoque annelé par de la viande du même animal constitue l'une des stratégies susceptibles de réduire l'apport en mercure sans avoir d'effet néfaste sur l'apport en nutriments.

Objectives

Short-term Objectives:

- Measure the body burden of environmental contaminants including persistent organic pollutants (POPs) and mercury (Hg);

- Study the relationship between diet intake of contaminants and body burden;

- Evaluate the complex interactions between lifestyle factors (obesity, smoking, physical activity, alcohol use) and contaminants exposure including POPs and Hg exposures as determinants of health;

- Investigate the interactive effects between dietary nutrients such as vitamin D, iron, selenium, and fatty acids with POPs and Hg on health status of the participants;

- Study the relationship between contaminant exposures, nutrient intakes, lifestyle factors and their relationship with markers of thyroid function, blood pressure, insulin resistance, lipid profiles, markers of oxidative stress and inflammation, neurotoxicity and bone mineral density.

- Develop health prevention and health promotion policy and communication strategy for contaminants in partnership with the regional Inuit organizations and health authorities.

Long-term Objectives:

- To close some of the existing gaps in knowledge that affect communities undergoing acculturation by providing them with information on the benefits and risks for adults associated with the consumption of traditional and market food.

- To collect baseline data in a format compatible with work in Greenland, Nunavik and Alaska to allow for prospective evaluation of factors associated with new emerging disease cases to enable improved evaluation of contaminant risks and nutrient benefits.

- To build capacity for the communities and local health authorities in public health. To engage in knowledge translation of findings in communities, with the larger network of NCP colleagues, and with scientific audiences including peer-review publications.

Introduction

While the NCP and Arctic Monitoring and Assessment (AMAP) programs are very successful in monitoring the levels of body burden and exposures in the northern populations, there is an increasing demand from the Inuit and health professionals alike to collect more information to interpret the contaminant data in the context of the health status of the populations. The Inuit Health Survey provides an excellent opportunity to conduct a comprehensive study that will include the measurement of dietary intake of contaminants, contaminant body burden, as well as other determinants of health and their relationship with health outcomes of the participants. It is the first time that such a complete set of data has been collected from Inuit in Nunavut, Inuvialuit Settlement Region, and Nunatsiavut. The study is a result of the integrated efforts of Inuit, Inuit Organizations, the Departments of Health of the Territorial and regional Inuit governments, and scientists from a variety of different disciplines.

Country food is a cornerstone of Inuit culture and spirituality. It provides social cohesion through sharing, saves money due to the high cost of living in the Arctic, and imparts many physical health benefits (AMAP 2009). In addition, country foods provide excellent sources of protein, healthy fats, minerals, and vitamins (Kuhnlein et al 1991; Kuhnlein and Soueida 1992; Kuhnlein et al. 2002). However, country foods can also contain contaminants and emerging research suggests linkages between contaminant exposure, chronic diseases, and the potential for nutrient and lifestyle factors to modify risks associated with contaminant exposures (Donaldson et al 2010). For example, there is evidence that nutrients such as fatty acids, selenium, vitamin E etc could alter the toxicity of MeHg (Mergler et al

2007). NCP sponsored laboratory studies also suggest such interactions in animal models (Van Oostdam et al 2005; Beyrouty and Chan 2006; Jin et al 2007). Therefore, it is important to contextualize the risk posed by contaminants in country foods relative to the many nutritional benefits they provide along with the complex nutrient-contaminant interactions that have been identified.

Activities in 2011-2012

Data Analysis
A total of 2595 Inuit from the ISR, Nunavut, and Nunatsiavut between 18 and 100 years of age participated in the survey; however, not all participants completed each part of the study. Of the 2595 participants, 2172 provided blood samples for the measurement of blood Hg, Se, EPA, DHA, and PUFA and 2072 of those reported consuming country food during the past 12 months. We successfully developed a probabilistic statistical model to quantify the intake of contaminant and nutrients from country foods. This modeling incorporated country food intake data collected during the Food Frequency Questionnaire (FFQ) along with the respective mercury (Hg) and selenium (Se) concentrations for each country food. Typical Hg concentrations of country foods were analyzed and reported by Dr. Gary Stern (Department of Fisheries and Oceans) as part of the Inuit Health Survey. Since country food nutrient composition data was not directly measured during the survey, we compiled a database using Se concentrations previously reported by CINE, peer-reviewed articles, the Canadian Arctic Contaminant Assessment Report (CACAR II), as well as Health Canada's Canadian Nutrient File. The Se database includes data from more than 80 foods and reflects the composition of 3489 individual food samples. Monte-Carlo simulations were completed using Crystal Ball (Fusion Edition, v11.1.1.1, Oracle).

We identified the primary dietary contributors of Hg and Se for each of the 3 participating regions (i.e. Inuvialuit Settlement Region, Nunavut, and Nunatsiavut). In addition, we repeated these analyses for the overall FFQ database to evaluate the primary contributors of Hg and Se for all the participants of survey. We evaluated the percent of Inuit that meet nutrient DRI and contaminant Toxicological Reference Values (TRV), and explored options that maximize nutrient intake while minimizing contaminant exposure.

Reporting Results to the Regions
The research team worked in partnership with the members of the Inuvialuit Inuit Health Survey Steering Committee to develop a community contaminants research results report, and in September 2011, met face-to-face with the steering committee to review and edit the final version of the results report. A results distribution plan was also developed. Based on the results for Inuvialuit, it was determined by the steering committee and research team that no health advisories related to country food consumption and contaminants were required for the region. The report will be printed and distributed in June 2012. The research team and the Inuvialuit Steering Committee have also submitted poster abstract reviewing the consultative process for community results report development utilized in Inuvialuit. The abstract was presented at the 2012 IPY conference.

In October of 2011, the research team presented the draft results report to the Nunatsiavut Inuit Health Survey Committee in Goose Bay. The committee reviewed and finalized the community results report, and a distribution plan was developed. Based on the results for Nunatsiavut, it was determined by the steering committee and the research team that in Nunatsiavut no health advisories related to country food consumption and contaminants were required. The results report will be translated, printed and distributed in June 2012.

In Nunavut, the research team presented the results to the steering committee in October 2011 in Iqaluit. The committee suggested revisions on the contents and layout of the draft report and also developed key public health messages. Based on the results for

Table 1. Spearman correlation coefficients (R) show that dietary intakes of Hg, Se, PUFA, EPA, and DHA are correlated to their respective blood concentrations. *P<0.05; **P<0.01; ***P<0.001.

Estimated Dietary Intake	Blood Concentrations (μg L^{-1}) of Mercury, Selenium, and Essential Fatty Acids									
	Hg		Se		PUFA		EPA		DHA	
	N	R	N	R	N	R	N	R	N	R
Hg (μg/kg/wk)	1979	0.478***	1979	0.410***	2007	0.094***	2008	0.376***	2008	0.270***
Se (μg/kg/wk)	1979	0.474***	1979	0.441***	2007	0.081***	2008	0.326***	2008	0.218***
PUFA (g/wk)	1979	0.347***	1979	0.297***	2007	0.061**	2008	0.273***	2008	0.221***
EPA (g/wk)	1979	0.416***	1979	0.373***	2007	0.072**	2008	0.317***	2008	0.256***
DHA (g/wk)	1979	0.411***	1979	0.366***	2007	0.084***	2008	0.320***	2008	0.276***

Nunavut, it was determined by the steering committee and research team that public advisories and messages regarding country food consumption, smoking, and contaminants should be developed and released. Specific advisories and messages regarding mercury and ringed seal liver consumption and smoking and high cadmium levels will be developed and communicated. This is the first time that dietary advisories are issued based on NCP sponsored research results in Nunavut. As a result, the steering committee determined that a detailed communication plan must be developed and an evaluation on the effectiveness of the communication must be conducted. The preparation of a final regional report, including translation, printing and distribution will be completed by June 2012.

Results

Estimated Hg dietary intake according to the Monte-Carlo simulations of the Crystal Ball model was significantly correlated to the measured Hg blood concentrations of Inuit Health Survey participants (Table 1). Similarly, estimated dietary intakes of Se (R=0.441), EPA (R=0.317), and DHA (R=0.276) from country foods were all significantly correlated to their respective blood concentrations. In contrast, the correlation between PUFA intake and blood PUFA concentrations was considerably weaker (R=0.061).

Overall, the arithmetic mean of Hg dietary exposure of all 2074 participants was 7.9 μg/kg/wk with 35% of participants exceeding the Health Canada TRV of 5 μg/kg/wk (Table 2). The major country food sources of Hg identified by the Monte-Carlo simulations are listed in Table 3 with the single largest country food source of Hg being ringed seal liver (59.1%). Ringed seal liver, is also an excellent source of Se. In fact, all of the major Hg sources for participants of the Inuit Health Study are rich in Se. Of the 722 participants that exceeded the Hg TRV, 94.7% also met the AI/RDA of Se, EPA, and DHA. As such, each of the major country food sources of Se (beluga muktuk), PUFA (arctic char), EPA (arctic char), and DHA (arctic char) were also within the top three country food sources of Hg. Accordingly, dietary nutrient intake was strongly correlated with dietary Hg exposure with correlation coefficients ranging between 0.808 (DHA) and 0.923 (Se) (Figure 1).

The ringed seal liver was the major Hg contributor despite only providing 19.0%, 0.9%, 0.9%, and 0.5% of Se, PUFA, EPA, and DHA intake, respectively (Table 3). The high contribution of ringed seal liver to Hg exposure is especially remarkable when one considers the small quantities of ringed seal liver consumed by most Inuit (90th percentile: 71.8 g/wk). For example, in contrast the 90th percentile of arctic char consumption is 1243 g wk-1; but, arctic char only results in 8.4% of Hg exposure. These results underline the fact that ringed seal liver disproportionately elevates Hg exposure relative to nutrient intake. Therefore, additional Monte-Carlo simulations were performed to evaluate what Hg, Se, PUFA, EPA, and DHA

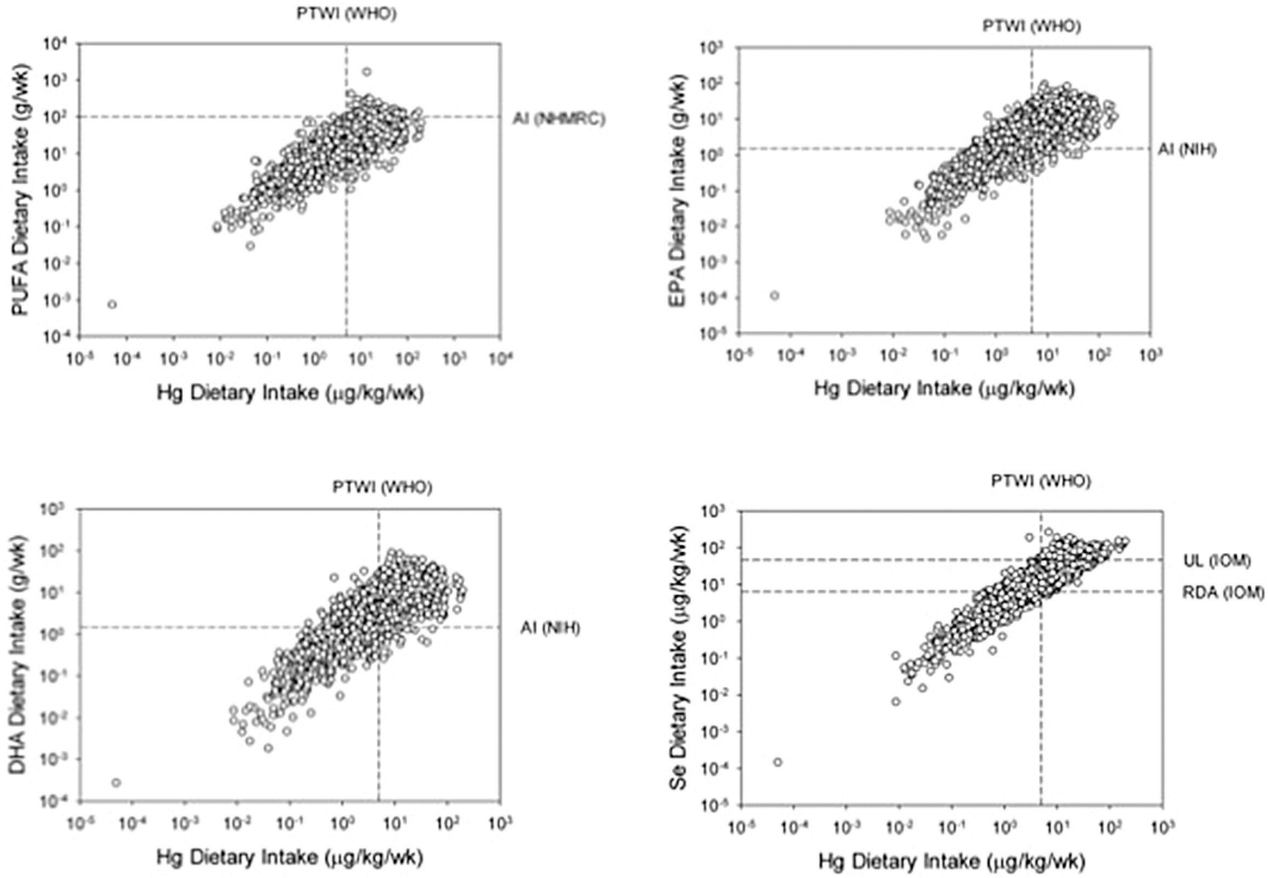


Figure 1. Hg Dietary Intake is strongly correlated with Se Deitary Intake, PUFA Dietary Intake, EPA Dietary Intake, and DHA Dietary Intake. Dietary guidelines for Hg (i.e. Provisional Tolerable Weekly Intake or PTWI), Se (Upper Limit or UL and Recommended Dietary Allowance or RDA), PUFA (Adequate Intake or AI), EPA (Adequate Intake or AI), and DHA (Adequate Intake or AI) are included for reference (IOM = Institute of Medicine).

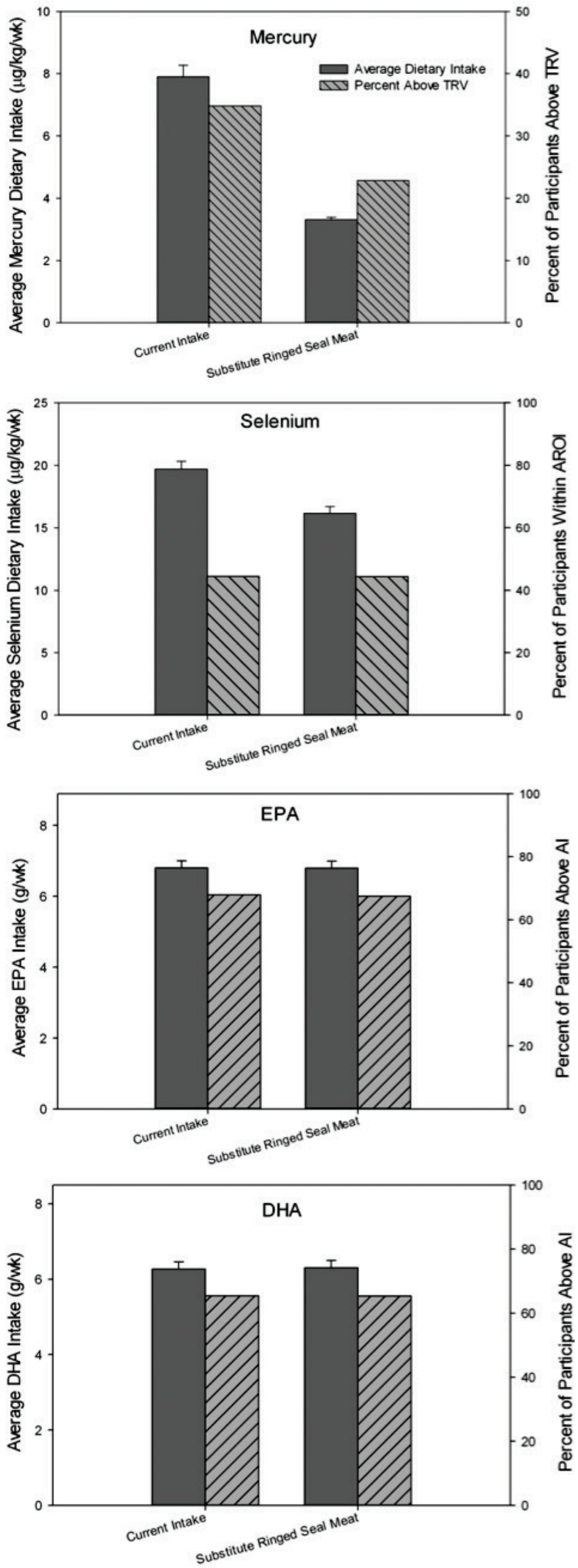
dietary intake would be if ringed seal meat was substituted in place of ringed seal liver in the diets of Inuit. This exercise demonstrated that the substitution of ringed seal liver with ringed seal meat would decrease mean Hg exposure of Inuit by 58% while decreasing average intake of Se by 18% but negligibly affected PUFA intake (Figure 2). Despite the 18% decrease in average Se intake, there was no appreciable change to the percent of participants below selenium's AROI (Figure 2).

Discussion and Conclusions

The types of country foods consumed varied between the three participating regions of the Inuit Health Survey due to, in a large part, differences in local scarcity and abundance of specific food items. Similarly, exposure levels and the primary Hg and nutrient contributors also differed between regions. Consequently, the dietary exposure levels (Table 2) and source apportionment (Table 3) reflect the average intake of all Inuit Health Survey participants and do not necessarily represent any one region. This necessitated risk communication strategies to be developed at the regional level so that public health messages could be tailored to the specific situations present in each region.

The results of the Inuit Health Survey showed that Hg body burden was positively correlated ($R=0.827$; $p<0.001$) with selenium blood concentrations. This correlation between Hg and Se exposure was equally strong when based upon dietary intake estimates (Figure 1) and is substantially stronger than recently reported for school-age Inuit children in Nunavik (Boucher

Figure 2 . Substituting Ringed Seal liver with Ringed seal meat significantly decreases Hg dietary exposure but has negligible effects on nutrient intake by the population.



et al. 2011). Similarly, Hg blood concentrations and dietary intakes for Inuit Health Survey participants were correlated with EPA blood concentrations (R=0.609; p<0.001) and intake (Figure 1; R=0.816; p<0.001) and DHA blood concentrations (R=0.616; p<0.001) and intake (R=0.808; p<0.001). These results are in agreement with NHANES data that showed a correlation (R=0.66) between PUFA intake and dietary Hg intake from fish and shellfish (Mahaffey et al. 2008). Our results are also in agreement with the correlations observed between Hg, Se, and PUFA for the Inuit village of Salluit in Nunavik, Québec (Belanger et al. 2006). In contrast, the lack of a correlation between total PUFA intake and blood PUFA concentrations could be due to varying metabolisms of PUFA between types of foods (Philbert et al. 2006).

The fact that 42.8% of Inuit Health Survey participants had Se dietary intakes below the RDA of 6.4 µg/kg/week (Institute of Medicine. 2000) does not indicate that numerous Inuit are Se deficient. Firstly, it is important to note that the nutrient intakes reported in this manuscript were based solely upon country food consumption and, therefore, does not include Se obtained from store-bought foods. This is especially important since the results of the 24-hour recall indicated that most Inuit adults obtain ca. 70% of their daily caloric intake from store-bought foods. Secondly, blood micronutrient concentrations offer the most reliable measure of Se status since they are not subject to the large uncertainties present in the FFQ. Every survey participant possessed Se blood concentrations in excess of the 7 µg dL-1 plateau concentration associated with maximal plasma selenoprotein concentrations (Institute of Medicine. 2000); therefore, 100% of study participants had adequate levels of Se to prevent deficiency. Furthermore, comparing the 10th, 50th, and 90th percentiles of Se blood concentrations from the Canadian Health Measures Survey (CHMS) with those from the Inuit Health Survey shows that Inuit adults have consistently higher levels of Se

Table 2. Hg and nutrient (Se, PUFA, EPA, and DHA) intakes of Inuit Health Survey participants as calculated using Crystal Ball.

Range		Percentile					Average[a] (Std Err)	Reference Intake	Percent Above Reference	Percent Below Reference	
		10th	20th	50th	80th	90th					
Hg (µg/kg/wk)	0 – 198	0.3	0.7	2.8	9.9	17.3	7.9	(0.4)	5.0[b]	34.8	-
Se (µg/kg/wk)	0 – 267	0.9	2.1	8.4	30.4	56.5	19.7	(0.6)	6.4 – 46.7[c]	12.8 (UL)	42.8 (RDA)
PUFA (g/wk)	0 – 1693	2.4	4.8	18.1	47.2	69.2	30.6	(1.1)	100[d]	-	95.4
EPA (g/wk)	0 – 95	0.3	0.8	3.5	11.4	16.9	6.8	(0.2)	1.5[e]	-	32.2
DHA (g/wk)	0 – 91	0.3	0.6	3.1	10.1	15.6	6.3	(0.2)	1.5[e]	-	34.6

[a] Arithmetic mean of the average intake for each of the 2074 participants (10 iterations per participant).

[b] Provisional Tolerable Weekly Intake (PTWI) for total Hg (WHO, 1972). Assumes 60 kg body weight.

[c] Recommended Daily Allowance (RDA) – Tolerable Upper Limit (UL) for Se (Food and Nutrition Board, 2005). Assuming 60 kg body weight.

[d] Sum of adult-male Adequate Intake (AI) for LA (linoleic acid) and ALA (α-linolenic acid) (National Health and Medical Research Council, 2005)

[e] Adequate Intake (AI) for EPA and DHA according to Workshop on the Essentiality of and RDIs for Omega-6 and Omega-3 Fatty Acids (Simopoulos, AP. et al. 2000. JACN: 18, 487-489)

than the general population of Canada, for which there is no evidence of Se deficiency (Health Canada, 2010). Additionally, the Se dietary intake estimates calculated using Crystal Ball appeared to overestimate the percent of participants at risk of selenosis (12.8%; Table 2). In contrast, only 4.3% of participants had blood Se concentrations above the guideline (100 µg dL-1) associated with selenosis (Institute of Medicine. 2000). However, it is not possible to determine whether or not these participants were adversely affected by excessive Se exposure since symptoms of selenosis (e.g. hair loss, nail sloughing) were not directly measured during the health exam.

Average EPA and DHA intake from country foods were 4.5-fold and 4.2-fold their respective AI values prescribed from the 1999 NIH workshop in Bethesda, MD (Table 2). These results are in agreement with those generated in the Inuit region of Nunavik where average DHA blood concentrations were significantly greater than individuals following a typical Western diet (Jacobson et al. 2008). In contrast to the omega-3 fatty acid intake by Inuit, typical North American EPA and DHA intake values for adults (Institute of Medicine. 2005) are approximately one-third of the AI recommended by the National Institute of Health of the United States (Simopoulos et al. 1999).

Risk communication efforts regarding the presence environmental contaminants must be designed to: firstly, emphasize the healthfulness of country foods and secondly, prevent concomitant harm to the nutrient status of Inuit in Canada's Arctic. As seen in Figure 2, the substitution of ringed seal liver with ringed seal meat is one such strategy that decreases Hg intake without adversely affecting the nutrient status of Inuit. However, it is critical to note that this intervention may prove to be relevant for only specific regions and/or sub-populations.

Expected Project Completion Date

March 2014

Table 3. The top ten dietary sources of Hg for Inuit Health Survey participants and the respective contribution of these ten foods to Se, PUFA, EPA, and DHA dietary intake.

Food Item	Food Intake[1] (g/wk)	Mercury		Selenium		PUFA		EPA		DHA	
		Average Dose[1] (μg/kg/wk)	Hg Intake (%)	Average Dose[1] (μg/kg/wk)	Se Intake (%)	Average Dose[1] (g/wk)	PUFA Intake (%)	Average Dose (g/wk)	EPA Intake (%)	Average Dose (g/wk)	DHA Intake (%)
Ringed seal liver	32.7	4.7	59.1	3.8	19.0	0.3	0.9	6.1E-02	0.9	3.0E-02	0.5
Arctic char meat	378.0	0.7	8.4	1.4	7.3	7.4	24.1	2.6E+00	37.7	2.0E+00	31.9
Beluga muktuk (skin only)[a]	50.2	0.3	4.4	2.9	14.8	0.4	1.3	1.4E-01	2.0	1.8E-01	2.9
Beluga muktuk (skin + fat)[b]	76.7	0.3	4.1	4.0	20.4	3.2	10.5	9.1E-01	13.3	7.9E-01	12.6
Ringed seal meat	148.3	0.3	4.0	0.9	4.7	1.2	4.0	3.0E-01	4.4	3.3E-01	5.2
Caribou meat	731.2	0.3	3.8	1.0	5.3	3.9	12.7	2.8E-01	4.1	1.1E-01	1.8
Narwhal muktuk (skin + fat)[b]	31.2	0.2	2.0	2.3	11.9	0.7	2.2	1.9E-01	2.8	1.5E-01	2.4
Dried caribou meat	269.1	0.1	1.6	0.0	0.2	1.9	6.1	3.0E-02	0.4	2.3E-02	0.4
Narwhal muktuk (skin only)	19.5	0.1	1.5	1.0	5.3	0.1	0.2	2.0E-02	0.3	1.8E-02	0.3
Beluga meat	25.3	0.1	1.2	0.2	0.8	0.1	0.3	1.3E-02	0.2	1.1E-02	0.2
Top 10 Foods Subtotal	**1762**	**7.1**	**90.0**	**17.7**	**89.8**	**19.0**	**62.3**	**4.5E+00**	**66.2**	**3.6E+00**	**58.2**
Total of All 82 Foods	**2227**	**7.9**	**100.0**	**19.7**	**100.0**	**30.6**	**100.0**	**6.8E+00**	**100.0**	**6.3E+00**	**100.0**

[1] Arithmetic mean of 10 iterations for each of the 2074 study participants that reported eating country foods in the FFQ.
[a] Muktuk not including subdermal fat
[b] Muktuk including subdermal fat

NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	35	ISR Project Committee – 14 Nunavut Project Committee – 6, Nunavut translation 4 Nunatsiavut Project Committee – 7, Nunatsiavut translation – 2
number of project–related meetings/ workshops held in the North (April 1, 2011 – March 31, 2012)	3	1. September 17–21 2011 – ISR Results Communications Booklet Workshop. Yellowknife. 2. October 20–21 2011 – Nunavut Results Communications Booklet Meeting. Iqaluit. 3. October 26–27 2011 – Nunatsiavut Results Communications Booklet Meeting. Goose Bay.
number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	3	Brian Laird Alexey Goncharov Yueting Shao
number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	2011:2 2012:1	2 NCP presentations by Chan and Laird 1 presentation at the Society of Toxicology by Laird and Chan

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Contaminant Nutrient Interaction Issues as Part of a Public Health Intervention Study of Inuit Children in Nunavik: Data Analysis and Communication

Questions liées à l'interaction des contaminants et des nutriments dans une étude d'intervention en santé publique portant sur les enfants inuits du Nunavik : analyse des données et communication.

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Abstract

Children are particularly vulnerable to toxic exposures since their organs and nervous systems are still developing and they may sometimes have a poor nutritional status. Various nutrients and diet components may protect against the adverse effects of contaminants on health. This study was conducted as part of the Nutrition Program in Nunavik Childcare Centres. Blood contaminant levels, dietary intakes and nutritional status of participating children were measured at recruitment and twelve months later. Data collection is now completed (2006-2010) and statistical analysis is underway. A total of 245 children were recruited (mean age 25.1 ± 9.8 months) and 110 of them were seen at the follow-up visit. Mercury, lead, PCB-153, BDE-

Résumé

Les enfants sont particulièrement vulnérables à l'exposition aux substances toxiques, car leurs organes et leur système nerveux sont encore en développement. En outre, leur état nutritionnel peut être faible. Divers nutriments et composants alimentaires peuvent toutefois les protéger contre les effets indésirables des contaminants sur la santé. La présente étude a été réalisée dans le cadre du Programme de nutrition dans les centres de la petite enfance du Nunavik. Les concentrations sanguines de contaminants, les apports alimentaires et l'état nutritionnel des enfants participants ont été mesurés au moment du recrutement et douze mois plus tard. La collecte de données (de 2006 à 2010) est maintenant terminée, et l'analyse statistique est en cours. Au total, 245 enfants

47, PFOS, and PFOA were detected in 97.5% to 100% of participating children. Exposure to mercury, *p,p'*-DDE and toxaphene Parlar 26 increased significantly between recruitment and the one-year follow-up visit, although these levels are still in agreement with the decreasing trends observed in other studies carried out in Nunavik residents of various age groups. On the contrary, exposure to BDE-47 decreased significantly over this period. Nevertheless, these levels are still higher than those reported in Nunavimmiut adults and of many children and adolescents worldwide. The present study on contaminant nutrient interactions will provide the scientific community, the public health authorities and Nunavimmiut essential information about dietary patterns and intakes, nutritional status and contaminant exposure of young Inuit children and the risks/benefits concerning the use of traditional foods during preschool age in the context of a healthy diet.

ont participé à cette étude (âge moyen : 25,1 ± 9,8 mois), et 110 d'entre eux ont été revus au cours d'une visite de suivi. Les substances suivantes : mercure, plomb, BPC 153, BDE-47, PFOS et PFOA ont été détectés chez 97,5 % à 100 % des sujets. L'exposition au mercure, au p,p'-DDE et au toxaphène Parlar 26 avait grandement augmenté entre le recrutement et la visite de suivi de l'année suivante, mais les concentrations étaient tout de même conformes aux tendances à la baisse observées dans d'autres études réalisées auprès d'habitants du Nunavik de divers groupes d'âge. Par contre, l'exposition au BDE-47 a considérablement diminué au cours de cette période. Néanmoins, ces concentrations sont plus élevées que celles qui ont été observées chez les Nunavimmiuts adultes et chez bon nombre d'enfants et d'adolescents à l'échelle planétaire. La présente étude sur les interactions entre les contaminants et les nutriments fournira à la communauté scientifique, aux autorités de santé publique et aux Nunavimmiuts des renseignements essentiels sur les tendances, les apports alimentaires, l'état nutritionnel et l'exposition aux contaminants des enfants inuits ainsi que sur les risques et les avantages de l'utilisation des aliments traditionnels à l'âge préscolaire dans le contexte d'un régime alimentaire sain.

Key Messages

- Between 2006 and 2010, 245 Nunavimmiut preschool children have been recruited from both coasts and 110 of them were seen for a follow-up visit one year after recruitment (which represents 53% of children recruited from 2006 to 2009).
- Blood levels of mercury, *p,p'*-DDE and toxaphene Parlar 26 increased significantly between recruitment and the one-year follow-up visit, although these levels are still consistent with the decreasing trends observed in the Nunavik population.
- On the contrary, one "emerging contaminant", namely BDE-47, decreased significantly during the one-year period,

Messages clés

- Entre 2006 et 2010, 245 enfants nunavimmiuts d'âge préscolaire ont été recrutés dans l'ensemble du Nunavik, et 110 d'entre eux ont été revus dans le cadre d'une visite de suivi, un an après le recrutement (soit 53 % des enfants recrutés de 2006 à 2009).
- Les concentrations de mercure, de *p,p'*-DDE et de toxaphène Parlar 26 détectées dans le sang des sujets ont considérablement augmenté entre l'année de recrutement et la visite de suivi effectuée un an plus tard, mais ces concentrations sont tout de même conformes aux tendances à la baisse observées au sein des populations du Nunavik.

despite the fact that it is still detected at higher levels in these preschoolers than in Nunavimmiut adults and in many children and adolescents worldwide.

- Our previous results also suggested that, for the same level of consumption of traditional foods, the consumption of tomato products and an adequate calcium intake could reduce mercury and lead exposure respectively, thus providing essential information about the risks/benefits of traditional food consumption in the context of a healthy diet.

- Par contre, les concentrations d'un « contaminant émergent », soit le BDE-47, ont considérablement diminué au cours de cette période de un an. Néanmoins, ces concentrations sont plus élevées que celles qui ont été observées chez les Nunavimmiuts adultes et chez bon nombre d'enfants et d'adolescents à l'échelle planétaire.

- Nos résultats précédents indiquent aussi que, pour la même consommation d'aliments traditionnels, la consommation de produits à base de tomate et un apport adéquat en calcium pourraient réduire l'exposition au mercure et au plomb, respectivement. Ces résultats offrent des renseignements essentiels sur les risques et les avantages de la consommation d'aliments traditionnels dans le contexte d'un régime alimentaire sain.

Objectives

The **overall objectives** of the present study are:

i) To document the contaminant nutrient interactions in Nunavik children of preschool age.

ii) To assist daycare directors, cooks and parents in making informed decisions concerning the benefits/risks of traditional/country foods among preschool children using dietary intakes, biochemical/hematological parameters and clinical information.

The **specific objective** of this report is to describe blood contaminant levels of children at recruitment and follow-up visit (2006-2010), and their changes over a one-year period.

Introduction

Traditional foods are extremely important to ensure adequacy of nutrient intakes for the Canadian Arctic Indigenous Peoples (Kuhnlein and Receveur 2007). However, the multiple nutritional and socioeconomic benefits of traditional foods must be weighed against the detrimental aspects of contaminants that are bio-amplified in Arctic food webs (Dewailly 2006).

Among their adverse health effects, toxic metals (mercury, lead) are associated with developmental deficiencies and learning disabilities in young children (Després et al. 2005; Huntington 2009). Exposure to POPs has also been associated with adverse health effects, such as an abnormal neurodevelopment, reduced immunity and altered levels of thyroid hormones (Dallaire et al. 2006; Darnerud et al. 2010; Gilman et al. 2009). On the other side, the definite health risks of emerging contaminant have not been determined yet, but experimental toxicology studies suggest thyroid hormone perturbations, neurobehavioral effects, liver toxicity and possible reproductive effects (Gilman et al. 2009).

Levels of metals and legacy POPs have decreased in Arctic populations during the past years (Van Oostdam and Donaldson 2009). In Inuit from Nunavik, temporal variations of toxic metals and POPs have been monitored over the last two decades. Preliminary results from our study (Turgeon-O'Brien et al. 2012) revealed lower levels of metals and legacy POPs than those observed in other surveys carried out in Nunavik Inuit children, pregnant women and adults (Després et al. 2005; Dewailly et al. 2007a; Dewailly et al. 2007b; Muckle et al. 2001).

Lower proportions of children exceeding the blood guidance for mercury and lead were also observed (Turgeon-O'Brien et al. 2012).

Concerning emerging contaminants, PBDEs and PFASs (perfluoroalkyl and polyfluoroalkyl substances) levels had never been reported in Nunavimmiut children or in Inuit children elsewhere. Our preliminary results (Turgeon-O'Brien et al. 2012) revealed higher levels of PBDEs than in Nunavimmiut adults and in children from many countries around the world, but lower than in children from California and Ohio, and in children working on a waste disposal site in Nicaragua (Athanasiadou et al. 2008; Carrizo et al. 2007; Chen et al. 2010; Dewailly et al. 2007b; Fangstrom et al. 2005; Lunder et al. 2010; Perez-Maldonado et al. 2009; Rose et al. 2010; Thomsen et al. 2002; Windham et al. 2010)

Time trend studies on contaminant exposure typically compare contaminant concentrations among populations at different discrete time points (Dallaire et al. 2003; Dewailly et al. 2007a; Dewailly et al. 2007b; Van Oostdam and Donaldson 2009). There are very few studies that evaluated changes on an individual basis and most of them were performed among infants (Ayotte et al. 2003; Verner et al. 2009) or adults (Humblet et al. 2011; Knobeloch et al. 2009). We aim to assess time trends in blood contaminants in a cohort of preschool Inuit children while adjusting for intra-individual differences.

Activities for 2011-2012

Data analysis. Statistical analyses on data collected from 2006-2008 continued in 2011-2012. We also began to analyse the whole data set (2006-2010). One team member worked on statistical analysis along with the support of a statistician from Université Laval.

Capacity building. Our team works closely with Inuit people and organizations to ensure the success of the Nutrition Program, including its research component. In doing so, we learn more about the Inuit culture and their ways of living which helps us to ensure that our work is appropriate and relevant for Nunavimmiut. During all data collections we also hired Inuit liaison persons to help the research team in contacting eligible families and performing questionnaires and blood sampling. Moreover an important component of the Nutrition Program is related to training of childcare centres cooks, directors and educators. We have also trained Inuit field workers who now participate actively in the training of childcare centres staff.

Communications. Preliminary results were published in the 2010-2011 NCP Synopsis report and an oral presentation was presented at the NCP meeting in Victoria in September 2011. Some results were also presented at the NNHC meeting in November 2011. The abstract that we submitted to IPY 2012 Conference was accepted.

An article on blood contaminant levels for data collected in 2006-2008 was published in *Environmental Science & Technology* (Turgeon-O'Brien et al. 2012). We also submitted an article on nutritional benefits of eating traditional foods to *International Journal of Circumpolar Health* (Gagné, Blanchet et al., *unpublished data*). We are currently working on four scientific articles to be published in peer reviewed journals.

Traditional knowledge. Regular consultations are carried out with childcare centres' representatives of each community to assess their needs and to develop/adapt the Nutrition Program according to their values and the reality of Nunavimmiut. Their advices are also very important in the realisation of this study and will be considered in the dissemination of results.

Results

Children recruited between 2006 and 2010 were living in Inukjuak (24%), Kuujjuaq (14%), Kangiqsujuaq (14%), Kangiqsualujjuaq (13%), Salluit (10%), Kuujjuarapik (10%), Quaqtaq (8%), Umiujaq (3%), Ivujivik (2%) and Akulivik (2%) (data not shown). As shown in

Table 1. Descriptive characteristics of participants at recruitment

Child characteristics	N=245
Gender (%)	
Male	52.2
Female	47.8
Age (months)	25.1 (9.8)
Breastfeeding status (%)	
Never breastfed	29.2
Have been breastfed	52.3
Still breastfed	18.5
Respondent characteristics	
Marital status (%)	
Married/Common law/Living with a partner	71.4
Single/Divorced/Widowed	28.6
Secondary school completed (%)	
Yes	39.6
No	60.4
Currently employed (%)	
Yes	83.3
No	16.7
Household characteristics	
Adults at home (n)	2.8 (1.4)
Children at home (n)	2.9 (1.5)
Crowding (%)[a]	48.6

Numbers are mean (SD) or %.

[a] Defined as more than one person per room where the number of rooms includes bedrooms, kitchen and living room.

Table 1, the mean age of participating children was 25.1 ± 9.8 months (11-54 months), 52% of them were male and 18% were still breastfed at the recruitment visit.

Percentages of detection and blood concentrations of toxic metals and POPs at the recruitment (Time 1) and follow-up visit (Time 2) are presented in Table 2. At recruitment, lead, PCB-153, PFOS, and PFOA were detected in all of the participants. One year later, lead and PCB-153 were still detected in every child, whereas PFOS and PFOA were detected in 98% of them. Mercury and BDE-47 were both detected in >97% of the children at Time 1 and Time 2. On both visits, one third of the PCB congeners tested were detected in ≥ 50% of the children; PCB-153 was the most prevalent and the most abundant (Time 1/Time 2: 100/100%; GM 20.6/18.7 ng/g lipid). Among pesticides, *p,p'*-DDE had the highest concentration (GM 74.2/67.5 ng/g lipid). Both toxaphene congeners were detected in >60% of participants in both occasions. About half of the PBDE congeners were detected in >50% (BDE-47, -99, -100, -153) at both visits, with the exception of BDE-153 (46% at Time 2). BDE-47 was the most abundant at both time periods (GM

Table 2. Descriptive statistics for toxic metals and persistent organic pollutants (POPs)[1]

	Recruitment			Follow–up visit		
	N	%	GM (95% CI)	N	%	GM (95% CI)
Heavy metals						
Mercury (nmol/L)t	190	97.9	8.8 (7.3–10.4)	83	97.6	11.4 (8.6–15.1)
Lead (μmol/L)	190	**100**	0.08 (0.07–0.09)	83	**100**	0.08 (0.07–0.09)
PCB (IUPAC #) (ng/g lipid)						
Aroclor 1260	181	95.6	152.6 (123.4–188.8)	79	93.7	131.4 (99.4–173.5)
118	181	81.8	5.0 (4.2–5.9)	79	84.8	4.5 (3.6–5.6)
138	181	92.3	9.9 (8.0–12.1)	79	91.1	8.5 (6.5–11.1)
146	181	52.5	3.1 (2.5–3.7)	79	57.0	2.6 (2.1–3.3)
153	178	**100**	20.6 (16.7–25.4)	76	**100**	18.7 (14.3–24.4)
163	181	58.6	3.6 (2.9–4.4)	79	62.0	3.2 (2.5–4.1)
170	181	62.4	3.5 (2.9–4.4)	79	58.2	2.8 (2.2–3.6)
180	181	84.0	8.3 (6.7–10.4)	79	81.0	6.7 (5.0–9.1)
187	181	63.0	4.0 (3.3–4.9)	79	68.4	3.7 (2.9–4.8)
Chlorinated pesticides (ng/g lipid)						
p.p'–DDE	181	87.3	74.2 (60.0–91.6)	79	91.1	67.5 (52.2–87.2)
β–HCH	181	50.3	2.5 (2.1–2.9)	78	46.2	–
Hexachlorobenzene	181	51.4	11.2 (9.4–13.4)	79	54.4	10.0 (8.1–12.4)
cis–Nonachlor	181	69.1	2.5 (2.0–3.1)	79	73.4	2.4 (1.8–3.1)
Trans–Nonachlor	181	92.8	14.7 (11.6–18.5)	79	89.9	13.1 (9.6–18.0)
Oxychlordane	181	93.4	8.5 (6.7–10.8)	79	92.4	7.5 (5.5–10.3)
Toxaphene (ng/g lipid)						
Parlar #26	181	60.2	2.0 (1.6–2.5)	79	70.9	2.1 (1.6–2.7)
Parlar #50	181	74.0	3.0 (2.4–3.8)	79	76.0	2.9 (2.1–3.9)
PBDE (IUPAC #) (ng/g lipid)						
47	181	98.3	28.8 (25.5–32.6)	79	97.5	23.5 (19.8–28.0)
99	181	85.6	8.8 (7.7–10.0)	79	82.3	7.4 (6.1–9.0)
100	181	65.2	5.3 (4.6–6.0)	78	65.4	5.2 (4.2–6.4)
153	164	55.5	4.5 (3.9–5.2)	66	45.5	–
Perfluoroalkyl and polyfluoroalkyl substances (ng/L)						
Perfluorooctanesulfonate (PFOS)	126	**100**	3101 (2641–3642)	48	97.9	2577 (2105–3154)
Perfluorooctane (PFOA)	126	**100**	1571 (1409–1752)	48	97.9	1513 (1335–1715)
Perfluorohexanesulfonate (PFHxS)	114	62.3	378 (322–444)	39	84.6	419 (345–508)

%: percentage of detection.

[1] The following contaminants were detected in less than half of the blood samples at recruitment and follow–up visit: PCB congeners 28, 52, 66, 74, 99, 101, 105, 128, 156, 167, 178, 183, 194, 201, 203, 206, *p,p'*–DDT, γ–HCH, Mirex, PBB–153, BDE–25, and BDE–28. The following were not detected in the samples: PCB–52, aldrin, α–chlordane, γ–chlordane, BDE–15, BDE–17 and BDE–33.

Table 3. Repeated blood concentrations of toxic metals and POPs

	N	Recruitment	Follow–up visit	
		GM (95% CI)	GM (95% CI)	p[1]
Heavy metals				
Mercury (nmol/L)	73	8.7 (6.4–11.7)	12.5 (9.0–17.4)	<0.05
Lead (μmol/L)	73	0.08 (0.07–0.10)	0.08 (0.07–0.09)	0.74
PCB (IUPAC #) (ng/g lipid)				
Aroclor 1260	66	151.4 (113.8–201.4)	160.6 (120.9–213.2)	0.29
118	66	5.0 (3.9–6.4)	5.3 (4.2–6.6)	0.40
138	66	9.9 (7.5–12.9)	10.2 (7.7–13.5)	0.59
146	66	2.8 (2.1–3.7)	2.9 (2.3–3.8)	0.34
153	66	19.6 (14.8–26.1)	20.5 (15.4–27.4)	0.43
163	66	3.3 (2.5–4.4)	3.6 (2.7–4.8)	0.16
170	66	3.2 (2.5–4.2	3.2 (2.4–4.2)	0.78
180	66	8.4 (6.15–11.4	7.8 (5.6–10.9)	0.36
187	66	3.7 (2.8–5.0)	4.2 (3.2–5.6)	0.11
Chlorinated pesticides (ng/g lipid)				
p,p'–DDE	66	69.6 (51.6–93.8)	79.2 (60.4–103.7)	<0.05
Hexachlorobenzene	66	10.0 (7.7–13.0)	11.5 (9.1–14.4)	0.07
cis–Nonachlor	66	2.6 (1.9–3.5)	2.7 (2.0–3.7)	0.43
Trans–Nonachlor	66	14.7 (10.6–20.3)	16.1 (11.6–22.4)	0.18
Oxychlordane	66	8.8 (6.4–12.1)	9.3 (6.8–12.8)	0.38
Toxaphen (μg/kg lipid)				
Parlar 26	66	2.0 (1.4–2.7)	2.4 (1.8–3.2)	<0.05
Parlar 50	66	3.0 (2.2–4.3)	3.4 (2.5–4.7)	0.20
PBDE (IUPAC #) (ng/g lipid)				
47	66	31.3 (24.8–39.4)	24.1 (19.7–29.5)	<0.001
99	66	8.6 (6.8–11.0)	7.2 (5.8–9.0)	0.11
100	65	6.0 (4.6–7.7)	5.5 (4.3–6.9)	0.25
Perfluoroalkyl and polyfluoroalkyl substances (ng/L)				
Perfluorooctanesulfonate (PFOS)	20	2786.2 (2140.9–3625.9)	3284.0 (2375.2–4540.6)	0.15
Perfluorooctane (PFOA)	20	1563.4 (1257.3–1944.0)	1661.7 (1355.4–2037.3)	0.56
Perfluorohexanesulfonate (PFHxS)	19	342.8 (245.6–478.5)	445.9 (327.7–606.8)	0.16

[1] p values derived from paired t test

28.8/23.5 ng/g lipid). All measured PFASs were detected in >60% of the children at Time 1 and Time 2. PFOS was the most abundant (GM 3101/2577 ng/L).

Table 3 presents repeated measures for blood contaminant concentrations for children with results at both times (paired *t*-test analyses). Blood concentrations of 18 of the 24 contaminants detected in ≥50% of the participants increased between recruitment and the one year follow-up visit although only mercury, *p,p'*-DDE, and toxaphene Parlar 26 increased significantly in the year between blood samplings. PCB-180, BDE-47, -99 and -100 were the only contaminants that decreased between both visits although only BDE-47 reached statistical significance.

Discussion and Conclusions

These final results on the prevalence of blood contaminant levels (2006-2010) confirm preliminary results (2006-2008) previously published (Turgeon-O'Brien et al. 2012). The percentage of detection of BDE-47 at Time 1 changed from 100% to 98.3% (2006-2008 versus 2006-2010), whereas the prevalence and concentrations of the other contaminants are very similar between both time periods.

Blood concentrations of three-quarters of the contaminants detected in more than half of the children increased between recruitment and the one-year follow-up visit although only mercury, *p,p'*-DDE and toxaphene Parlar 26 reached statistical significance. These preschool children were one year older at the follow-up visit and possibly more exposed to mercury and organochlorine pesticides through increased consumption of marine mammal meat and fat. Nevertheless, these levels are still in agreement with the decreasing trends observed in Nunavik (Van Oostdam and Donaldson 2009). To our knowledge, no studies have evaluated blood contaminants changes over time in Inuit children while controlling for intra-individual differences. However, in highly mercury-exposed Brazilian children (Marques et al. 2007), a decrease in hair mercury concentrations was observed between the ages of 6 and 36 months old, whereas no difference was shown between concentrations at 36 and 60 months.

In the present study, we also observed a significant decrease in BDE-47, although this level still remains higher than what has been reported in many children and adolescents worldwide, except for data obtained in some US (Ohio and California) and Nicaraguan children (Turgeon-O'Brien et al. 2012). We also found higher PBDE concentrations in our children compared to Nunavik adults. Indeed, using data from 2006 to 2008, we found that BDE-47, -99, and -100, were detected in a larger proportion of our participants (100%, 94.4%, and 73%, respectively) than in Nunavimmiut adults (57%, 19.8%, and 18.3%, respectively) (Turgeon-O'Brien et al. 2012). Also, BDE-47 was detected at higher levels in our participants than in those adults (GM 184 versus 36 ng/L). As one of the main sources of PBDEs in preschoolers is indoor dust (Jones-Otazo et al. 2005), this decrease in BDE-47 levels could be partially explained by a decrease in mouthing behaviors as children grow. It could also reflect a lower exposition over time since pentaBDE and octaBDE were voluntarily withdrawn or banned in the mid- or late 2000s (Government of Canada 2008; US EPA 2012). Determinants of blood contaminant concentrations and changes over time will need to be further assessed.

Overall, this research project revealed many important results. Indeed, this study showed preoccupying concentrations of PBDEs among these Inuit preschoolers. In addition to the findings presented in this report, we found that for the same level of consumption of traditional foods, the consumption of healthy store-bought foods such as tomato products could reduce mercury exposure while calcium intake could lessen lead exposure in these children (Gagné, Lauzière et al., *unpublished data*; Turgeon O'Brien et al. 2011) We also showed that although traditional foods were consumed by only 36% of the participants on the day of the dietary recall, it contributed significantly to their nutrient intake (Gagné, Blanchet et al., unpublished data) These results are very

NCP Performance Indicators

Performance Indicator	Number	Details / Description
Number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	0	Although this year's budget was devoted to statistical analyses, 245 children and their caregivers and over 25 Inuit liaison persons participated in this study over the life of the project. As part of the nutrition intervention, we are working in close collaboration with many Inuit individuals and organisations.
Number of project–related meetings/ workshops held in the North (April 1, 2011 – March 31, 2012)	1	We attended one meeting in Kuujjuaq with the NNHC.
Number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	0	
Number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	2011:0 2012:1	Published article : Turgeon–O'Brien et al. 2012 Submitted article: Gagné, Blanchet et al., *unpublished data* In preparation: 4 articles

meaningful in a nutrition point of view since they bring practical solutions that might help to lessen the risks associated with the consumption of traditional foods while taking advantage of their beneficial effects.

Expected Project Completion Date

Most data related to blood contaminant levels will be analysed by March 2013. Communication of the final results will follow and will be done in accordance with the recommendations of the NNHC.

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Monitoring Spatial and Temporal Trends of Environmental Pollutants in Maternal Blood in Nunavik (year 1)

Surveillance des tendances spatiales et temporelles des concentrations de polluants environnementaux dans les échantillons de sang provenant de mères au Nunavik (année 1)

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Abstract

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

Résumé

Les Inuit sont exposés à une vaste gamme de contaminants environnementaux par l'entremise de leur régime alimentaire traditionnel, qui comprend d'importantes quantités de poissons et de mammifères marins. Au cours des vingt dernières années, l'exposition des Inuit du Nunavik aux polluants organiques persistants et à d'autres métaux lourds a fait l'objet d'une surveillance dans le cadre de plusieurs études. Depuis la fin des années 1990, les études réalisées ont été centrées sur les effets de l'exposition aux biphényles polychlorés, aux pesticides chlorés, au mercure et au plomb sur la santé des habitants du Nunavik. Dans le cadre du présent projet, on propose de reprendre les activités de

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 were conducted on maternal blood, and the results 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, as well as information about the efficiency of intervention programs implemented following earlier surveys. During the year 2011-2012 this was conducted as a pilot project.

biosurveillance au Nunavik dans le but : 1) de comparer les niveaux d'exposition actuels à ceux qu'on observait il y a dix à vingt ans d'après nos derniers relevés; 2) d'évaluer l'exposition aux contaminants environnementaux émergents pour lesquels l'augmentation des concentrations dans les échantillons recueillis chez les espèces sauvages et les humains a été signalée à l'échelle de la planète; 3) de surveiller les effets de l'exposition aux contaminants sur la santé des nouveau nés. Les résultats de nos analyses de sang provenant de mères au Nunavik offrent une mise à jour des tendances géographiques de l'exposition ainsi que de l'information indiquant si les niveaux d'exposition à différentes classes de contaminants augmentent, diminuent ou demeurent stables au sein des populations du Nord. Ils fournissent aussi des renseignements sur l'efficacité des programmes d'intervention mis en œuvre à la suite des relevés précédents. Au cours de l'exercice 2011-2012, ces activités ont été réalisées dans le cadre d'un projet pilote.

Key Message

Although we present results of a small pilot study, measurements in the blood of Nunavik pregnant women in 2011 suggest that:

- Organic contaminants concentrations have continue to drop or stabilize
- Lead has also decreased
- Trans fatty acids are very low
- Omega-3 fatty acids have increased as well as selenium
- Mercury exposure remains very high

Messages clés

Bien que ces résultats aient été obtenus dans le cadre d'un projet pilote mené à petite échelle, les mesures issues de l'analyse de sang provenant de mères au Nunavik en 2011 indiquent que :

- les concentrations de contaminants organiques ont continué à diminuer ou sont demeurées inchangées;
- les concentrations de plomb ont aussi diminué;
- les concentrations d'acides gras trans sont très faibles;
- les concentrations d'acides gras oméga-3 ont augmenté, tout comme les concentrations de sélénium;
- l'exposition au mercure demeure très élevée.

Objectives

The general objective of this project was to *monitor prenatal exposure to food chain contaminants in Nunavik and to assess spatial and temporal trends of environmental contaminants found in maternal blood.* Targeted contaminants include the traditional suite of contaminants measured in previous projects since the mid-80s (polychlorinated biphenyls (PCBs), organochlorine pesticides, mercury (Hg) and lead (Pb) as well as emerging contaminants such as halogenated phenolic compounds (HPCs), perfluorooctanesulfonate (PFOS) and related compounds and brominated flame retardants (BFR), including brominated diphenyl ethers (BDEs) This project corresponds to point 4.3.2.2 on biomonitoring of the applicable NCP Blueprint for 2011-2012 This proposal aimed to continue similar activities conducted between 1993 and 2004.

The specific objectives were:

- To follow temporal trends for contaminants and assess the effectiveness of the Stockholm convention and prepare to assist the future UNEP convention on mercurym At the same time, by establishing this monitoring activity Canada will meet AMAP requirements.
- To follow temporal trend of key nutrients such as n-3 FA and selenium in order to interpret contaminants trends.
- To detect and quantify new emerging contaminants which have never been detected in maternal blood in the Arctic.
- To detect effects related to contaminants on maternal thyroid function during pregnancy and growth indices.
- To establish a potential new future mother/child cohort based on the 2-3 first years of recruitment.
- To use the monitoring tool for evaluation purposes (nutritional policies smoking etc).

Introduction

Three studies (fully or partially funded by NCP) were carried out in Nunavik to address temporal trends of POPs in Inuit populations.

The first study addressing temporal trends of environmental contaminants in Nunavik was carried out on cord blood data obtained in earlier surveys and addressed POPs and heavy metals (Dallaire et al 2003). In that study, 251 cord blood samples, collected between 1993 and 1996 on the east coast of Hudson Bay (Puvirnituq Inukjuak Kuujjuaraapik), were analyzed for PCBs, chlorinated pesticides, lead and mercury (the conventional suite of environmental contaminants). Significant decreasing trends were noted for PCBs (7.9%/year), DDE (9.1%/year), DDT (8.2%/year) and HCB (6.6%/year). Significant reductions were also found for lead and mercury although no clear trend could be established.

Between 1996 and 2001, a birth cohort was established in Nunavik. 213 pregnant women from Hudson Bay were enrolled. Pb, Hg, n-3 fatty acids and legacy POPs were measured in maternal and umbilical cord blood samples (Muckle 2004). This ongoing cohort study has already revealed that subtle developmental and cognitive deficits are related to prenatal exposure to mercury and different OCs and that beneficial effects are related to high n-3-fatty acids intakes. The effects of prenatal exposure to emerging contaminants such as BDEs and other BFRs, HPCs and PFOS have not yet been investigated.

In 2004, pregnant women participating to the Nunavik Health Survey in fall 2004 were included in a POPs monitoring study, a procedure which also prevented women to be solicited twice for different studies. Blood samples for contaminants analyses were sampled during the Nunavik Health Survey and dedicated to measurements of environmental contaminants (among other parameters pertaining to the health survey).

This project not only aimed assessing exposure to environmental contaminants through maternal blood monitoring but it also proposed to examine n-3 fatty acids and selenium content in order to interpret any change in contaminant body burdens. Linking POPs exposure to maternal thyroid status was also an important objective of this project which is now abandoned due to the reorientation of the sampling strategy for 2012-2013.

Activities in 2011-2012

Our research team from the Centre Hospitalier Universitaire de Québec (CHUQ) has worked closely with the the Nunavik Regional Board of Health and Social Services of Kuujjuaq to monitor prenatal exposure to food chain contaminants in the fourteen (14) communities of Nunavik. Our goal was to recruit by the end of March 2012 one hundred (100) pregnant women of eighteen (18) years old and over during their prenatal follow-up at the nursing clinic or maternity departments in Nunavik. Samples of blood and urine were collected and a questionnaire was administered about nutritional lifestyle habits and sociodemographics data.

The nurses, midwifes and head laboratories coordinators were training in each communities of Nunavik by a research nurse from September 26th until November 8th 2011. The project was generally welcomed in most communities but we realized that it was very difficult for most communities to absorb any supplementary work on their daily routine load work. Many efforts and arrangements were made by the project nurse coordinator in collaboration with the health professional's coordinators of both coasts to provide new tools in order to facilitate their work. As the health professionals rotate very frequently in this region, it was decided to help this situation by calling them on a monthly basis to encourage them and provide information or help whenever needed. The project nurse coordinator did phone calls in each community from the beginning of December 2011 until March 2012 on a regular basis. A letter was also sent to remind the importance of transmitting all informations required to maintain the project whenever their personnel turnover within their respective CLSC. This letter was addressed to all CLSC hospitals and laboratories of Nunavik on December 16th 2011

In spite of all the efforts made, we had only obtained a total of seventeen (17) participants. They were recruited in the following communities; Kangiqsualujjuaq (n=5), Kuujjuaq (n=1), Tasiujaq (n=1), Aupaluk (n=1), Kangirsuq (n=4), Akulivik (n=2) and Umiujaq (n=3).

Letters were sent to participants with abnormal results concerning one or few of these analysis; vitamins A and D, folic acid, mercury and lead. We considered important a follow up on these specifics results during their pregnancy to improve the mother and foetus health status.

Results (Preliminary)

Temporal comparisons between the 2011-2012 sampling period and previous ones should be interpreted with caution considering the limited sampling size (n=17). During most of the previous years, the numbers of pregnant women participating to monitoring or cohort programs varied between 20 and 53. Data were

Table 1. Mercury lead and selenium in whole blood of Nunavik pregnant women (2011)

Analytes blood	N	Mean	Low 95%	Up 95%	Min	Max	Geo mean	Geo M Low 95%	Geo M Up 95%
Hg (nmol•L)	17	40.9	28.2	53.5	54	78.0	32.6	22.1	48.2
Pb (μmol•L)	17	0.087	0.042	0.132	0.027	0.410	0.069	0.05	0.094
Se (μmol•L)	17	3.54	2.69	4.38	2.20	9.00	3.29	2.74	3.96

compared with previous monitoring data on pregnant women (Dewailly et al. 2007; Dallaire et al. 2003. Donaldson et al. 2010) Data from the Qanuippitaa survey (Dewailly et al. 2007) are also used for comparisons (but comparison between a general population and pregnant women should be interpreted with caution).

Metals (Table 1)

For *total mercury*, maternal whole blood concentrations decreased regularly from 12-13 ug•L in 1992-1993 to 4 ug•L in 2007. Our geometric mean was 8.2 ug•L indicating a stabilisation or even an increase in Hg exposure of these women.

Table 2. Phenolic compounds in maternal blood (Nunavik 2011)

Analytes in blood (ug•L)	N	Mean	Low 95%	Up 95%	Min	Max	Geo mean	Geo Low 95%	Geo Up 95%
Pentachlorophenol	17	0.333	0.199	0.467	0.16	1.3	0.287	0.223	0.369
Triclosan	17	0.055	0.028	0.081	0.03	0.23	0.043	0.031	0.060
Dichlorophenol_2_4	17				0.01	0.01			
Trichlorophenol_2_4_5	17				0.005	0.005			
Trichlorophenol_2_4_6	17				0.025	0.025			
Dichlorophenol_2_5	17				0.015	0.015			
hydroxy_4_BPC107	17	0.031	0.020	0.042	0.02	0.08	0.027	0.020	0.035
hydroxy_4_BPC_146	17	0.049	0.025	0.074	0.01	0.16	0.029	0.017	0.051
hydroxy_4_BPC187	17	0.051	0.025	0.076	0.01	0.16	0.030	0.017	0.053

Table 3. Perflorinated compounds in in maternal blood (Nunavik 2011)

Analytes in blood (ug•L)	N	Mean	Low 95%	Up 95%	Min	Max	Geo mean	Geo Low 95%	Geo Up 95%
Ac perfluorobutycic	17				0.25	0.25			
Ac perfluorodecanoic	17	0.70	0.45	0.94	0.20	1.90	0.57	0.41	0.80
Ac perfluorohexanoic	17				0.05	0.05			
Ac perfluorononanoic	17	2.88	2.12	3.64	1.10	6.10	2.57	2.00	3.31
Ac perfluorooctanoic	17	0.94	0.77	1.11	0.30	1.50	0.87	0.69	1.10
perfluoroundecanoic	17	0.68	0.42	0.94	0.20	1.90	0.54	0.38	0.77
Lipides_totaux	17	8.04	7.27	8.80	5.80	12.00	7.92	7.24	8.66
Perfluorobutane_ sulfonate	17				020	0.20			
Perfluorohexane_ sulfonate	17	0.51	0.36	0.65	0.10	1.30	0.43	0.30	0.60
Perfluorooctane_ sulfonate	17	6.15	3.48	8.83	1.40	23.00	476	3.27	6.92
Perfluoro1octane sulfonamide	17				0.045	0.045			

Table 4. Thyroid parameters in maternal blood (Nunavik 2011)

Blood Analytes	N	Mean	Low 95%	Up 95%	Min	Max	Geo mean	Geo Low 95%	Geo Up 95%
Anti–TPO (KIU/L)	17	8.20	6.68	9.72	5.00	14.65	7.75	6.49	9.24
Thyroglobuline (ug/L)	17	34.06	28.83	39.29	8.89	47.75	32.06	26.07	39.43
Anti–thyroglobuline (KIU/L)	17	11.72	10.96	12.49	10.00	14.84	11.64	10.90	12.42
T3 total (nM)	17	2.81	2.57	3.04	2.03	3.65	2.77	2.55	3.01
T4 libre (pM)	17	14.31	13.07	15.55	10.20	19.25	14.13	12.95	15.40
TSH (MIU/L)	17	0.95	0.48	1.42	0.02	3.47	0.50	0.24	1.03
TBG (g/L)	17	0.017	0.016	0.019	0.013	0.024	0.017	0.016	0.019
TTR (g/L)	17	0.26	0.21	0.30	0.15	0.57	0.25	0.21	0.29

Table 5. Fatty acids profile in compounds in maternal blood (Nunavik 2011)

Analytes (% total fatty acids)	N	Mean	Low 95%	Up 95%	Min	Max	Geo mean	Geo Low 95%	Geo Up 95%
EPA 5c8c11c14c17c_20_5_n3	15	0.73	0.56	0.90	0.25	1.28	0.67	0.52	0.86
DPA 7c10c13c16c19c–22:5 n3	15	1.85	1.76	1.94	1.60	2.09	1.84	1.76	1.93
DHA 4c7c10c13c16c19c–22:6 n3	15	4.43	3.94	4.93	2.53	5.85	4.34	3.84	4.90
n–3/n–6	15	0.28	0.24	0.31	0.16	0.35	0.27	0.24	0.31
n–6 total	15	26.94	26.01	27.87	24.17	30.46	26.89	25.98	27.83
n–3 total	15	7.36	6.69	8.03	4.79	8.96	7.26	6.59	8.00
Saturated	15	43.36	42.80	43.92	41.74	44.74	43.35	42.79	43.91
P (n–3 & 6)/S	15	0.79	0.77	0.81	0.71	0.84	0.79	0.77	0.81
Polyinsaturated n3 cis	15	7.36	6.69	8.03	4.79	8.96	7.26	6.59	8.00
Polyinsaturated n6 cis	15	26.86	25.96	27.77	24.17	30.23	26.82	25.93	27.73
Polyinsaturated n3 trans	15				0.00	0.00			
Polyinsaturé n6 trans	15	0.07	0.03	0.11	0.00	0.15	0.07	0.03	0.11
monoinsaturated trans	15	0.09	0.04	0.13	0.00	0.22	0.08	0.04	0.13
monoinsaturated cis	15	22.26	21.68	22.83	20.90	24.39	22.23	21.67	22.81
monoinsaturatedn6 cis	15	0.007	–0.007	0.021	0.00	0.10	0.01	–0.01	0.02
Total trans	15	0.16	0.12	0.20	0.00	0.33	0.15	0.12	0.20
Total cis	15	56.48	55.92	57.04	55.11	58.04	56.47	55.92	57.04
Total omega–6 cis	15	26.87	25.95	27.79	24.17	30.35	26.82	25.92	27.76

Table 6. POPs in maternal plasma (Nuanvik. 2011. µg/Kg lipds)

POPs (µg/kg lipids)	N	Mean	Low 95%	Up 95%	Min	Max	Geo mean	Geo Low 95%	Geo Up 95%
Aldrin	17	1.28	1.17	1.39	0.83	1.72	1.26	1.16	1.38
Alpha_Chlordane	17	0.64	0.59	0.69	0.42	0.86	0.63	0.58	0.69
Alpha_Endosulfan	17	0.64	0.59	0.69	0.42	0.86	0.63	0.58	0.69
Beta_Endosulfan	17	0.64	0.59	0.69	0.42	0.86	0.63	0.58	0.69
PCB 101	17	1.92	1.76	2.08	1.25	2.59	1.89	1.73	2.07
PCB 105	17	1.83	1.23	2.42	0.62	4.32	1.50	1.06	2.11
PCB 118	17	8.21	5.47	10.95	1.76	21.62	6.54	4.48	9.56
PCB 128	17	0.73	0.60	0.87	0.42	1.50	0.70	0.60	0.82
PCB 138	17	25.17	15.10	35.25	2.94	73.49	18.42	11.79	28.78
PCB 153	17	62.50	33.11	91.89	6.18	228.92	42.92	26.58	69.31
PCB 156	17	3.04	1.32	4.75	0.60	13.25	1.90	1.15	3.15
PCB 170	17	9.37	4.12	14.63	0.74	42.17	5.85	3.45	9.91
PCB 180	17	30.15	13.44	46.85	2.50	132.53	18.62	10.91	31.78
PCB 183	17	3.53	2.10	4.96	0.64	11.45	2.63	1.72	4.02
PCB 189	17	0.72	0.55	0.89	0.42	1.93	0.68	0.57	0.80
PCB 209	17	0.76	0.58	0.94	0.42	1.81	0.71	0.59	0.85
PCB 28	17	3.20	2.93	3.47	2.08	4.31	3.16	2.89	3.45
PCB 52	17	19.20	17.57	20.84	12.50	25.86	18.94	17.33	20.71
PCB 99	17	9.11	5.77	12.44	2.11	25.30	6.90	4.54	10.49
cisNonachlor	17	7.13	4.67	9.59	1.18	14.86	5.37	3.49	8.28
Dieldrin	17	8.69	5.47	11.91	2.67	21.00	6.70	4.56	9.86
Endrin	17	1.92	1.76	2.08	1.25	2.59	1.89	1.73	2.07
Gamma_Chlordane	17	0.32	0.29	0.35	0.21	0.43	0.32	0.29	0.35
Gamma_HCH	17	0.64	0.59	0.69	0.42	0.86	0.63	0.58	0.69
Heptachlor_epoxyde	17	4.05	2.46	5.63	1.25	12.05	3.20	2.26	4.54
Heptachlor	17	0.64	0.59	0.69	0.42	0.86	0.63	0.58	0.69
Hexachlorobenzene	17	20.96	15.14	26.78	3.82	41.89	17.44	12.27	24.79
Mirex	17	4.61	2.15	7.08	0.64	19.28	2.98	1.80	4.93
Oxychlordane	17	31.56	16.54	46.59	2.65	116.87	20.51	12.12	34.73
p.p'–DDE	17	172.72	112.61	232.82	23.53	405.41	129.30	83.10	201.10
p.p'–DDT	17	4.65	3.23	6.07	2.08	12.16	4.11	3.21	5.26
Beta–HCH	8	4.81	3.49	6.13	3.02	7.35	4.58	3.47	6.05
Toxaphene–26	17	6.53	3.92	9.14	1.15	16.00	4.65	2.94	7.36
Toxaphene–50	17	11.58	6.99	16.17	2.18	27.00	8.26	5.22	13.08
TransNonachlor	17	53.54	33.70	73.38	6.47	115.66	38.06	23.53	61.56

For *lead*, the geometric mean was 0.087 nmol•L. This concentration (18.1 ug•L) is in accordance with concentrations measured since the early 2000s. Lead blood concentration averaged 45-55 ug•L in the 1990s. No women were over the recommended limit (100 ug•L) *Selenium* geometric mean is still very high (3.54 µmol/L) indicating a large consumption of marine food.

Organics
Phenolic compounds: PCP 0.33 ug•L compared to 0.82 ug•L in 2004 in all Inuit adults OH-PCBs 107, 146 and 187 were found at respective concentrations of 0.031, 0.049 and 0.051 ug•L compared to 0.159, 0.126 and 0.149 ug•L in Qanuippitaa (2004).

PFOS was found in average concentration of 6.15 ug•L compared to 18.4 ug•L in all adults in 2004.

POPs: 35 different POPs (including 15 PCB congeners) were measured in the plasma of participating pregnant women. Compared to published integration of data (Donaldson et al. 2010) from Nunavik, PCB 138, 153 and 180 were respectively in 2004/2007: 37/22; 72/40 and 31/16 ug•kg (lipids). In 2011, we found for these three congeners of PCBs: 25, 62 and 30 ug•kg respectively, showing almost no change since 2004. Data from 2007 were only coming from the Ungava Bay and since exposure is lower in this area compared to Hudson Bay, comparisons have to be done with caution.

Omega-3 FA
Few comparison data are available for *omega-3 fatty acid* profile in maternal **red blood cell membranes.** The only reliable time trend data are from the Qanuippitaa survey for which **plasma** FAs were measured in addition to the RBC measurements to allow comparison with the 1992 survey. Comparisons of results from the Nunavik health survey administered in 1992 with that from 2004 provide information on time trends. Indeed, analysis of fatty acids profiles for 1992 and 2004 found that n-3 PUFA in plasma went from about 10% in 1992 to about 7% of total fatty acids in 2004. EPA+DHA dropped from 8.57% to 5.99 % and the n-6/n-3 ratio increased from 2.87 to 5.78. During the same period, for 19-39 yrs participants,

NCP Performance Indicators

Performance Indicator	Number	Details / Description
Number of Northerners engaged in your project		This phase of the project involve northerners such as midwifes and health professionals.
Number of project–related meetings/ workshops held in the North	3	One NNHC meeting in Kuujuuak and two conference calls with health professionals coordinators, head laboratories, midwives of both coast (Hudson Ungava) and the Nunavik Regional Board of Health.
Number of students (both northern and southern) involved in your NCP work	1	Thérèse Adamou
Number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	0	

EPA+DHA dropped from 7% to 4.6% (in plasma phospholipids) and n-6/n-3 increased from 3.6 to 6.8. In red cell membranes (as in this study). EPA+ DHA measured in 2004 among < 40 years participants (both genders) was 5.61% and n6/n-3 ratio was 3.96 In our data (Table 5). EPA+DHA averaged 5.16 % and the n-6/n-3 ratio was 3.57 showing a better fatty acid profile or at least no aggravation. Whether or not the Charr program has influenced the trend will be investigate with next year data *Trans fatty* acids (0.16 % are now very low compared to 1992 (1.95%) and 2004 (1.20%) showing the success of national and regional actions aiming at reducing the presence of Trans Fats in store food.

Discussion and Conclusion

In 2011-2012, we had a lot of difficulties to complete the expected sampling plan. Instead of 100 participating mother, we were able to recruit only 17. The sampling and procedure strategy has been changed and we are confident that the 2012-2013 monitoring campaign will be successful. These preliminary data may indicate a very strong decrease in exposure to lead and trans fatty acids, both deleterious elements which were under a "ban" during the last years. However, mercury exposure continues to be as high as before. The situation with nutrients seems favourable with a relative stabilization in body burdens of omega-3 and selenium, indicating that sea and land food is still largely consumed by pregnant women These trends will however need to be confirmed when the sample size will be sufficient.

Expected Project Completion Date

TBD (March 2013 or 2014)

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Mercury Exposure and Emergence of Cardio-Vascular Diseases in Inuit

Exposition au mercure et émergence de maladies cardiovasculaires chez les Inuit

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Abstract

More and more data suggest that the cardiovascular system should be considered a potential target for Arctic contaminants. This project aims to investigate associations between exposure to mercury and the emergence of heart disease and related risk factors using the 3 large epidemiologic studies conducted among adults and children in Arctic Canada. We report that Hg is associated with high blood pressure, low heart rate variability and atherosclerosis in some but not all population studied. Since heart disease represents one of the most importance 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.

Résumé

De plus en plus de données portent à croire que l'appareil cardiovasculaire peut être atteint par les contaminants de l'Arctique. Le présent projet a pour but d'examiner les rapports entre l'exposition au mercure et l'apparition de maladies cardiaques et de facteurs de risque connexes à l'aide des trois grandes études épidémiologiques réalisées auprès d'adultes et d'enfants de l'Arctique canadien. Le mercure est associé à l'hypertension artérielle, à une faible variabilité de la fréquence cardiaque et à l'athérosclérose chez une partie de la population étudiée, mais pas toute. Puisque les maladies cardiaques sont l'une des causes les plus importantes de décès, même une légère incidence négative sur l'appareil cardiovasculaire peut avoir une importance plus grande, en ce qui concerne la santé publique, que tout autre effet sur la santé lié à une exposition aux contaminants.

Key Messages

- Inuit are among the people in the world most exposed to mercury and this exposure is not decreasing.
- In parallel, many health indicators show that cardiovascular diseases (CVD) are increasing.
- Recent international studies support the association between mercury and CVD.
- Hg is associated with high blood pressure in Nunavik but not in the IPY cohort or in children
- Hg is associated with low heart rate variability in all cohorts.
- Hg increases atherosclerosis in Inuit adults.
- Omega-3 and selenium are protective nutrients.

Messages clés

- Les Inuit font partie des personnes les plus exposées dans le monde au mercure, et cette exposition ne diminue pas.
- Parallèlement, de nombreux indicateurs de santé montrent que les maladies cardiovasculaires sont à la hausse.
- De récentes études internationales établissent un lien entre le mercure et les maladies cardiovasculaires.
- Le mercure est lié à l'hypertension artérielle au Nunavik, mais ce n'est ni le cas pour la cohorte étudiée dans le cadre de l'Année polaire internationale, ni pour les enfants.
- Le mercure est associé à une faible variabilité de la fréquence cardiaque dans toutes les cohortes.
- Le mercure augmente l'athérosclérose chez les Inuit adultes.
- Les oméga 3 et le sélénium sont des nutriments qui ont un effet protecteur.

Objectives

The general objective of this project was to evaluate the role of mercury exposure in the emergence of chronic diseases in the Arctic with the following hypothesis:

- Mercury exposure is associated with elevated *blood pressure* in adults and children even after controlling for major confounders.
- Mercury decreases *heart rate variability* in adults and children.
- Mercury is a risk factor for *atherosclerosis and oxidation.*
- Mercury is associated with higher prevalence of *cardio vascular diseases.*
- Study the role of *omega-3 fatty acids and selenium* in the above mentioned hypothesis.

Introduction

Most studies on the relationship between toxic metals and the risk for clinical cardiovascular disease has been on mercury exposure. The first studies reporting a relationship between methylmercury exposure and carotid intima-media thickness came from Finland (Salonen et al. 2000). Since then, several other studies have been published offering support to varying degrees. The same study group in a follow-up study showed that a high content of mercury in hair may be a risk factor for acute coronary events and cardiovascular disease (CVD), CHD, and all-cause mortality in middle-aged eastern Finnish men, and that mercury also may attenuate the protective effects of fish on cardiovascular health (Virtanen et al. 2005). The US Health Professionals' Follow-up Study (Yoshizawa et al. 2002) showed only a minimal overall risk. However, when analyses were performed after the exclusion of dentists, the relative risk for myocardial infarction (MI) increased to 1.7. The most important study was conducted in Europe and found a dose response relationship between Hg in toenails and MI (Guallar, 2002). Intake of mercury through food items from sea mammals and fish has been suggested to be involved in cardiovascular disease, and the relationship between mercury in blood and 24-h ambulatory blood pressure (BP) was studied in Greenland. Blood pressure in childhood is an important determinant of hypertension risk later in life, and methylmercury exposure is a potential environmental risk factor. A birth cohort of 1,000 children from the Faeroe Islands was examined for prenatal exposure to methylmercury, and at the age of 7, blood pressure, heart rate and heart rate variability were determined (Sorensen et al., 1999). In Nunavik, we aimed to study the impact of mercury levels on BP among Nunavik Inuit adults. The Health Survey «Qanuippitaa?» was conducted in Nunavik. Mercury was associated with increasing BP and pulse pressure among adults after considering the effect of fish nutrients (n-3 fatty acids and selenium) and other confounders (Valera et al. 2009). Some studies have reported an association between in utero exposure to mercury and reduced heart rate variability (HRV) (Sorensen et al. 1999; Oka et al., 2002; Grandjean et al., 2004). This latter effect reflects the balance between the cardiac parasympathetic and sympathetic activities of the autonomic nervous system (ANS) but information concerning the influence of MeHg on HRV is sparse.

Activities In 2011-2012:

Follow up of medical files (cohort Nunavik)
The project was presented to the ethics committee of CHUQ-CHUL, during summer 2011, and had the final approbation on September 14th 2011. The archivists from both Nunavik coasts; Hudson Bay and Ungava Bay, gave us the authorization to access all medical files for all people involve in the inuit cohort. A health professional of our team from the Centre Hospitalier Universitaire de Québec (CHUQ), went in the 14 communities of Nunavik last October 2011. The health professional scanned most of the cohort participants' medical files. Two trips were done in Nunavik to complete the medical file review. Afterwards we compiled all data requested within this project. information is available on cardiac and metabolic disorders, cancer, neurological affections, hospitalizations, since 2005, and actual medication. We did revise 924 medical files on the 929 targeted. Therefore, we do have only 5 missing medical files. We also contacted the Montreal General hospital and the Royal Victoria hospital, where few died. Of the number of 924, we documented 68 deaths between 2005 up to October 2011 (37 at the Hudson Bay, 26 at the Ungava Bay, and 5 from the Hudson Bay in Montréal).

Epidemiological analyses

- **Blood pressure and Hg** in adults and children: In the *child cohort*, both pre and post natal Hg exposure were considered. Major confounding factors were child gender (modifying) mother weight, mother BP, birth weight, child weight, mother and child BMI, child n-3 PUFA in blood, child physical exercise. *For adults:* BMI, gender, age, Se and n-3 PUFA. Analyses of BP-Hg in Nunavik adults has been published previously (Valera et al, 2009). Analyses were done retrospectively on the Nunavik 1992 adult survey. Epidemiological analyses were also conducted on the IPY cohort.

- **Heart variability and pulse and Hg** in Inuit. HRV indices were derived from a 2-hour Holter monitoring. For children, both pre and post natal Hg exposure were considered. Major confounders for adults and children are: n-3 fatty, age, gender, cholesterol, diabetes, obesity, physical exercise, smoking and alcohol consumption. Analyses of HRV-Hg in Nunavik adults has been published (Valera et al 2009) and data on children were published I June 2012. In addition, specific analyses between HRV and n-3 fatty acids were performed and published (Valera et al. 2011) this year. Activities on the IPY and Greenland cohort were also conducted.

- **Oxidation in adults (2004) and Hg.** The level of plasmatic LDL oxidation has been measured during the Qanuippitaa survey as a potential marker of oxidative stress. Association between mercury exposure, PON 1 activity, lipid oxidation (LDL-C) were assessed within the Nunavik (2004) data set and published (Ayotte et al. 2011). Similar analyses are being conducted by Dr Laurie Chan in the IPY cohort.

- **Carotid thickness (IMT) and Hg** in 40+ yrs old adults from the entire Inuit Cohort study (n=1033). We have finished the reading of the entire IPY cohort and Greenland. Preliminary analyses were performed on Nunavik and IPY data. Further epidemiological analyses for Greenland are also being conducted.

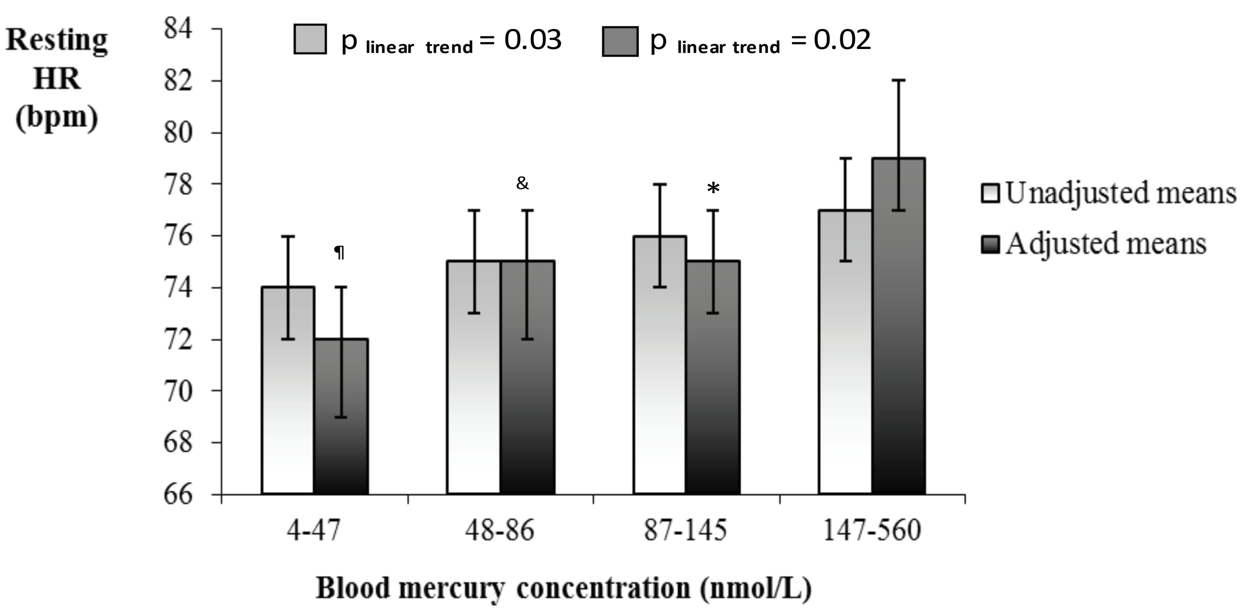
- Cardio vascular events and Hg exposure. All medical files were scanned and review. All data were captured in the pretested questionnaire. Preliminary analyses were conducted.

Results

Blood pressure and heart rate variability

Santé Quebec 1992 adults health survey
Mercury, resting heart rate (HR) and blood pressure (BP). The "Santé Quebec" health survey was conducted in 1992 in the 14 villages of Nunavik and a complete set of data was obtained for 313 Inuit adults ≥ 18 years. Blood pressure (BP) and resting heart rate (HR) were obtained using standardized protocols. Pulse pressure (PP) was calculated as systolic BP minus diastolic BP.

Figure 1. Resting heart rate by quartiles of blood mercury concentrations (Nunavik 1992).



¶ Significant difference with respect to quartile 4 (p= 0.003)
& Significant difference with respect to quartile 4 (p= 0.02)
* Significant difference with respect to quartile 4 (p= 0.03)
Means were adjusted for sex, WC, total PCBs and DHA+EPA

Mean age of the participants was 38 ± 14 years and the sample was composed of 132 men (42.2%) and 181 women (57.8%). Mercury geometric mean was 77.1 nmol/L (95%CI: 69.8-85.2) and levels ranged from 4 to 560 nmol/L. Means of systolic BP, diastolic BP, PP and resting HR were 114 ± 14 mm Hg, 74 ± 9 mm Hg, 40 ± 9 mm Hg and 75 ± 10 beats per minute (bpm); respectively.

Resting HR increased linearly across quartiles of blood mercury concentration after adjusting for confounders (p for trend = 0.02) (**Figure 1**). Taking the 1st quartile as reference, an increase of 6.9 beats per minute (bpm) was observed in the 4th quartile after adjusting for confounders. Regarding BP, crude means of systolic BP, diastolic BP and PP increased across quartiles of mercury concentration but only a slightly significant trend was observed for diastolic BP after adjusting for confounders. These results are part of a manuscript that is under revision in the *Environmental research* journal.

Nunavik Inuit Children
Mercury, heart rate variability (HRV) and blood pressure (BP). A cohort of 226 children was followed from birth to 11 years old. Mercury concentration in cord blood and in blood and hair at 11 years old were used as markers of prenatal and childhood exposure, respectively. HRV was measured using ambulatory 2h-Holter monitoring while BP was measured through a standardized protocol.

Median cord blood mercury and blood mercury levels at 11 years old were 81.5 nmoL/L (IQR: 45.0-140.0) and 14.5 nmol/L (IQR: 7.5-28.0), respectively. In simple regression, cord blood mercury tended to decrease the mean of R-R intervals (NN) (β= -0.13, p = 0.05) and the standard deviation of R-R intervals (SDNN) (β= -0.13, p= 0.06) but the associations did not reach the significance level after adjusting for covariates. However, after adjusting covariates [age, sex, birth weight, body mass index (BMI), height, total n-3 fatty acids, polychlorinated biphenyls (PCB 153), lead, selenium and maternal smoking during pregnancy], child blood mercury was associated with lower HRV (Table 1). Specifically, significant associations were observed with low frequency (LF) (β= -0.24, p= 0.02), SDNN (β= -0.28, p= 0.01), the standard deviation of R-R intervals measured over 5-minute periods (SDANN) (β= -0.32, p= 0.003) and the coefficient of variation of R-R intervals (CVRR) (β= -0.06, p= 0.01). These associations remained statistically significant after adjusting for cord blood mercury. Regarding BP, mercury biomarkers were not significantly associated with systolic BP or diastolic BP after adjusting for covariates (Table 2). These results are part of a manuscript that has been published in *Neurotoxicology* (http://www.sciencedirect.com/science/article/pii/S0161813X12001209)

Adult Inuit Health Survey (IPY): 2007-2008
Mercury and blood pressure (BP). The analyses of BP were conducted in a sample of 1759 adults ≥ 18 years with complete data on mercury, BP and the adjustment variables. Mean age was 45 ± 15 years and the study sample was composed of 673 men and 1086 women. Mean of blood mercury was 6.7 $\mu g \bullet L^{-1}$ (33.5 $nmol \bullet L^{-1}$) and levels were higher in men than women (7.7 vs. 6.1 $\mu g \bullet L^{-1}$, p< 0.0001).

Men showed higher systolic BP (119 vs. 114 mm Hg) and diastolic BP (78 vs. 74 mm Hg) than women (p< 0.0001 in both cases) while no significant difference was observed in PP (39 mm Hg in men and women, p= 0.51). Systolic BP increased with age (r= 0.27, p< 0.0001), while a negative correlation was observed with diastolic BP (r= -0.17, p< 0.0001).

As shown in Figure 2, the risk of hypertension increased significantly across quintiles of blood mercury concentration. With respect to the 1st quintile (the lowest mercury concentration), individuals in the 4th and 5th quintiles showed 1.6 and 2.5 higher risk of hypertension. However, after adjusting for BP risk factors (age, sex, triglycerides, fasting glucose, waist circumference, smoking and physical activity) and fish nutrients (selenium and EPA+DHA), a positive trend was still present but the ORs did not reach the significant level [ORs from the 2nd to 5th quintile: 1.03 (0.66-1.62), 0.93 (0.58-1.49), 1.08 (0.63-1.86) and 1.24 (0.64-2.38)]. Further adjustment for lead and PCB153 did not change the results.

Table 1. Simple and multiple regressions relating childhood mercury exposure to HRV parameters at 11 years (Nunavik).

HRV param.	Blood mercury (nmol/L)*		Hair mercury (nmol/g)*	
	Crude β (p–value) †	Adjusted β (p–value) †	Crude β (p–value) †	Adjusted β (p–value) †
LF (ms²)*	–0.15 (0.03)	–0.24 (0.02) § –0.21 (0.05) ¶	–0.12 (0.10)	– 0.14 (0.14) § – 0.12 (0.23) ¶
HF (ms²)*	–0.10 (0.15)	–0.17 (0.11) § –0.15 (0.19) ¶	–0.08 (0.26)	–0.12 (0.22) § –0.11 (0.30) ¶
LF/HF	–0.04 (0.57)	–0.04 (0.72) § –0.04 (0.72) ¶	–0.03 (0.71)	0.02 (0.82) § 0.02 (0.81) ¶
NN (ms)	–0.09 (0.20)	–0.20 (0.06) § –0.15 (0.18) ¶	–0.06 (0.43)	–0.14 (0.16) § –0.10 (0.30) ¶
SDNN (ms)*	**–0.19 (0.01)**	**–0.28 (0.01) §** **–0.26 (0.02) ¶**	–0.11 (0.10)	–0.11 (0.27) § –0.08 (0.41) ¶
SDANN (ms)*	**–0.22 (0.001)**	**–0.32 (0.003) §** **–0.31 (0.01) ¶**	–0.13 (0.05)	–0.10 (0.33) § –0.08 (0.43) ¶
rMSSD (ms)	–0.07 (0.28)	–0.15 (0.16) § –0.12 (0.28) ¶	–0.05 (0.46)	–0.10 (0.33) § –0.07 (0.48) ¶
CVRR (%)*	**–0.05 (0.002)**	**–0.06 (0.01) §** **–0.06 (0.02) ¶**	–0.03 (0.08)	–0.02 (0.41) § –0.01 (0.54) ¶

* Log–transformed variables; † standardized betas

§ Adjusted for sex, child age, birth weight, BMI, smoking during pregnancy, child selenium, child total n–3 PUFAs, child lead and child PCB 153.

¶ Further adjustment for cord blood mercury.

LF: low frequency; HF: high frequency; NN: mean R–R interval; SDNN: standard deviation of R–R intervals; SDANN: standard deviation of the average R–R intervals calculated over 5–minute periods; rMSSD: square root of the mean squared differences of successive R–R intervals; CVRR: coefficient of variation of R–R intervals (SDNN/NN*100)

Table 2. Simple and multiple regressions relating mercury biomarkers to BP parameters at 11 years old Nunavik children.

BP parameters	Cord blood mercury (nmol/L)*		Child Blood mercury (nmol/L)*		Child Hair mercury (nmol/g)*	
	Crude β † (p–value)	Adjusted β † (p–value)	Crude β † (p–value)	Adjusted β † (p–value)	Crude β † (p–value)	Adjusted β † (p–value)
SBP (mm Hg)	–0.10 (0.13)	0.09 (0.22) § 0.12 (0.13) ¶	**–0.18 (0.01)**	0.17 (0.06) § 0.15 (0.11) ¶	**–0.20 (0.004)**	0.10 (0.21) § 0.09 (0.31) ¶
DBP (mm Hg)	**–0.13 (0.05)**	–0.14 (0.10) § –0.15 (0.09) ¶	–0.11 (0.12)	0.14 (0.17) § 0.15 (0.15) ¶	**–0.15 (0.03)**	–0.005 (0.96) § –0.04 (0.63) ¶

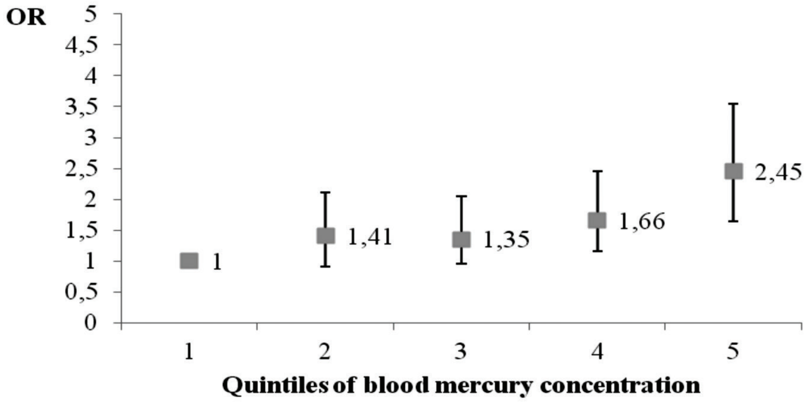
SBP: systolic blood pressure; DBP: diastolic BP

* Log–transformed variables; † standardized betas

§ Adjusted for sex, child age, birth weight, BMI, height, smoking during pregnancy, cord selenium, cord total n–3 PUFAs, cord lead and cord PCB 153.

¶ Further adjustment for child blood mercury.

Figure 2. Crude ORs of hypertension by quintiles of mercury distribution (IPY survey).



The 1st quintile was used as reference; *** p< 0.0001, **p= 0.01

We also analysed the association between quintiles of blood mercury and systolic BP, diastolic BP and PP after excluding individuals using anti-hypertensive medication. Although a positive trend was observed for crude means of systolic BP and PP, only differences in PP remained statistically significant after adjusting for age, sex, triglycerides, fasting glucose, waist circumference, smoking, physical activity, selenium and EPA+DHA. Specifically, PP was significantly higher in the 4th and 5th quintiles with respect to the 2nd quintile and also significantly higher in the 3rd quintile with respect to the 1st quintile. Further adjustment for lead and PCB153 did not change the results.

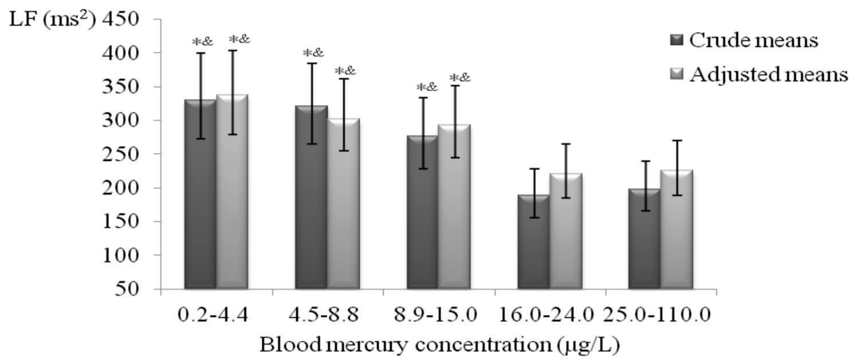
Mercury and resting heart rate (HR) and heart rate variability (HRV). The analyses of resting heart rate (HR) were conducted in a sample of 1759 adults ≥ 18 years with complete data on exposure, outcome and the adjustment variables, while the HRV analyses were conducted in a sample of 717 adults ≥ 40 years. The geometric mean of blood mercury concentration was 10.8 $\mu g \bullet L^{-1}$ among adults ≥ 40 years (range: 0.20-110.0 $\mu g \bullet L^{-1}$) and levels were higher in men than women (12.1 vs. 10.0 $\mu g \bullet L^{-1}$, p= 0.01).

All HRV parameters decreased with age, with Pearson correlations ranging from -0.14 to -0.32 (p< 0.0001 in all cases). Low frequency (LF), high frequency (HF) and the mean squared differences of successive R-R intervals (rMSSD) were lower in women. Since HF and rMSSD are specific indices of parasympathetic activity, these results suggest lower HRV among women due to lower parasympathetic activity. No significant difference was observed in the standard deviation of R-R intervals (SDNN), which represents the variation of consecutives heartbeats. Similarly, no significant difference was observed in the standard deviation of the average R-R intervals calculated over 5-minute periods (SDANN), which represents the overall HRV. Women also showed higher resting HR, which confirms the lower parasympathetic activity suggested by decreases in HF and rMSSD.

Figure 3 shows crude and adjusted means of LF (similar for HF) across quintiles of blood mercury distribution. Parameters such as LF and HF decreased across quintiles of blood mercury concentration and the differences remained statistically significant after adjusting for confounders. LF was significantly lower in the 4th and 5th quintiles compared to the 3 lowest quintiles while HF was significantly lower in the 4th and 5th quintiles compared to the 1st and 3rd quintiles. In contrast, no significant trend was observed for SDNN, SDANN and rMSSD. Regarding resting HR, crude means decreased across quintiles of blood mercury concentration. However, an increase in HR means was observed after adjusting for confounders with significant difference between the 4th and 5th quintiles.

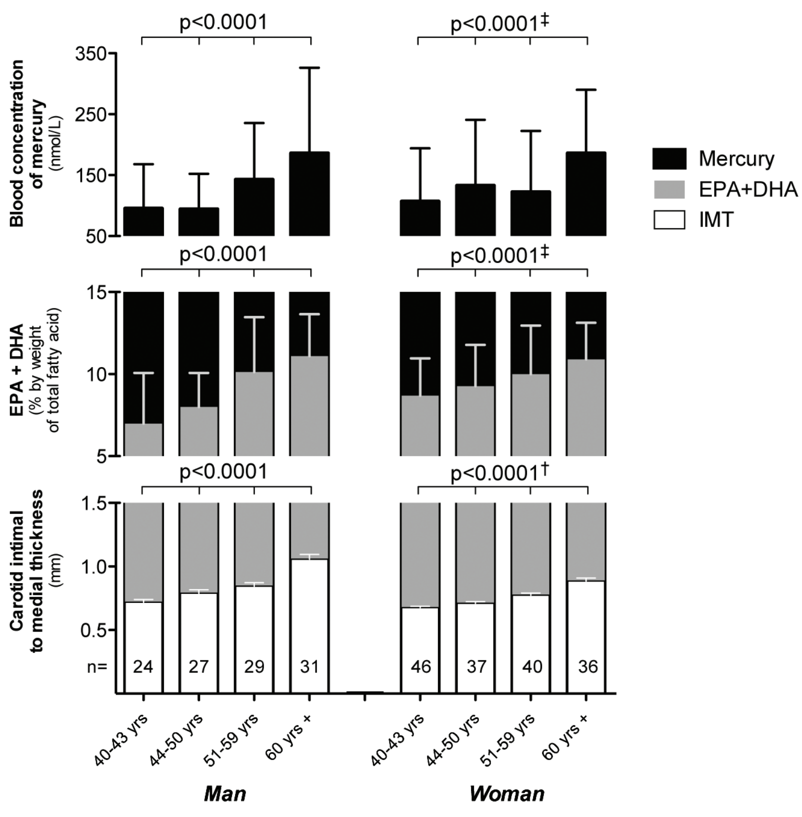
Atherosclerosis (CIMT)and mercury exposure. In Nunavik, as expected, we noted that Carotid Intima Media Thickness (CIMT) was associated with aging and gender (Noel et al. 2012). Older

Figure 3. Crude and adjusted means of LF by quintiles of blood mercury concentration(IPY survey)



Means were adjusted for age, sex, triglycerides, smoking, waist circumference, fasting glucose, physical activity and EPA+DHA
* Significant difference with respect to the 5th quintile ($p< 0.05$); & significant difference with respect to the 4th quintile ($p< 0.05$); p_{trend} (crude means) < 0.0001; p_{trend} (adj means) = 0.0006

Figure 4. Circulating blood concentration of methyl mercury, combined percentage of concentration of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (omega-3) and carotid intimal to medial thickness stratified according to quartile of age and gender.



individuals had thicker CIMT and therefore prone to potentially lethal atherosclerotic events including myocardial thrombosis and stroke. These observations were true for men and women though female tended to have thinner CIMT than men. (Figure 4) Likewise, the combined

Table 3. Circulating concentration of methyl mercury (MeHg) and Selenium multivariated independent predictors of the carotid intima–media thickness (entered as logarithm continuous variable) (≥ 40 years).

	Multivariated β coefficient	Standardized β coefficient	P value
Mercury	0.0371	0.0136	0.01
Selenium	–0.0121	0.0231	0.60
Age quartile_2	0.0457	0.0198	<0.02
Age_Quartile_3	0.1015	0.0215	<0.0001
Age_quartile_4	0.2354	0.0277	<0.0001
Gender	0.1006	0.0162	<0.0001
Hx hypertension	0.0953	0.0243	

Adjusted r–square:0.50, p<0.0001

Hx hypertension=Medically documented history of hypertension

Table 4. Circulating concentration of methyl mercury (MeHg), Selenium and combined percentage of concentration of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (omega–3) multivariated independent predictors of the carotid intima–media thickness (entered as logarithm continuous variable) (≥ 40 years).

	Multivariated β coefficient	Standardized β coefficient	P value
Mercury	0.0299	0.0151	0.05
Selenium	–0.0134	0.0036	0.24
Omega–3	0.0043	0.0229	0.56
Age quartile_2	0.0441	0.0202	0.02
Age_Quartile_3	0.0956	0.0220	<0.0001
Age_quartile_4	0.2280	0.0284	<0.0001
Gender	0.1029	0.0167	<0.0001
Hx hypertension	0.0937	0.0243	<0.0001

Adjusted r–square:0.49, p<0.0001

Hx hypertension=Medically documented history of hypertension

percentage of concentration of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) from the total polyunsaturated fatty acid measured in the blood and referred as omega-3 was higher amongst the elderly independently of gender. Identical associations were evaluated when circulating concentration of MeHg analysed. A negative association was noted when CIMT was compared with MeHg. When omega-3 and selenium were included in the model, the association between Hg exposure and high CIMT remained significant. (Table 4).

In the **IPY study**, the associations between Hg exposure and CIMT is being finalized. Access to the data was only authorized last February. Overall Carotid Intima Media Thickness (CIMT) measures (mean of all carotid segments) were obtained for 738 adults ≥ 40 years from the IPY cohort, with 294 men (40%) and 444 women (60%). By region: n=115 in Kivaliq; n=253 in Baffin; n=180 in Kitikmeot; n=62 in Inuvialiut and n= 128 in Nunatsiavut. Median age of our population was 51 (IQR=44-60) and maximum was 87 years old. Geometric mean of CIMT was 0.74 mm [0.73; 0.75] and thickness was higher in men than women (0.78 mm vs. 0.71 mm, p<0.0001). Geometric mean of blood mercury

Table 5. Simple and multivariable linear regressions between CIMT[a] and Mercury

	β	*p* ttest	Partial R^2	R^2
Crude (n=709)				
Blood Mercury[a]	**0.052**	**<0.0001**	**8%**	**8%**
Adjusted (n=709)				44%
Blood Mercury[a]	**0.018**	**0.001**	**1.5%**	
Age	0.012	<0.0001	39%	
Adjusted (n=678)				50.5%
Blood Mercury[a]	**0.019**	**0.04**	**0.6%**	
Age	0.012	<0.0001	38.5%	
Gender: male	0.066	<0.0001	5.8%	
EPA_DHA	–0.004	0.07	–	
Seleniuma	0.007	0.61	–	
LDL–Cholesterol	0.016	0.004	1.3%	
HDL–Cholesterol	–0.031	0.004	1.2%	
Hypertension	0.036	0.002	1.4%	

CIMT=Carotid Intima Media Thickness; EPA=eicosapentaenoic acid; DHA=docosahexaenoic acid;
[a] log–transformed variables

was 10.3 µg•L^{-1} (51.5 nmol/L^{-1}). Levels were not significantly different between genders (11.1 µg•L^{-1} for men vs 9.7 µg•L^{-1} for women, p=0.08) and the maximum value was 95 µg•L^{-1} (475 nmol/L^{-1}).

In Table 5 the regression analyzes between CIMT and blood mercury was conducted in a sample of 678 adults ≥ 40 years with complete data on mercury and all adjustment variables. We observed that mercury was significantly associated with an increase of CIMT (p=0.043) after adjustment for confounding and significant predictive factors. In every case, age represented the main predictive factor of the increase of CIMT with a partial R2 around 40%.

Discussion and Conclusion

"Santé Quebec" 1992 health survey

Mercury and resting HR and BP. In the present study, blood mercury was associated with increasing resting HR after adjusting for n-3 PUFAs and other confounders. Although means of resting HR were in the normal range in all quartiles of blood mercury concentration, we observed an increase of 6.9 bpm between the 1st and 4th quartile. This increase could have important clinical implications in the general population since increased HR has been associated with increased risk of sudden cardiac death (SCD) and CVD mortality among subjects free from known CVD (Jouven et al. 2001).

In conclusion, mercury was associated with increasing resting HR after considering traditional risk factors as well as other contaminants (lead and total PCBs) and n-3 PUFAs. In contrast, no significant association with blood pressure was observed in this study.

Nunavik Inuit Children

Mercury and HRV and BP. In this study, prenatal mercury exposure was not associated with decreased HRV. However, blood mercury concentration at school age was negatively associated with HRV parameters representing the overall HRV after adjustment for a set of covariates that could influence the association between mercury and the outcomes. These associations remained statistically significant after adjusting for cord blood mercury as well as fish nutrients (n-3 PUFAs and selenium), which suggests that the influence of childhood mercury exposure on HRV may be independent of the effect of fish nutrients. In contrast, mercury exposure either prenatally or during childhood was unrelated to BP parameters.

In conclusion, mercury exposure during childhood seems to affect HRV among Nunavik Inuit children at school age.

Adult Inuit Health Survey: 2007-2008
Mercury and blood pressure (BP). In the present study, increasing blood mercury levels were not significantly associated with hypertension after considering risk factors as well as fish nutrients (n-3 PUFAs and selenium) and other contaminants (lead and PCB 153). Furthermore, mercury was not associated with systolic BP or diastolic BP when analyses were restricted to participants without anti-hypertensive medication. In contrast, a significant increase in PP was observed in the highest quintile of the mercury concentration.

In conclusion, no significant association was observed between blood mercury levels and BP in this population although a slight but significant increase in pulse pressure was observed in the highest quintile of the blood mercury distribution.

Mercury and heart rate variability (HRV). In the present study, increasing mercury levels were associated with lower HRV after adjusting for risk factors as well as n-3 polyunsaturated fatty acids (PUFAs), which are positively correlated with mercury and have been associated with increased HRV in clinical trials and population-based studies (Christensen et al. 1999; Christensen et al. 2001; Holguin et al. 2005; Romieu et al. 2005; Mozaffarian et al. 2008; Valera et al. 2011a). LF and HF decreased significantly in the 4th and 5th quintiles ($\geq 16\ \mu g \bullet L^{-1}$) with respect to the lowest concentrations, suggesting a threshold for the deleterious impact of mercury on HRV. Although a less clear trend was observed for resting HR, a significant increase in adjusted means was also observed in the 5th quintile.

Our findings agree with a growing body of literature suggesting that mercury could low HRV in moderate to high exposed populations. We have previously observed significant associations between blood mercury levels and low HRV in two native populations from Northern Canada (Valera et al. 2008; Valera et al. 2011b). One of the studies was conducted among Inuit from Nunavik (Valera et al. 2008) while the other involved Cree from the James Bay (Valera et al. 2011b). We also observed a decrease in HRV among Polynesians teenagers while only a negative trend was observed among adults from the same population (Valera et al. 2011c).

In conclusion, our results suggest that high mercury levels can influence resting HR and HRV. Since low HRV and high resting HR are associated with increased risk of sudden cardiac death in the general population (Jouven et al. 2001; Makikallio et al. 2001), mercury exposure should not be neglected in the evaluation of the cardiovascular risk in populations with high fish consumption. However, further cohort studies are necessary to validate these cross-sectional results and assess the long-term impact of mercury exposure.

IMT (atherosclerosis). In a representative population of Inuit from Arctic Canada, circulating concentration of methyl mercury was observed in greater concentration in elderly compared to younger Inuit independently of their gender. Similar observations were also noted with PUFA. Circulation MeHg was associated with signs of atherosclerosis and the later observation was almost not attenuated when adjusted for plasmatic poly unsaturated fatty acid concentration of EPA+DHA.

Despite the fact that CIMT has been well recognized to be a strong surrogate marker of atherosclerosis increased IMT cannot be solely associated with increased cardiovascular mortality. Coagulation, heart rate variability and other mechanisms are possibly involved. Finally, further investigation is required to confirm our observations in a long-term follow-up.

Hg exposure and incidence of cardio vascular diseases (Nunavik follow up).
In the follow-up medical file review of 2011, preliminary analyses show a frequency of 75 cases of hypertensive syndrome for 924 persons monitored. Of these, 54 were new cases between the years 2005 to 2011. There also was a frequency of 34 cases of ischemic heart disease

NCP Performance Indicators

Performance Indicator	Number	Details / Description
Number of Northerners engaged in your project	0	Since data collection for the two cohorts were done previously, this phase of the project did not involve northerners. Most of the data collection took place in 1992 (Nunavik adults), Fall 2004 (Nunavik adults) and 2007-2008 and Nunavut Health Study), 2007-2008 (Nunavut/NWT/Nunatsiavut adult cohort and Inuit students were trained by Nasivvik, ITK and other staff.
Number of project–related meetings/ workshops held in the North	1	One NNHC meeting in Kuujuuak.
Number of students (both northern and southern) involved in your NCP work	3	Beatriz Valera PhD student, Martin Noel, Post doc fellow, Claire Dupont PhD student, Olivia Drescher MSc student.
Number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	11	Peer review papers: 5 conferences: 6.

of which 19 were new events, as well as 14 cases of strokes of which 9 were new events. When comparing non standardized crude rates of disease, our preliminary results show an overall decrease in rates of hypertensive syndrome, ischemic heart disease, and strokes for 2011.

Expected Project Completion Date

2013-2015 for phase two (POPs and CVD)

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Examining Benefits and Risks of Traditional and Market Food: Hair Mercury Analysis and Communicating Research Results In The Community of Tulita, NWT

Examen des avantages et des risques inhérents aux aliments traditionnels et mis en marché : analyse du mercure dans les cheveux et communication des résultats de recherches dans la collectivité de Tulita (T.N.-O.)

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Abstract

Mercury is a toxic pollutant which can pose risks to human health. In June 2010, the community of Tulita, NT, population 565, raised concerns over a public health advisory to reduce consumption of lake trout due to high concentrations of mercury from Kelly Lake, a source of fish for the community. A study was designed to determine possible mercury contaminant risk, as well as the nutrient, and socio-cultural benefits of fish consumption. Study participants were sixty seven community residents and consumers of fish from the Kelly Lake area. Participants provided a hair sample for mercury analysis. Information on fish consumption for the summer 2010 and winter 2010-11 seasons were collected using a validated, semi-quantitative food frequency questionnaire. To investigate the social and

Résumé

Le mercure est un polluant toxique qui peut entraîner des risques pour la santé humaine. En juin 2010, la collectivité de Tulita (T.N.-O.), d'une population de 565 personnes, a soulevé des préoccupations relatives à un avis de santé publique recommandant de réduire la consommation de touladis en raison de concentrations élevées de mercure dans le lac Kelly, qui représente une source de poissons pour la collectivité. Nous avons conçu une étude visant à déterminer le risque potentiel de la contamination au mercure, ainsi que les avantages sur les plans nutritifs et socioculturels de la consommation de poissons. Soixante-sept membres de la collectivité et consommateurs de poissons de la région du lac Kelly ont participé à l'étude. Les participants ont fourni un échantillon de cheveux aux fins de

cultural context of fish consumption practices and mercury contamination, semi-structured individual interviews were conducted with seven community knowledge holders and a public health officer involved with Tulita. Hair mercury concentrations for all children and women of childbearing age reflected blood levels below Health Canada guidelines requiring intervention. Two older adults were followed up with dietary advice to address their hair mercury concentrations. Dietary results reveal higher fish consumption in summer that winter, with whitefish and lake trout being the species reported most often. Analysis of interviews reveal that in traditional lifestyles fish was a reliable and dependable food source that ensured survival of the Dene & Metis peoples, explaining the deep cultural significance. People still prefer fish as a food today and identify the need to ensure cultural practices of traditional food harvesting continue in the future. Interviews also suggest that negative reactions to the public health mercury advisory stemmed from the ways the information was handled and circulated in the community. The study findings are being used to create a public positive message about fish.

l'analyse des concentrations de mercure. Nous avons aussi recueilli des renseignements sur la consommation de poissons durant l'été 2010 et l'hiver 2010-2011 au moyen d'un questionnaire validé semi-quantitatif sur la fréquence de la consommation. Pour examiner le contexte social et culturel des pratiques de consommation de poissons et de la contamination par le mercure, nous avons réalisé des entrevues individuelles semi-structurées avec sept détenteurs de connaissances communautaires et un agent de santé publique travaillant auprès de la collectivité de Tulita. Les concentrations de mercure dans les cheveux de tous les enfants et de toutes les femmes en âge de procréer étaient inférieures aux concentrations dans le sang nécessitant une intervention d'après les lignes directrices de Santé Canada. Deux adultes plus âgés ont fait l'objet d'un suivi comprenant des conseils en matière d'alimentation visant à réduire les concentrations de mercure détectées dans leurs cheveux. Les résultats de l'analyse nutritionnelle révèlent une consommation de poissons plus élevée en été qu'en hiver, et les espèces les plus souvent consommées sont le grand corégone et le touladi. L'analyse des entrevues indique quant à elle que, dans le cadre d'un mode de vie traditionnel, le poisson constitue une source d'alimentation fiable qui a assuré la survie des Dénés et des Métis, ce qui explique son importance culturelle profonde. Encore aujourd'hui, les membres des collectivités préfèrent le poisson comme source d'alimentation, et ils soulignent le besoin de veiller à ce que les pratiques culturelles entourant la récolte d'aliments traditionnels se poursuivent dans l'avenir. Les entrevues indiquent aussi que les réactions négatives à l'avis de santé publique sur le mercure concernaient la manière dont l'information avait été diffusée au sein de la collectivité. Les résultats de l'étude sont utilisés pour élaborer un message positif sur la consommation de poissons destiné au public.

Keys Messages

- Hair mercury concentrations revealed low exposure of methylmercury for summer and winter 2011 -12. Only two older adults required any follow-up to address their hair mercury concentrations.

- In both seasons, lake trout and whitefish were the most important species consumed in terms of quantity and the number of people reporting their consumption. Grayling and loche were two other important species. Great Bear Lake was the source of fish for most of those interviewed, followed by Stewart Lake, and Bear River.

- Traditionally, fish was a reliable and dependable food source that ensured survival of the Dene and Metis people in Tulita. This explains the deep cultural significance of fish, preferences for fish as a food today and the need to ensure cultural practices of traditional food harvesting continue. Negative reactions to the public health mercury advisory stemmed from the ways the information was handled and circulated in the community in addition to concerns about a deeply culturally important food source being threatened.

- A banner emphasising the positive nutritional and cultural features of fish harvest and consumption is being prepared to share the results of the study. The banner will be hung in prominent places in the community in September 2012.

Messages clés

- Les concentrations de mercure dans les cheveux ont indiqué une faible exposition au méthylmercure à l'été et à l'hiver 2011-2012. Seuls deux adultes plus âgés ont été ciblés par un suivi visant à réduire les concentrations de mercure détectées dans leurs cheveux.

- Au cours des deux saisons, le touladi et le grand corégone étaient les espèces consommées les plus importantes sur le plan de la quantité et du nombre de personnes ayant déclaré en consommer. L'ombre arctique et le poulamon constituent deux autres espèces d'importance. Pour la plupart des personnes rencontrées, les sources de poissons étaient le Grand lac de l'Ours, le lac Stewart et la rivière Bear.

- Sur le plan traditionnel, le poisson constitue une source d'alimentation fiable qui a assuré la survie des Dénés et des Métis à Tulita, ce qui explique l'importance culturelle profonde du poisson, la préférence actuelle de ces peuples pour le poisson et le besoin d'assurer la poursuite des pratiques culturelles entourant la récolte des aliments traditionnels. Les réactions négatives à l'avis de santé publique sur le mercure concernaient la manière dont l'information avait été diffusée au sein de la collectivité. Elles ont aussi été alimentées par les préoccupations associées à une menace pesant sur une source d'alimentation profondément importante sur le plan culturel.

- Une bannière soulignant les aspects nutritionnels et culturels positifs de la récolte et de la consommation de poissons est en cours de préparation pour présenter les résultats de l'étude. La bannière sera accrochée à plusieurs endroits bien en vue dans la collectivité en septembre 2012.

Objectives 2011-12

- To analyze collected hair samples to determine mercury exposure in the summer (2010) and winter (2011) seasons.
- To determine risk of mercury exposure determined from dietary data and hair samples.
- To characterize the social and cultural importance of fish (traditional food) to the Dene/Métis in Tulita.
- To collaboratively develop a plan and implement a communications strategy with Tulita community stakeholders and public health authorities to

  a) inform study participants about possible risks, if any, determined from hair mercury tests and their fish consumption practices

  b) to inform the community, collectively, about the risk of mercury exposure determined from fish consumption and hair sampling based on the study results;

  c) to address the nutrition benefits of fish based upon diet survey data

  d) to address the social and cultural benefits of traditional fish consumption practices in contemporary diet of the Dene/Métis of Tulita. Project objectives, preferably in bullet form

Introduction

Mercury is a toxic pollutant which can pose risks to human health (NCR, 2000). In June 2010, concerns in the Dene/Métis community of Tulita, NT, population 565, were raised when a public health advisory on an increase in mercury in four lakes was released. The advisory was based upon Health Canada's guidelines (Legrand, Feeley, Tikhonov, Schoen, & Li-Muller, 2005) and recommended people limit the amount of Lake Trout they eat from four lakes, including Kelly Lake from where the community of Tulita fished and consumed Lake Trout. The findings upon which the public health advisory were made came from an environment mercury monitoring research program conducted in 2006 by Northern Contaminants Program researcher Dr. Marlene Evans from Environment Canada (Evans et al., 2005). Leadership and knowledgeable community members expressed concerns about the possible health risk eating Lake Trout posed given that fish consumption continues throughout the winter period suggesting exposure to mercury continues year round. Therefore the need to assess the risk and benefits of fish consumption was identified by the community with support from public health officials.

Fish consumption data to estimate the possible contaminant risk that fish consumption posed for Tulita did not exist. A dietary study conducted 1994 among adults in sixteen Dene/Métis communities in the Northwest Territories characterized variance in traditional food across communities, seasons, ages and sexes (Receveur, Boulay, Mills, Carpenter, & Kuhnlein, 1996). Tulita did not participate in this study. Tulita did participate in a dietary study that measured children's traditional and market food use in 5 Dene/Métis communities (Nakano, Fediuk, Kassi, & Kuhnlein, 2005). From this study it was determined that 4.7 % of the total energy, came from all traditional food combined, including all fish species. Nonetheless the small amount provided a substantial amount of a number of nutrients.

Traditional food remains an important source of food and nutrition benefits for Tulita. Fish and traditional food are associated with social and cultural benefits as well (Receveur & Kuhnlein, 1998). Thus a study of the risks and benefits of traditional food would be more complete by including an investigation of the community perceptions of these social and cultural benefits. Understanding community traditional food practices and the meanings they hold can inform health promotion practitioners on the meanings and resources involved with traditional food use.

In this report we follow up the hair mercury analysis funded by NCP for 2010 – 2011. This report addresses research activities that took place from April 2011 to June 2012. These activities focus on reporting 1) mercury exposure from hair mercury analysis 2) preliminary dietary data, and fish consumption patterns and 3) the social cultural context of traditional food and fish consumption practices.

This study addresses an NCP identified need to include food choice surveys and monitoring of traditional/country food to better understand how changing diet is impacting contaminant concentrations in Aboriginal northerners.

Activities in 2011-2012

June 28 – July 7, 2011 – Delormier returned to the community of Tulita as requested in early July to report on the Hair mercury analysis. En route she met Mireille Gionet, Director Health and Social Programs to provide the Sahtu Regional Health and Social Services Authority with a copy of the results to return to the research participants, as outlined in the protocol to handle this data. Dr. Delormier was in Tulita for a week to talk to individuals, and to make a public presentation about the results of the hair analysis, and to meet with students at the school. The findings showed only two people with hair mercury concentrations in the low end of range of increasing risk. The two participants were individually consulted for recommended follow up at the Health Center in Tulita. Concerns about research suggesting that mercury levels are increasing in lakes and fish in the north, and about the impacts on human and wildlife health were voiced in the public meeting and through people's questions to Dr. Delormier while she was in the community. Lorna Skinner who was present in Tulita for the public meeting discussed these community concerns with Dr. Delormier, during a debriefing session after the meeting.

July 2011 to April 2012 – Transcription of qualitative interviews, and data management and preliminary analysis of the dietary data. A change was been made to data analysis plans, and fish intakes will not be used to estimate mercury exposure. This decision was made in consultation with Dr. Grace Egeland who identified that the hair analysis gives the best picture of mercury exposure, and that food frequency data tend to overestimate the consumption levels of similar food types, like fish species. Therefore we risk estimating higher levels of exposure to mercury through diet, so we should rely on the hair analysis as the valid measure of mercury exposure. Food frequencies will be used to describe consumption patterns for fish species in different seasons.

September 2011 – Tulita Renewable Resource Council Board member Frederick Andrew, and Dr. Delormier attended the NCP results symposium in Victoria, BC and co-presented the Tulita study focusing on its collaborative features and the results from the hair mercury results.

April – May 2012 – Analysis and member checking (verification) of qualitative interviews.

June 4 – 15, 2012 – Delormier returns to Tulita to discuss interview findings, preliminary dietary data and to plan the communication medium of the study results for the community. En route to Tulita stops were made in Yellowknife to meet with the Deputy Chief Public Health Officer, and in Norman Wells to meet with the Director Health and Social Programs. During the Tulita visit, 'member checking', a qualitative data analysis step which corresponds to the idea of validation, was carried out with each of the eight interview participants. Delormier was invited to attend the public meeting by Chief Frank Andrew to address any questions people may have on the study about mercury and fish. While in the community Delormier made a presentation to the students of the cultural program to discuss the findings and to gain their input on why fish is important to the community. Delormier talked about the study to interested community members who came to speak with her while she was present.

Results & Discussion

Participants
Characteristics of participants are presented in Table 1.

Hair mercury concentrations
Hair specimens were analyzed and compared to the Health Canada existing and harmonized blood methylmercury guidance values (Legrand, et al., 2005) converted to hair total mercury (Table 2). For all, except two individuals, values were associated with no immediate health risk and no further follow-up was required. For the two individuals their levels were in the lower end of the range (5 – 25 $\mu g \cdot g^{-1}$) where recommended follow-up is re-testing mercury concentrations 6 months following dietary advice to stop eating predatory fish (Lake Trout and Pike) as the main source of fish, and to eat instead whitefish, grayling, cisco, conni.

The analysis of mercury exposure through hair analysis suggests that there was low exposure to mercury through the diet in the period of June to August 2010 and December to February 2011. Though community perspectives are that mercury may not be harmful now, concerns remain about the future given other research that is monitoring mercury is the surrounding environment.

Dietary Intakes of Fish
In this report we provide descriptive summary statistics only. Table 4 shows the mean intakes per week of all species combined for the summer 2010 and winter 2010-11 seasons. A small number of participants reported very high total fish intakes in both seasons. While it is possible that some individuals who eat only fish when they have access to it, can eat a large amount of fish per week, the outlying reported intakes are likely due to errors in estimating amounts consumed. In future analysis these over reported amounts will be corrected and more accurate mean gram intakes per week will be estimated. However, considering the mean intakes per week *with* the over reported amounts, we see that more fish is reported being eaten in the summer versus the winter season. This interpretation was confirmed in discussing these results in the community. As well, the reported average amount for all species eaten was two to three times higher than the amounts recommended from the advisory for Lake Trout only for the general population (150g). This finding supports that low levels of hair mercury concentrations reflect current consumption levels of Lake Trout intake associated with low risk of methymercury exposure.

The number of participants who reported eating different species of fish, by season, are reported in table 5. In both the summer and winter season the species reported being consumed by the highest percentage of people were Whitefish (74.6 % and 76.1% respectively) and Lake Trout (74.6 % and 53.7 respectively). Grayling was reported by a majority (64.2%) in the summer season.

In terms of the lakes where people reported getting the fish they consumed, the highest percentage of people reported Great Bear Lake (86%) followed by Stewart Lake (68%); Bear River (67%); Mackenzie River (59%) and then Kelly Lake (50%) (data not shown). The species taken from each lake was not asked of participants.

Table 1. Characteristics of study participants

Age group	Gender		
	female % (n=)	male % (n=)	total %
child (<12 yrs)	37.5 (10)	62.5 (6)	*100 (16)*
adult (>18 yrs)	54.3 (20)	45.7 (16)	*100 (36)*
elder (>65 yrs)	37.5 (10)	37.5 (6)	*100 (16)*
total	*58.2 (40)*	*41.8 (28)*	*100 (68)*

Table 2. Classification of individual hair mercury concentrations by Health Canada hair mercury guidance values* for Pregnant women, Women of child–bearing age & children.

Guidance Values for Pregnant women, Women of child–bearing age, & Children			
Represents mercury in the diet from December – February 2011 Hair Segment 1			
Age–sex category	**< 2 µg·g–1**	**2 to 10 µg·g–1**	**>10 µg·g–1**
Recommended follow–up	– no follow–up required	– repeat hair/blood test in 6 months –dietary advice	– repeat hair/blood test immediately – meet with health professional to review diet and give dietary advice.
All children <18 yrs (n=16)	16	0	0
Women child bearing age 18 – 49 yrs (n=13)	13	0	0
Represents mercury in the diet July–August 2010 Hair Segment 2			
All children <18 yrs (n=16)	**13 (3 no sample)**	**0**	**0**
Women child bearing age 18 – 49 yrs (n=13)	**12 (1 no sample)**	**0**	**0**

Table 3. Classification of individual hair mercury concentrations by Health Canada hair mercury guidance values* for males over 18 yrs, women over 50 yrs.

Guidance Values for Males over 18 yrs, Women over 50 yrs, Females & Males all ages			
Represents mercury in the diet from December – February 2011 Hair Segment 1			
Age–sex category	**< 5 µg•g 1**	**5 – 25 µg•g 1**	**> 25 µg•g 1 (females any age males any age)**
Recommended follow–up	– no follow–up required	– repeat hair/blood test in 6 months – dietary advice	– repeat hair/blood test immediately – meet with health professional to review diet and give dietary advice.
males > 18 yrs (n=22)	20	2	0
females ≥ 50 yrs (n=17)	17	0	0
Represents mercury in the diet July–August 2010 Hair Segment 2			
males > 18 yrs (n=22)	6 {16 no sample}†	0	0
females ≥ 50 yrs (n=17)	14 {3 no sample}†	0	0

* Values from (Legrand et al., 2010)

† Hair was not long enough (7 cm) to provide the hair segment 2 specimen.

Table 4. Mean and median intakes of fish, per week, all species combined, fresh and dried fish flesh, by season

	n=	mean (g/wk)	s.d.	median (g)	min (g)	max (g)
Winter	n=56	1213 g/wk	3101	248 g	12 g	18 935 g
Summer	n=66	1129 g/wk	1680	406 g	4 g	7 590 g

Table 5. The number and percent of participants who reported eating fish species by season.

	Summer June – July 2010		Winter December – February	
Species	Number who reported eating (n=67)	%	Number who reported eating (n=67)	%
Whitefish	50	74.6	51	76.1
Lake Trout	50	74.6	36	53.7
Inconnu	15	22.4	5	7.5
Cisco	8	11.9	4	6.0
Loche (burbot)	5	7.5	3	4.5
Jackfish (pike)	2	3.0	2	3.0
Grayling	43	64.2	9	13.4
Walleye (pickerel)	0	0	0	0
Sucker	2	4.5	1	1.5

Food harvesting and consumption practices and the meaning of the public health advisory to limit Lake Trout

This is an brief overview of the findings based on qualitative interview that were analysed to present a characterization of fish harvesting and consumption practices in Tulita. They describe traditional and current patterns, as well as changes occurring in these practices. The social meanings and norms, as well as resources that shape current practices is presented setting up the context that he;p explains the reaction to the public health advisory of June 2010.

Traditional practices related to fish harvesting and consumption

Fish was a staple food source when the Dene and Metis people lived traditional lifestyles on the land, for most of the year. They relied upon catching fish when they needed food. In late and colder parts of wintertime, it could become more difficult to catch large game, however knowing the right fish lakes, one could set a net and catch fish that would provide food.

> *…fish is a really, way of life, for everybody. And people survive on them, in the cold winter. You can't hunt, you just, you know if you catch one fish a day, or two, your family is going to survive and eat. They used everything, even the broth. (community knowledge holder)*

Thus, fish were essential food sources for people but fish was also used to feed dogs necessary to travel on the land to hunt, trap and fish. Due to its year round availability fish is regarded as a staple food, a reliable food source that ensured food security and survival, yet is also food people still enjoy eating.

Current practices related to fish harvesting and consumption

Currently fish harvesting and consumption continues among the people of Tulita reflecting traditional, seasonal patterns and practices shaped but by the modern reality of life circa 2010. No one lives on the land for most of the year as in earlier times. Families and individuals do continue to go out on the land to hunt and fish but for shorter durations. Many elders, and older adults in Tulita were raised on the land, or have parents who were raised on the land, and hold extensive knowledge and skills required to survive and live in the harsh climate. When someone catches a large amount of fish it is typically brought back to the community to be shared with those who need food and those who are known to prefer and enjoy eating fish, such as elders, and families without someone to hunt or fish, or single parent households.

> *They'll come back with a bunch of fish, and people will ask "Do you have a fish, that I can have?" Or they'll just go phone people, and say "Well, you know, I have fish. Do you want a fish?" So, people still have that spirit of sharing. And usually, that's how it's done, or if someone shoots a moose, then you know, they'll provide to elders and single parents, people that they know don't have meat. INT 6*

Many expressed concerns about the limited opportunities that exist for youth to learn the skills and gain the knowledge to be able to live on the land. Significant value placed on learning to live on the land.

> *"Well, makes them [youth] work hard. Make them work good. Make them feel good about themselves; who they are; where they come from. A lot of those kids don't know nothing, not even how to make a fire. That's something all of us, we knew by the time we were six, seven, we knew how to make fire. And now, nobody knows how to do that, nothing. It's changes so much in the past thirty years, too fast. INT 4*

While the preference of traditional food is often expressed for elders, youth and children enjoy eating fish and traditional food as well. Changes in lifestyle in the past 30 years are evident in the skills for bush living that the children lack. Decreases in the frequency of traditional food harvesting and consumption activities are linked to fewer opportunities to practice traditional lifestyles, not the desire to learn about these.

Recently observed changes in fish harvesting and consumption in Tulita

Patterns of hunting and fishing are changing, decreasing and becoming unpredictable from year to year. Fall hunting and fishing depends on waterways freezing so that these can be traversed to access hunting and fishing areas by snowmobile.

> *At the mouth of Kelly Lake in November, early December, whitefish run. So guys like to go out there, set a net and harvest, maybe about, two to five hundred fish. Then they pass [them] out to the community. But that hasn't been done the last couple years. The reason is that, we always have a late season freeze up. We have to get across the Mackenzie, or the Bear River, to get on the other side, to get to Kelly Lake, by snowmobile. So, a lot of time, we can't make it in there. INT 7*

In addition to environmental and climate changes, research participants identify changes in the social and economic circumstances of Tulita, and relates to explain changes in traditional food use. Living in the settled community, holding employment, children going to school and attending post secondary education are ways that challenging the amount of time and effort people can dedicate to traditional lifestyle pursuits.

Fish harvesting and consumption practices: the social meanings, norms and resources that support them

Fish is a highly valued food for people from Tulita because of its reliability and availability across the rivers and lakes in the Sahtu region. Fish assured survival, and are valued, preferred and enjoyed as food. The significance of fish explains participant's serious concerns about mercury contamination in fish and about youth not having opportunities to learn to live on the land. Sharing fish expresses the social connections and express the important sense of community. Elders are shown respect by offering fish and there are expectations for those with access to traditional food to share. Fish harvesting and consumption practices remain deeply meaningful and valued activities.

In terms of material resources, the costs of equipping oneself to go out onto the land are very expensive. Large equipment like snowmobiles and boats, and equipment like nets, gasoline, guns are required. Having time to go out on the land is challenging when time is dedicated to work or school. If one is not engaged in employment, the cost of living in the community challenges those with large families and who rely on social assistance benefits, or fixed or seasonal incomes. Many families are credited with the knowledge and skills to hunt, trap and fish, to live on the land, and many people value and respect traditional lifestyles, resource availability challenges opportunities to practice these important activities.

Fish, Mercury and the 2010 Public Health Advisory in Tulita

The initial reaction to the advisory described was quite negative. Confusion over whether the advisory meant stopping or limiting fish consumption arose. While the advisory was perceived as confusing and challenging to put into practice, the panic associated with the public health advisory stemmed from the ways and timing in which the information reached the people of Tulita.

> *So, so suddenly everybody's quit eating fish. Yeah, even they had fish, and they had to throw it away, 'cause they were scared, but they didn't know what, what kind of fish at the time. It was, like, you know, the panic. INT 1*

Though the public health officer wanted to work on a communication strategy to address the mercury issue with the community, the general public advisory was released before Tulita received it. The publicized information reached Tulita in a few ways and was posted in Tulita in the usual public places. News of the advisory was picked up the CBC North television and some radio stations amplifying the seriousness of the problem. The Tulita Renewable Resource Council and the Sahtu Renewable Resource Board did hold a public meeting to listen to the concerns and reactions of the community. However, when it surfaced that the information in the advisory came from a study[1] done four years earlier people became upset and angry. In the weeks following a group of public health officials, researchers and Northern Contaminant Program staff and researchers came to Tulita to explain the Public Health Advisory and field questions.

The presence of mercury in an important of a traditional food source understandably raises questions about environmental contamination in general. Many Dene Metis people from Tulita are knowledgeable about the interconnectedness of the natural environment and the traditional food system. Thus mercury contamination of Lake Trout in Kelly Lake is not an isolated issue, it is situated, for the people of Tulita in a geographical and social context where environmental contamination is being regularly monitored, and where regional contaminants committees address contaminant issues in the Sahtu. Mercury contamination of Lake Trout signifies a larger problem of climate change, decreasing environmental integrity, the impact of contamination on the food harvested from it, and its potential harmful effects on health.

Conclusions

This study aimed to assess the benefits and risks associated with eating traditional fish food species in the community of Tulita. Hair mercury concentrations revealed that the risk associated with current consumption levels of fish, including Lake Trout from Kelly Lake in Summer 2012 and winter 2011-12 was very low. No child or woman of child-bearing age required any follow-up to manage mercury exposure risk. The dietary data show patterns

[1] The research in question measured concentrations of mercury in Lake Trout as a means to monitor global patterns of environmental mercury contamination, not to monitor human exposure. Unfortunately the results of the study were not interpreted for impact on human health nor were they identified by the mechanisms in place to manage contaminant research results that carry human health risks.

NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	9	Tulita renewable resource council collaborated on the research, Deputy Public Health Officer a team member, NCP staff in Yellowknife assisted as needed.
number of project–related meetings/workshops held in the North (April 1, 2011 – March 31, 2012)	4 meetings	July 2011 & June 2012 special public meetings and presentations to students both years.
number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	1 student	Did dietary data entry
number of citable publications (e.g., in domestic/ international journals, conference presentations, book chapters, etc)	2011: 0 2012: 0	Data returned to community finished June 15 2012.

of consumption of fish continue throughout the year, with Whitefish and Lake Trout being important species, and more fish being consumed in summer than in winter. From the perspectives of local knowledge holders in Tulita, fish harvesting and consumption practices continue and reflect the way these practices were carried out traditionally when people lived on the land. In the current context people do not rely on fish for survival, but do value fish for its meaning as a life sustaining food which assured survival. Fish harvesting and consumption practices connect people socially through sharing, and reinforce the importance of traditional lifestyles which are the roots of Dene and Metis cultural identity and relationship with the land. Advisories to limit consumption of staples food like fish due to contamination are perceived not only as possible threats to health, but to a traditional way of life and thus a culturally distinct people as well. The perceptions of the benefits of fish, nutrient, and sociocultural and risk of contamination can be better understood when taking into account the fish harvesting and consumption practices and their social meanings.

The 2011-12 funding year marks the final funding period for this study. In the coming months the dietary data analysis will be completed. The findings from the study will be developed into banners that will be posted publicly in the community. The messages and visuals will emphasise the benefits of harvesting and practices, while being mindful of the need to monitor mercury and other contamination which can negatively impact valued tradition ways of life, and health.

This study was designed to address the concerns and questions of the community of Tulita. The way in which the project was managed and coordinated reflects a respectful relationship between researchers and the community organisation who assumed responsibility for the project in Tulita. The findings from the study so far, and the way the study was conducted, has been received positively in the community. The researcher has been invited to return to the community as it has been made clear that the work we did was a positive contribution to understanding the complicated issue of contamination in key cultural food sources.

Expected Project Completion Date

September 2012 upon delivery of the poster summarizing study results and demonstrating the benefits and risks of fish consumption.

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Community Based Monitoring

Surveillance Communautaire

Tukisimakatigennik ('Understanding Together'): Inuit Knowledge and Scientific Inquiry Into Contaminant Trends in Nunatsiavut, Year 2

Tukisimakatigennik (« comprendre ensemble ») : Connaissances inuites et recherche scientifique sur les tendances des contaminants au Nunatsiavut, deuxième année

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Abstract

This project took a multidisciplinary approach to exploring connections between science and Inuit Knowledge (IK) to better understand trends in contaminants in ringed seals along the Nunatsiavut coast. The project used a mixed-methods research design and interviewed hunters and IK holders about changes in ringed seal ecology over time. This knowledge was then linked with scientific findings regarding contaminant trends in ringed seals in the region. In 2010-11 preliminary interview guides and supporting materials (maps and multi-lingual field guide) were developed to lead discussions with IK holders on the topics of ringed seal ecology, movements, diet and body

Résumé

Une approche multidisciplinaire a été utilisée dans le cadre de ce projet pour explorer les liens entre les connaissances inuites et scientifiques afin de mieux comprendre les tendances des contaminants chez le phoque annelé le long de la côte du Nunatsiavut. Les chercheurs ont eu recours à des méthodes mixtes de conception de la recherche et ont rencontré des chasseurs et des détenteurs de connaissances inuites pour discuter des changements de l'écologie du phoque annelé avec le temps. Des liens ont ensuite été établis entre ces connaissances et des résultats scientifiques concernant les tendances des contaminants chez le phoque annelé dans la région. En 2010-2011, les premiers guides

condition. Initial interviews were conducted and IK was documented on these topics both during hunting trips in the field and through interviews in the community of Nain. The interview guide was then refined and interview tools were finalized. Analysis of the IK documented through interviews showed that seals closer to the community have become more vigilant, there has been a shift from larger to smaller prey items, there have been observed changes in fat composition and are fewer younger seals. All of these changes have important implications for contaminant trends in ringed seals. A knowledge exchange and data linking workshop was then held in Nain in January 2012 bringing together IK holders and scientists working on contaminant issues in ringed seals along the Nunatsiavut coast. This workshop identified that there is both interest and commitment from both groups of knowledge holders to work together through a structured process. There is greater agreement between knowledge sources and more linking opportunities for cooperative inquiry when the discussion is focused at the same scale (geographic, temporal and conceptual). IK holders tended to discuss their understanding and observations of ecology of the species at the whole animal and ecosystem level whereas the scientists focused their discussion and knowledge exchange input to their specific disciplinary area. As a result, it was noticed that ideally a team of scientists should be engaged in such a process to get a broad, ecosystem wide understanding and discussion going with IK holders.

d'entrevue et documents à l'appui (cartes et guide de terrain multilingue) ont été élaborés pour diriger les discussions avec les détenteurs de savoir inuit sur des sujets liés à l'écologie du phoque annelé, les déplacements, le régime alimentaire et l'état corporel de cette espèce. Les premières entrevues ont été menées, et les connaissances inuites sur ces sujets ont été documentées à la fois pendant des voyages de chasse sur le terrain et lors de rencontres avec des membres de la collectivité de Nain. Le guide d'entrevue a ensuite été amélioré, puis on a mis la dernière main aux outils d'entrevue. L'analyse des connaissances inuites qui ont été recueillies dans le cadre des entrevues indique que, dans les environs de la collectivité, les phoques sont devenus plus vigilants; leurs proies sont maintenant plus petites, la proportion de tissus adipeux a changé et les jeunes phoques sont moins nombreux. Tous ces changements ont des conséquences importantes pour les tendances des contaminants chez le phoque annelé. Un atelier de couplage des données et de mise en commun des connaissances, qui a eu lieu à Nain en janvier 2012, a réuni des détenteurs de connaissances inuites et des scientifiques qui s'intéressent à la question des contaminants chez le phoque annelé le long de la côte du Nunatsiavut. Cet atelier a permis de constater qu'il y a à la fois un intérêt et un engagement de la part des deux groupes de détenteurs de connaissances à travailler ensemble dans le cadre d'un processus structuré. Les sources de connaissances montrent une très grande volonté de mener des études conjointes et les occasions de réseautage sont plus nombreuses lorsqu'il s'agit d'enjeux à la même échelle (géographique, temporelle et conceptuelle). Les détenteurs de connaissances inuites ont tendance à discuter de leurs observations et de la compréhension qu'ils ont de l'écologie des espèces à l'échelle de l'animal et de l'écosystème dans son ensemble, tandis que les scientifiques situent leurs discussions et la mise en commun de leurs connaissances dans le contexte de leur propre discipline. On a donc constaté que, dans une situation idéale, une équipe de scientifiques devrait participer à ce genre de processus pour acquérir une compréhension approfondie à l'échelle de l'écosystème et discuter avec les détenteurs de connaissances inuites.

Key Messages

- A mixed methods approach to linking Inuit Knowledge and science to understand trends in ringed seal contaminant levels shows promise in bridging these knowledge systems and providing a way for knowledge holders to work together on issues of common interest;
- The rigorous documentation and development of an IK database on ringed seal ecology provided the foundation for structured discussions between IK holders and scientists at a knowledge exchange workshop in this project;
- Working together, IK holders and scientists recommended ways forward in the investigation and explanation of ringed seal contaminant trends along the Nunatsiavut coast;
- Recommendations for future cooperative research and monitoring on ringed seals and contaminants using IK-science collaboration include: a yearly, standardized sampling program for contaminants, a continuation of the satellite telemetry program, increased IK documentation that includes standardized collection of observations relative to seal condition as well as sampling location and the establishment of research questions generated from both IK holders and scientists, to ensure each knowledge source is represented in future research.

Messages clés

- Les méthodes mixtes permettant de mettre en commun le savoir inuit et les connaissances scientifiques pour comprendre les tendances des contaminants chez le phoque annelé semblent établir efficacement des ponts entre ces systèmes de connaissances et créer des occasions pour les détenteurs de connaissances de travailler ensemble sur des enjeux liés à des intérêts communs.
- La documentation colligée avec rigueur et la création d'une base de données sur les connaissances inuites de l'écologie du phoque annelé ont servi de fondement aux discussions structurées entre les détenteurs de connaissances inuites et les scientifiques lors d'un atelier de mise en commun de connaissances qui a eu lieu dans le cadre du projet.
- Pour travailler ensemble, les détenteurs de connaissances inuites et scientifiques ont recommandé des façons d'aller de l'avant dans l'étude et l'explication des tendances des contaminants chez le phoque annelé le long de la côte du Nunatsiavut.
- Parmi les recommandations en vue d'une collaboration avec les détenteurs de savoir inuit dans le cadre des futurs travaux de recherche et activités de surveillance sur le phoque annelé et les contaminants, mentionnons un programme annuel d'échantillonnage normalisé des contaminants, le maintien d'un programme de mesures à distance par satellite, une documentation approfondie du savoir inuit qui comprend une collecte normalisée d'observations de l'état du phoque, des emplacements d'échantillonnage et l'établissement de questions de recherche par les détenteurs de connaissances inuites et scientifiques pour faire en sorte que chaque source de savoir est représentée dans les futures recherches.

Objectives

Specifically, the objectives of this project were to:

- Develop a method and process for linking Inuit Knowledge and science on the issue of ringed seal ecology, diet and contaminant trends along the Nunatsiavut coast
- Through a pilot study, finalize the design of an Inuit Knowledge study of ringed seal diet, ecology and contaminant trends with hunters in Nain, Nunatsiavut
- Document Inuit Knowledge among hunters and elders in Nain, Nunatsiavut on these topics and analyse this information for presentation and discussion
- Explore the connections between the ways of understanding ringed seal ecology to enhance understanding of contaminant trends in these marine mammals along the Nunatsiavut coast
- Make recommendations for future IK-science monitoring and research on ringed seals and contaminants

Introduction

Historically, our understanding of Arctic marine mammal ecology and behaviour has come from comparatively short term observation and measurement of animals in remote locations during times of year when scientists could gain access to these regions (e.g. aerial surveys, land and ship based counts and observations). More recently, this has been enhanced significantly by our use of a variety of remote sensing technologies and methods (e.g. satellite tags and radiotelemetry devices). An under-recognized, yet exceptionally valuable source of information, has always resided with the People of the North, the hunters and travelers that have relied on the local environment for food and warmth, and which has remained a central component of their identities, languages, traditions and cultures for thousands of years.

In the field of marine mammology, TEK has contributed to the scientific understanding of the ecology of several species, including, but not limited to beluga and bowhead whales and ringed seals (Furgal et al., 1996; 2002; Huntington 2000, Kilabuk 1998, Mymrin et al. 1999, Doidge et al. 2002, Lee et al. 2002).

Contaminants, Ringed seals, and Nunatsiavut
Ringed seal *(Phoca hispida)* are an abundant and widely distributed species in the Arctic. They are an upper trophic level predator, feeding on fish and crustaceans for the most part, and form the bulk of the diet of polar bears. Within Nunatsiavut, ringed seal are central to Inuit subsistence, culture and well-being. However, ringed seal within Nunatsiavut are vulnerable to various stressors, including contaminants and climate change. In the context of these stressors, and because of their close connection to the environment, harvesters from Nunatsiavut have observed changes in ringed seal behaviour and distribution over the past number of years as well as differences between local regions within Nunatsiavut.

Over the past four years, a holistic science program has been built in Nunatsiavut to better understand ringed seal behaviour, ecology, distribution and health. It is believed that contaminant exposures have changed and are likely to continue changing as physical and biological processes in northern environments change (Burek et al. 2008). Therefore, an overarching goal of this holistic ringed seal program was to better understand contaminant trends and the physical and biological factors that are affecting contaminant trends in this important species. Individual projects in this program included a large scale marine food web study using ringed seal as an upper trophic level predator (diet tracers include quantitative fatty acid signature analysis, stable isotopes and contaminants), a ringed seal satellite telemetry program and a ringed seal health study (using biomarkers).

A collaborative approach to inquiry on ringed seals and contaminants in Nunatsiavut

The ongoing multidisciplinary scientific inquiry into contaminant levels and trends in ringed seals in Nunatsiavut , and the strong relationship between Inuit experts, and natural and social scientists working in the region provided a unique opportunity to develop a cooperative exploration of this issue bringing together IK and science on the topic. At the same time, through documentation and review of the process, it provides an opportunity to develop a method and process for this 'knowledge interaction' and exploration that does not currently exist.

Therefore, this project was a pilot study using a mixed methods approach (Creswell, 2009) to document Inuit (Nunatsiavimmiut) Knowledge of ringed seal diet and ecology and to develop and conduct a process to explore the links between this knowledge and scientific knowledge on contaminant trends in these species along the Labrador coast. The ultimate goal of this work is to enhance understanding of contaminant levels and trends along the Labrador coast and identify opportunities for future collaborative inquiry and learning.

Activities in 2011-2012

Overview

During this past year (Year 2) the following was accomplished:

- Teleconferences and face to face meetings of team members (CF, TS, KW, RL, DM and TB) took place to discuss project goals, process, feasibility;
- Ringed seal IK interview protocol development was finalized (information and consent form development, and interview guides were finalized based on the previous years pilot study, where these documents were tested with participants in the field during video interviews in northern Nunatsiavut and in community (Nain) during participant mapping interviews);
- Community researchers, trained in the previous year, conducted interviews (observations of changes as well as participant mapping/ethnographic in northern Nunatsiavut with seal hunters (n=15));
- The NVivo qualitative database was created with the IK from interviews and was was used to provide structure for qualitative analysis;
- The finalization and publication of an Inuktitut-Labrador local name-English prey species guide and marine mammal identification guide;
- Qualitative (IK gathered through interviews) and quantitative (scientific contaminant trend and ecology) data were reviewed for connection with phenomenological, temporal and geographic scale similarity to assess feasibility of proposed "linking" and "complementary" analysis through triangulation process;
- Mixed methods data triangulation and sequential analysis were performed and discussed among team members and through an IK holder and scientist knowledge exchange workshop held in Nain.

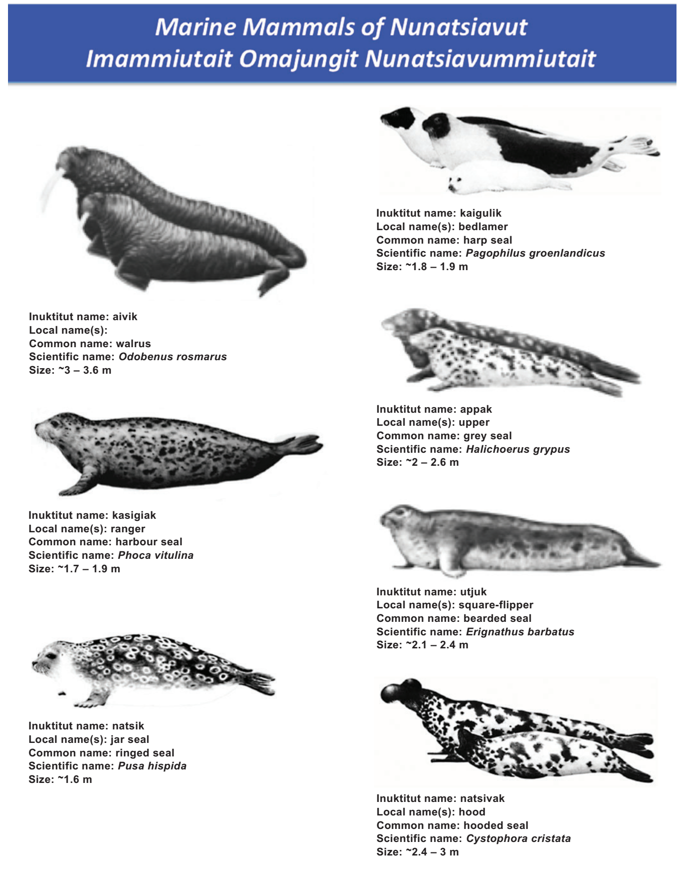
Results

It is critically important that IK be gathered and documented in as accurate and precise a manner as possible. To this end, it was necessary to use the resource materials prepared during the pilot study for IK interviews and mapping exercises that allowed harvesters and other knowledge holders to document their knowledge of ringed seal diet and ecology accurately and using appropriate terminology. To support this goal, an English – Labrador – Inuktitut illustrated ringed seal prey species guide and marine mammal identification guide were finalized and used in the interviews (Figure 1a,b; McLeod et al., 2012a,b).

Figure 1: Ringed seal prey species guide (a) and marine mammal identification guide (b) developed for IK holder interviews.

Figure 1. a

b



These guides allowed for accurate identification of marine mammal and prey species, while allowing for a better understanding of ringed seal diet and how these species relate to contaminant trends.

A total of 7 interviews were conducted with hunters in a field setting (during ringed seal hunts and sampling trips). It has been argued that the most rich and detailed IK information is exchanged in settings of practice (ie. on the land, or out on a hunt). Additional digital photos and video of potential relevance for the interviews (common phenomenon being observed by hunters re: ringed seal diet or health) were also gathered at this time. Ten (10) semi-directive, individual ethnocartographic (also referred to as participant mapping) interviews were also held with local Nunatsiavimmiut harvesters and other experts from Nain, Nunatsiavut. Interviews were conducted in the location and in the language of the participants choosing. The interviews focused on ringed seal diet, behaviour and general ecology with a focus on spatial, temporal variation and change over time in the Nunatsiavut region. Hunters identified any observed changes in ringed seal, their coat, fat, stomach contents and if there was anything else that had changed in the seals over their life while hunting. They also talked about any concerns in regards to ringed seals, which included topics ranging from and inclusive of climate change to contaminants. The sample size of interviewees was identified to gather sufficient information to reach a saturation point, which then allowed for the analytical and triangulation protocols. All interview audio recordings were translated (if required) and transcribed verbatim and reviewed and verified for reliability in transcription by a second researcher and the participant. All documented map information was scanned and digitized.

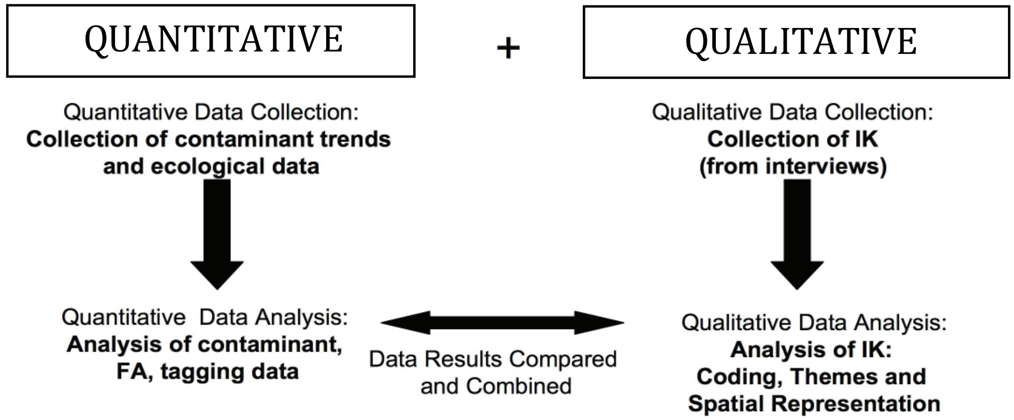


Figure 1: Concurrent Triangulation

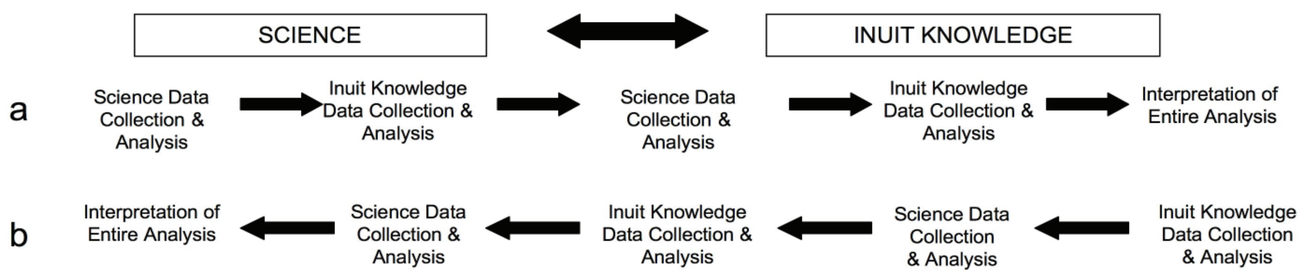


Figure 2: Sequential mixed explanatory (a) and exploratory (b) designs

Data analysis using the verified interview transcripts and digitized map files was completed using the qualitative software package Nvivo 9.0 (QSR International, 2011). As per thematic pattern analysis, common responses to semi-directive questions were identified, categorized and patterns in key themes and topics raised by participants in reference to the interview subjects were coded and analysed. The coding structure developed during the pilot study of 2010-2011 was applied to these analyses. Particular attention was paid to the phenomenological, temporal and spatial scale of the IK observations and data shared as these scale issues can significantly influence the complementary or linking possibilities with the science datasets on this topic in the region. The qualitative data collected covers themes representing elements of ringed seal ecology, including elements of potential influence on contaminant exposure and uptake (ie. diet, migration, feeding location, changes in molting behaviour, habitat changes, pupping success).

A summary presentation was prepared, shown and discussed with participants in both focus group and individual interviews for validation or 'member checking' (Creswell, 2009).

A focus group process for data triangulation with science and IK holders on ringed seal ecology and contaminants along the Nunatsiavut coast was held in Nain during January 2012. Through sequential knowledge interaction processes, connections between the IK and science were examined, to explore knowledge linkages and connections. The group explored and discussed the corroborating, contradictory and complementary nature of the knowledge systems on these topics and their implications for understanding contaminant trends in this species. This process allowed for both the science and IK holders to identify areas / topics that each group would like to gain a better understanding of through discussions and presentations. Analysis at this workshop was a combined complementary analysis of explanations for trends in ringed seal contaminant levels in Nunatsiavut. Workshop discussions were recorded and transcribed for qualitative analysis to identify conditions where hunters and IK holders were commonly observing and reporting the same, complementary or different observations regarding changes in ringed seals and aspects of species ecology that may be associated with changes in contaminant levels in these animals.

Discussion/Conclusions

Contaminants data has been collected for species in Nunatsiavut over the past 15 years. In addition, the Nunatsiavut Government feels strongly that information with respect to contaminant levels in ringed seal from Nunatsiavut is a priority now and going forward. As such, the Nunatsiavut Government was interested in co-leading this holistic program to better understand ringed seal behaviour and ecology in the region. It is believed that working closely with local hunters and experts to better document their observations and knowledge about ringed seals and the supporting ecosystem will complete this holistic approach and create a better framework for understanding changes to the ecology of this important species.

The IK component of this project complements and provides improved knowledge for the multiple large-scale projects that are already ongoing for ringed seals in northern Labrador. These include:

a) Monitoring contaminant trends (PCBs, OC pesticides, PBDEs, mercury)

- Provide information on locally contaminated sites as well as documented cases of abnormal seals / seal behaviour

b) Marine food web and energy transfer study (fatty acids, stable isotopes)

- Observed changes in smaller prey species for ringed seal

c) Ringed seal satellite telemetry study

- Identification of two 'types' of seals, in-land (travel in bays) and ocean seals

d) Ringed seal health (genomics) study

- Changes in fat thickness and condition of the fur during spring

e) Contaminants module of kANGIDLUASUk Student Program Inc.

- Hunters engaged the youth, along with scientists, on hunting trips to share their knowledge of ringed seals, including observed changes in biology and ecology

Capacity Building

For this program, Katie Winters has played a leading role on the local level, working closely with local researchers and harvesters from the community of Nain. They work closely with the University and government based members of the project team. Involvement and leadership by the regional research staff has contributed to capacity building for local and regional research staff. Individuals involved gained valuable experience in this new and innovative project bringing together science and IK. This project has been valuable in supporting a growing agenda at the Nunatsiavut Research Centre towards cooperative science and IK and innovative IK research.

The project members also worked closely with the kANGIDLUASUk student program to refine the Inuit Knowledge content and perspectives of a contaminants program for the 2011 field season. This outreach program in the Torngat Mountains has been successful at providing education and capacity building opportunities for 50 youth from Nunatsiavut and Nunavik. Although it is only four years old, the summer youth program has already seen students go on to work for University researchers, mining companies (as full-time environmental monitors) and Inuit owned environmental consulting companies.

Traditional Knowledge

This project is a Nunatsiavut Inuit Knowledge project. It is focused on gathering and documenting Nunatsiavimmiut Knowledge of ringed seal ecology. This project has followed established guidelines by the Nunatsiavut Government, Inuit Tapiriit Kanatami, as well as the Trent University Ethics Board in regards to conduct of research in Aboriginal communities and with regards to data ownership, access etc. The Nunatsiavut Government owns all data; C Furgal has access to data and facilitated documentation and analysis. All data is housed at the NG and Trent University and upon completion of the project it will be housed at the NG (both in the Environment Division and at the Torngasok Cultural Centre, assuming permission by participants).

Communications

In addition to the creation of a Nunatsiavut field guide on marine mammal species and ringed seal prey and ecology, local communications were and are continually coordinated by the Northern Contaminants Researcher for Nunatsiavut. Updates on the progress and results of this project are being included in semi-annual contaminants newsletters, written by the Northern Contaminants Researcher. The Nunatsiavut Government maintains continuous contact and discussions with the hunters to ensure they are comfortable and have significant input to communications coming from the project. Initial radio interviews were conducted with the community and University based RA on the project during which this project was discussed. Upon completion of the final project analysis and report writing in late 2012 / early 2013 an IK/science report will be released and presented in the community. A contribution to the Nunatsiavut regional NCP presentation was included on this project as well and updates were presented at the IPY conference at Montreal, during April 2012.

Project Completion Date

March, 2012

Acknowledgements

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NCP Performance Indicators

Indicator	Number in 2011–12
# of northerners engaged in the project:	22
# of meetings / workshops held in the North	3
# of students (northern and southern) involved:	10
# of citable publications produced:	2

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Updating Data on Mercury Levels in Food Fish Species in Lakes Used by Dehcho Communities

(Contributing to; Temporal Trends of Mercury Levels in Food Fish Species in Lakes Used by Dehcho Community Members.)

Mise à jour des données sur les concentrations de mercure dans les espèces de poissons de consommation humaine des lacs utilisés par des membres de la collectivité du Dehcho.

(Contribution à : Tendances temporelles des concentrations de mercure dans des poissons de consommation humaine des lacs utilisés par des membres de la collectivité du Dehcho.)

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Abstract

The Dehcho First Nations is requesting funding in order to update mercury levels data in fish from lakes utilized by Dene and Métis community members. The recent release of mercury data by Environment Canada and the new health advisories from Health Canada have caused increased concerns in our communities. There are lakes and species of fish which are safe to harvest and contain acceptable levels of

Résumé

Les Premières Nations du Dehcho demandent du financement pour mettre à jour les données sur les concentrations de mercure dans les poissons des lacs utilisés par les membres des collectivités des Dénés et Métis. La publication récente de données sur le mercure par Environnement Canada et les nouveaux avis de Santé Canada ont suscité de vives préoccupations au sein de nos collectivités. Certains lacs sont

mercury. We want to be able to reassure people in cases where risks are low and warn people in cases where health advisories have been released. There may be a need to re-evaluate health risks due to the possible increase in mercury due to climate change or other unknown causes.

This project will continue next fiscal year and into the future until a complete update of “fishing lakes” have been assessed. Next fiscal year our application for funding will include work with GNWT Health to build a comprehensive communications plan for the Dehcho.

The work this year will concentrate on collecting samples from five communities which seem to be most affected; Liidlii Kue (LKFN),Fort Simpson), Jean Marie River,(JMRFN) Ka’a’gee Tu (KTFN)(Kakisa), Fort Providence (FPRMB) and Sambaa K’e (Trout Lake). Twenty samples from each species of fish will be collected from each of seven lakes used by the communities. Marlene Evans of Environment Canada is partnering in this study and will arrange the processing, analysis and will interpret results. Data collected will be useful in her temporal studies as well, including her investigation of special variations in mercury concentrations and time trends.

toutefois sécuritaires, et certains poissons contiennent des concentrations acceptables de mercure et peuvent être récoltés. Nous voulons être en mesure de rassurer la population sur les lacs et les espèces qui présentent de faibles risques et de l’aviser lorsque des avis de santé publique sont émis. Il pourrait être nécessaire de réévaluer les risques pour la santé en raison de l’augmentation possible des concentrations de mercure résultant du changement climatique ou d’autres facteurs inconnus.

Ce projet se poursuivra au cours du prochain exercice financier et dans les années à venir jusqu’à ce que la mise à jour complète des données sur les « lacs de pêche » soit terminée. Au cours du prochain exercice, notre demande de financement comprendra la réalisation de travaux en collaboration avec le ministère de la Santé et des Services sociaux des T.N. O. visant à élaborer un plan de communication exhaustif pour la collectivité du Dehcho.

Les travaux de cette année seront centrés sur la collecte d’échantillons au sein des cinq collectivités qui semblent être les plus touchées, soit : Première Nation Liidlii Kue (PNLK) (Fort Simpson), Première Nation de Jean Marie River (PNJMR), Première Nation Ka’a’gee Tu (PNKT) (Kakisa), Nation métisse de Fort Providence (NMFP) et Sambaa K’e (Trout Lake). Vingt échantillons de chaque espèce seront recueillis dans chacun des sept lacs utilisés par les collectivités.

Marlene Evans, d’Environnement Canada, collabore à l’étude et effectuera le traitement et l’analyse des données, en plus d’interpréter les résultats. Les données recueillies seront aussi utiles dans le cadre des études temporelles qu’elle mène, qui comprennent l’examen des variations spatiales des concentrations de mercure et des tendances temporelles

Key Messages

- The study to update mercury levels in fish in lakes used by Dehcho Communities was continued in 2011-12.
- Training of local people in field research techniques increased capacity through the Dehcho First Nations initiative to have trained monitors in each of the Dehcho communities.
- Involvement of the community leadership and administration in this study will increase the capacity for collaborative management of aquatic resources in the Dehcho.

Messages clés

- L'étude visant à mettre à jour les données sur les concentrations de mercure dans les poissons des lacs utilisés par des membres de la collectivité du Dehcho s'est poursuivie en 2011-2012.
- La formation de membres de la population en matière de techniques de recherche sur le terrain, par l'entremise de l'initiative des Premières Nations du Dehcho visant à doter chaque collectivité du Dehcho de surveillants qualifiés, a permis de renforcer les capacités locales.
- La participation des dirigeants et des administrateurs des collectivités à cette étude aura pour effet d'accroître nos capacités en matière de gestion collaborative des ressources aquatiques dans le Dehcho.

Objectives

i. To determine through "Traditional Knowledge" which lakes are important as food sources in Dehcho communities and which fish from these lakes are used for human food.

ii. To train community monitors, to collect fish and other samples according to Environment Canada and DFO protocol.

iii. To involve local school children in our studies by arranging in-the-field study camps or in-school presentations with the schools and the community recreational directors.

iv. To determine trends in the levels of mercury in various species of fish from lakes used for subsistence fishing by community members and make community members aware if Health Canada determines there are risks resulting in further advisories.

v. To assist scientists in their investigation of factors affecting increased mercury concentrations in predatory fish in the Dehcho and elsewhere in the Northwest Territories.

vi. In the long-term; to contribute to the evidence data base used in National and International negotiations and in agreements to lower the levels of mercury and carbon dioxide pollution in the atmosphere.

Introduction

Mercury levels in predatory fish in some inland lakes in the Mackenzie Valley have been reported to be high following a DFO 1990's study of twelve lakes used by communities for subsistence fishing (Stewart et. al. 2003). Predatory species such as lake trout, walleye and northern pike were, in some cases, found to have levels exceeding Health Canada's Guidelines for safe human consumption (0.5 PPM). As a result, some fish species from some lakes in the Dehcho have been assigned consumption guidelines due to elevated concentrations of mercury which pose a risk to human health.

More recently, Dr. Marlene Evans conducted follow-up studies on some of these lakes in the Dehcho and others in the Sahtu region. She found that some predatory species such as lake trout and walleye have levels of mercury in the flesh which was much higher than in the 1990's. Mercury levels in fish seem to be increasing in recent years. Evans (2010) comments in her 2010 report to the NCP; *"What is striking is the general tendency for mercury concentrations to be highest in the last year investigated with striking increases in Kelly Lake, Lac Ste Therese, and Cli Lake;"* Cli Lake is in the Dehcho; other Dehcho lakes such as Deep, Sanguez, Tsetso, Little Doctor, McGill and Reade were reported to have elevated levels of mercury in predatory fish in earlier studies. Have mercury levels continued to increase further in these lakes as well? As relatively small lakes with large watersheds, this seems highly likely.

Mercury levels in lake trout from Trout Lake also have increased over the last three testing periods to reach a level where Health Canada has issued a consumption advisory limit. The Sambaa Ke First Nation resides on the shores of Trout Lake and fishes for trout and walleye. Have levels in walleye also increased? Have mercury levels in lake trout increased even more?

The upward trend in the levels of mercury in fish was reported in the media which has resulted in concern in some Dehcho communities. Thus there is an urgent need for updated mercury data on lakes in the Dehcho which are fished for food. In some cases, community members will no longer eat fish from inland lakes even though species such as suckers and whitefish which are usually safe.

Once fishing lakes are retested, a robust communication plan needs to be developed by GNWT Health with the input of the communities to communicate the results of further testing. Such information should weigh the benefits of eating fish against the risks from contaminants such as mercury. People need to be informed that non-predatory fish such as whitefish are usually low in mercury and that the fish from some lakes have tested as low risk and are safe to eat.

Generally, people want to be warned if there is a health risk and reassured that it is safe to eat certain fish from certain lakes if the fish are ok.

Activities in 2011 – 2012

- The Coordinator of the Dehcho AAROM program, George Low, met with the Jean Marie River First Nations (JMRFN) to discuss a summer fishing project on Ekali Lake which included collecting fish for mercury analysis.
- Likewise we met with the Liddlii Kue, Sambaa Kue, Ka'a'gee Tu and the Fort Providence Resource Mgmt. Board (FPRMB) to arrange for their winter fishing projects.
- In August, 2011, Dehcho AAROM staff George and Mike Low and the community monitors from JMR (Rufus Sanguez and Jonas Norwegian) conducted a gillnetting study on Ekali Lake. (AAROM also

Results; Lakes sampled and numbers of fish shipped for analysis.

	Northern Pike	Walleye	Lake Whitefish	Lake Trout	Burbot
Ekali Lake	16	18	20		
Sanguez Lake	20	20			
Tathlina Lake	20	20			
Trout Lake		20		20	
Willow Lake	20		19	16	
Big Island Lake	16		19	20	20
JMR/Mackenzie River (J.Carrie)					18

Total Samples; 7 Water-bodies – 322 fish sent for analysis in 2011-12

Analysis Results

Table 1. Mean (± standard deviation) of fork length, weight, age and mercury concentrations of various fish species collected over 2010–2011 in the Fort Simpson area. Also shown are historic data.

	Year	N	Fork length (mm)	Weight (g)	Age (Years)	Mercury (µg/g)
Big Island Lake						
Lake whitefish	2012	20	444.1 ± 30.0	1179.8 ± 354.7	9.4 ± 4.4	0.10 ± 0.04
Burbot*	2012	20	669.1 ± 48.8	2362.3 ± 509.2	14.6 ± 2.9	0.30 ± 0.13
Northern Pike	2012	16	780.5 ± 313.9	2562.8 ± 1210.9	10.4 ± 3.2	0.38 ± 0.26
Lake trout	2012	20	570.4 ± 60.1	2466.3 ± 1004.6	15.3 ± 4.7	0.38 ± 0.10
Deep Lake						
Lake whitefish	2000	28	443.5 ± 40.9	1253.1 ± 345.0	11.4 ± 2.9	0.25 ± 0.12
Lake whitefish	2010	1	474.0	1140.0		0.22
Burbot*	2010	3	414.3 ± 123.1	550.0 ± 525.7	13.7 ± 3.1	0.91 ± 0.24
Northern Pike	2000	6	583.7 ± 54.8	1420.0 ± 386.3	10.3 ± 4.3	0.67 ± 0.20
Northern Pike	2010	4	574.3 ± 117.5	1387.5 ± 809.2	9.7 ± 4.5	1.15 ± 0.30
Yellow walleye	2010	4	448.0 ± 40.2	1040.0 ± 238.5	15.3 ± 3.5	1.11± 0.35
Yellow walleye	2010	5	401.0 ± 63.6	766.0 ± 395.3	11.6 ± 5.0	1.21 ± 0.46
Ekali Lake						
Lake whitefish	1996	26	477.5 ± 70.4	1850.4 ± 807.3	7.9 ± 3.8	0.08 ± 0.04
Lake whitefish	2011	20	473.1 ± 70.2	1782.3 ± 743.8	7.6 ± 2.4	0.12 ± 0.04
Northern Pike	1996	7	577.6 ± 90.8	1534,3 ± 960.7	7.6 ± 2.2	0.30 ± 0.11
Northern Pike	2011	16	622.1 ± 95.5	1910.6 ± 1085.8	8.3 ± 2.1	0.62 ± 0.17
Yellow walleye	1996	16	411.8 ± 28.9	842.5 ± 175.8	8.3 ± 1.6	0.26 ± 0.06
Yellow walleye	2011	18	410.3 ± 42.0	738.3 ± 246.7	9.9 ± 3.3	0.54 ± 0.20
Fish Lake						
Lake whitefish	2011	25	393.2 ± 45.7	850.0 ± 299.9	8.8 ± 3.2	0.09 ± 0.03
Burbot*	2011	7	675.0 ± 48.2	2432.9 ± 218.0	8.3 ± 2.1	0.40 ± 0.10
Northern Pike	2011	20	733.6 ± 97.1	3256.0 ± 1570.7	11.8 ± 2.4	0.67 ± 0.15
Lake trout	2011	7	582.4 ± 58.5	2552.1 ± 692.8	17.7 ± 9.7	0.46 ± 0.17
Yellow walleye	2011	5	484.8 ± 40.8	1449.6 ± 385.3	17.6 ± 3.2	0.91 ± 0.21
McGill Lake						
Lake whitefish	2000	3	392.2 ± 57.0	1153.3 ± 582.8	7.7 ± 2.7	0.16 ± 0.05
Lake whitefish	2010	3	419.7 ± 58.2	1168.3 ± 518.1	9.0 ± 4.0	0.10 ± 0.04
White sucker	2000	17	471.4 ± 33.3	1740.6 ± 441.7		0.21 ± 0.08
White sucker	2010	12	447.3 ± 39.6	1497.9 ± 403.4	11.6 ± 2.3	0.16 ± 0.06
Northern pike	2000	28	577.2 ± 171.3	1905.8 ± 2127.8	8.5 ± 5.6	0.71 ± 0.37
Northern Pike	2010	19	664.6 ± 180.8	2870.0 ± 2556.8	10.0 ± 4.1	0.83 ± 0.38

McGill Lake (continued)						
Yellow walleye	2000	19	480.4 ± 67.4	1428.6 ± 733.2	12.8 ± 5.4	1.13 ± 0.38
Yellow walleye	2010	20	464.4 ± 29.9	1162.8 ± 252.8	12.1 ± 3.0	1.25 ± 0.39
Sanguez Lake						
Northern Pike	1990	20	682.8 ± 84.8	2562.0 ± 985.3	9.7 ± 2.3	0.70 ± 0.18
Northern Pike	2011	20	638.3 ± 50.7	1950.0 ± 471.6	9.4 ± 2.2	0.96 ± 0.22
Yellow walleye	1996	20	439.9 ± 40.4	1070.5 ± 368.9	9.4 ± 1.7	0.54 ± 0.12
Yellow walleye	2011	20	523.5 ± 44.5	1875.0 ± 507.2	8.9 ± 2.0	0.78 ± 0.25
Tathlina Lake						
Northern Pike	1998	6	570.6 ± 50.1	1486.3 ± 456.3	n.d.	0.21 ± 0.04
Northern Pike	2012	20	711.4 ± 85.1	3038.3 ± 1360.2	10.5 ± 2.3	0.65 ± 0.22
Yellow walleye	1981	8	342.3 ± 13.7	776.3 ± 95.4	n.d.	0.36 ± 0.10
Yellow walleye	1998	6	417.6 ± 11.8	1040.7 ± 67.8	n.d.	0.33 ± 0.18
Yellow walleye	2012	34	417.3 ± 18.7	819.4 ± 100.8	15.3 ± 3.7	0.69 ± 0.22
Trout Lake						
Lake trout	1990	3	539.3 ± 22.7	1566.7 ± 76.4	16.0 ± 2.7	0.17 ± 0.09
Lake trout	1991	9	533.1 ± 17.9	1891.0 ± 265.6	14.5 ± 2.6	0.23 ± 0.07
Lake trout	2003	28	645.2 ± 35.5	2863.7 ± 743.0	17.2 ± 5.5	0.35 ± 0.08
Lake trout	2008	28	601.9 ± 71.0	3127.0 ± 1633.7	16.2 ± 7.7	0.61 ± 0.17
Lake trout	2011	20	680.5 ± 70.6	4394.5 ± 1632.8	14.5 ± 8.6	0.46 ± 0.08
Yellow walleye	1990	10	450.3 ± 73.2	1130.0 ± 525.7	8.8 ± 1.5	0.11 ± 0.04
Yellow walleye	1991	10	498.2 ± 52.7	1276.8 ± 345.5	10.0 ± 1.25	0.14 ± 0.06
Yellow walleye	2012	20	506.7 ± 45.0	1371.0 ± 290.9	18.9 ± 6.1	0.68 ± 0.27
Willow Lake						
Lake whitefish	1999	47	404.5 ± 44.5	993.6 ± 342.9	8.9 ± 2.7	0.10 ± 0.05
Lake whitefish	2012	20	440.2 ± 29.3	1238.5 ± 298.0	11.8 ± 1.7	0.10 ± 0.04
Northern Pike	1999	20	634.0 ± 96.0	2016.3 ± 976.2	n.d.	0.28 ± 0.15
Northern Pike	2012	20	691.1 ± 68.0	2617.3 ± 838.2	11.8 ± 3.0	0.38 ± 0.26
Lake trout	1999	32	613.7 ± 92.9	3067.5 ± 2159.9	15.8 ± 4.8	0.38 ± 0.10
Lake trout	2012	16	642.1 ± 72.4	3413.8 ± 1108.7	13.0 ± 2.2	0.38 ± 0.10

Ekali Lake; Excerpt from Environment Canada preliminary report; Marlene Evans, 2011.

partnered with ENR and contracted BEAT Environmental Inc. (Bruce Townsend) to conduct an ecological study of this lake as well as Sanguez and Gargon which are in the same lake chain that drains into the Jean Marie River).

- In December 2011, the JMR First Nation was contracted to provide two community monitor/harvesters to work with our technicians to gillnet and collect fish samples from Sanguez Lake for mercury analysis.

- In January, 2012, the FPRMB was contracted to gillnet and collect fish samples from Willow Lake; supervised by Dehcho AAROM; Mike Low.

- A local fisherman (Fred Jumbo provided AAROM with 20 lake trout and 20 walleye caught in Trout Lake near the community.

- A local fisherman (Fred Simba) provided AAROM with 20 pike and 20 walleye from Tathlina lake

- Local fishermen (Herb Norwegian and Jonas Antoine provided AAROM with 20 pike, 20 lake whitefish and 20 lake trout from Big Island Lake on the Horn Plateau.

- All fish were sampled by Mike Low and helpers and the data and flesh samples were shipped to Marlene Evans of EC for aging and mercury analysis.

- Dehcho AAROM contracted a graduate student (Amy Sett) to process the fish for mercury levels in the Environment Canada lab in Burlington, Ontario. Dr. Marlene Evans is the researcher scientist on the project (except for the burbot samples which were handled by Jessie Carrie of DFO).

- Dehcho AAROM, with funding from NCP, contracted Gary Carder and John Babaluk to provide fish ages from the collected aging structures (except the burbot).

- Jessie Carrie and Gary Stern of DFO are analysing the burbot from the Mackenzie River at the mouth of the Jean Marie River.

Three species of fish were harvested from Ekali Lake in 1996 and 2011. Mercury concentrations remain low in lake whitefish and lower than in Deep Lake. Mercury concentrations in pike and walleye were greater in 2011 than 1996 and exceeded the 0.5 µg/g commercial sale guideline. These data have not been analyzed for time trends but it seems probable that the higher mercury concentrations in 2011 than 1996 would be statistically significant.

Table 2. Mean (and 1 standard deviation) fork length, weight, age and mercury concentration in fish harvested from Ekali Lake in 1996 and 2011.

Ekali Lake	Yr	N	Fork Length (mm)	Weight (g)	Age (y)	Mercury (µg/g)
Lake whitefish	1996	20	477.5 ± 70.4	1850.4 ± 807.3	7.8 ± 3.7	0.08 ± 0.04
Lake whitefish	2011	20	473.1 ± 70.2	1782.3 ± 743.8	7.6 ± 2.4	0.12 ± 0.04
Northern pike	1996	7	577.6 ± 90.8	1534.3 ± 960.7	7.6 ± 2.2	0.30 ± 0.11
Northern pike	2011	16	622.1 ± 95.6	1910.6 ± 1085.8	8.3 ± 2.1	0.62 ± 0.17
Walleye	1996	14	411.8 ± 28.9	842.5 ± 175.7	8.3 ± 1.6	0.26 ± 0.06
Walleye	2011	18	410.3 ± 42.0	738.3 ± 246.7	9.9 ± 3.3	0.54 ± 0.20

Preliminary Conclusions

1. Average mercury concentrations were low in lake whitefish in Deep, McGill and Ekali Lake; however, mercury levels were highest in Deep Lake where previous work determined that some lake whitefish had high mercury levels.

2. Average mercury levels were high in the three burbot from Deep Lake.

3. Average mercury levels were above 0.5 µg/g for all pike and walleye populations analyzed. Mercury levels were higher than in previous studies although statistical analyses have not been conducted as of yet to assess whether these differences are significant.

NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	16	• One long-time northerner working as the AAROM Coordinator for the Dehcho First Nations coordinated the study. • One Aboriginal biologist/ technician organized and supervised the field work and sampled the catch. • Fifteen individual Dene community members provided the traditional knowledge guidance and gillnetting work for the seven projects.
number of project–related meetings/workshops held in the North (April 1, 2011 – March 31, 2012)	5	Five community meetings
number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	0	
number of citable publications (e.g., in domestic/ international journals, conference presentations, book chapters, etc)	0	Dehcho AAROM data has been archived. EC and DFO will publish papers based in part on the data we collected.

Recommendations

1. Deep Lake merits some attention from a scientific perspective as its burbot and lake whitefish have higher mercury concentrations than in other lakes including McGill Lake.

Further Mercury Analysis Results; not yet available for Sanguez Lake, Trout Lake, Tathlina Lake, Willow Lake and Big Island Lake. We expect this report will be available from EC in late April, 2012. Also for Mackenzie River burbot from DFO

Discussion and Conclusions

Environment Canada and DFO will be producing reports elaborating on project results and conclusions.

From an AAROM prospective the study went very well. We were able to collect samples from seven lakes at very economical costs by combining with other studies and utilizing community harvesters in some cases. To date the two year study has resulted in GNWT Health and Social Services issuing consumption advisories for predatory fish on five lakes.

Expected Project Completion Date

March, 2014

The Dehcho AAROM has changed the direction of this study towards communications and the promotion of including country food especially fish in the diet. We will be assisting GNWT, Health, DFO and EC to collect samples when able.

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- Mike Low supervised the field project at Willow Lake and Sanguez Lake and was responsible for sampling the fish and shipping them along with data on length, weight and aging structures to the Environment Canada lab in Saskatoon.

- Marlene Evans was responsible for handling the mercury data and reporting on mercury levels. Jonathan Keating received and organized the samples and sent the flesh samples on to the Burlington Lab and the aging structures to the various agers.

- Amy Sett, a graduate student working under the supervision of Xiaowa Wang of the Environment Canada, Burlington Lab, determined the mercury levels in the fish samples.

- Gary Carder and John Babaluk aged the fish.

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Appendices

Northwest Territories Health and Social Services

OFFICE OF THE CHIEF PUBLIC HEALTH OFFICER

Public Health Advisory

YELLOWKNIFE (August 19, 2011) – Dr. Lorne Clearsky, Chief Public Health Officer, is advising residents of the Northwest Territories of an increase in mercury levels in three lakes.

Thereby, a public health notice is in effect, recommending people limit the quantity of fish they eat from the following lakes:
McGill Lake – Dehcho
Deep Lake – Dehcho
Fish Lake – Dehcho

Generally, fish is a good source of nutrition and high in protein, Vitamin B and omega-3 fatty acids. The health benefits of eating fish outweigh the potential risks. Mercury is a contaminant that can be found in fish. Levels of mercury differ from lake to lake and can be due to human activities or to natural causes. Health Canada has established guidelines on what levels of mercury are acceptable to consume. To reduce exposure, it is recommended that people adhere to the following recommendations:
Eat smaller fish
Eat more fish that are lower in the food chain, such as whitefish or grayling and eat less that

are higher in the food chain such as walleye, northern pike or lake trout

Based on Canada's Food Guide, one serving of fish is considered to be 75 grams, about the size of a deck of cards. Below are recommendations specific to each lake: **McGill Lake** (Compared to 2000 levels, there has been no significant change in levels)

Pike

- Pike less than 43 cm in total length can be eaten without restriction
- Pike greater than 74 cm should not be consumed
- Pike between 43 and 74 cm should only be consumed twice a week, with serving sizes no larger than 75g, or the size of a deck of cards for non-pregnant or breast feeding mothers or children
- Pregnant or breastfeeding mothers should consume no more than 2 servings a month
- Children 5 to 11 should not consume more than 1 ½ serving per month
- Children under 4 should not consume more than 1 serving per month

Walleye

- Walleye less than 22 cm in total length can be eaten without restriction
- Walleye greater than 38 cm should not be consumed
- Walleye between 22 and 38 cm should only be consumed twice a week, with serving sizes no larger than 75g, or the size of a deck of cards for non-pregnant or breast feeding mothers or children.
- Pregnant or breast feeding mothers should consume no more than 2 servings a month
- Children 5 to 11 should not consume more than 1 ½ serving per month
- Children under 4 should not consume more than 1 serving per month

Deep Lake – A small sample was collected for both species. Compared to 2000 levels, there has been no significant change in levels)

Pike

- Pike greater than 50 cm should not be consumed
- Pike under 50 cm should only be consumed twice a week, with serving sizes no larger than 75g, or the size of a deck of cards for non-pregnant or breastfeeding mothers or children
- Pregnant or breastfeeding mothers should consume no more than 2 servings a month
- Children 5 to 11 should not consume more than 1 ½ serving per month
- Children under 4 should not consume more than 1 serving per month

Walleye

- Walleye greater than 37 cm should not be consumed
- Walleye under 37 cm should only be consumed twice a week, with serving sizes no larger than 75g, or the size of a deck of cards for non-pregnant or breastfeeding mothers or children.
- Pregnant or breast feeding mothers should consume no more than 2 servings a month
- Children 5 to 11 should not consume more than 1 ½ serving per month
- Children under 4 should not consume more than 1 serving per month

Fish Lake –
Lake Trout

- Due to small numbers of fish caught, retesting will be done, with avoidance of large fish for consumption

Pike

- Pike less than 57 cm in total length can be eaten without restriction
- Pike greater than 107 cm should not be consumed
- Pike between 57 and 107 cm should only be consumed twice a week, with serving sizes no larger than 75g, or the size of a deck of cards for non-pregnant or breast feeding mothers or children.
- Pregnant or breast feeding mothers should consume no more than 2 servings a month
- Children 5 to 11 should not consume more than 1 ½ serving per month
- Children under 4 should not consume more than 1 serving per month

Walleye

- Walleye less than 47cm in total length can be eaten without restriction
- Walleye greater than 47 cm should only be consumed twice a week, with serving sizes no larger than 75g, or the size of a deck of cards for non-pregnant or breast feeding mothers or children.
- Pregnant or breastfeeding mothers should consume no more than 2 servings a month
- Children 5 to 11 should not consume more than 1 ½ serving per month
- Children under 4 should not consume more than 1 serving per month

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Northwest Territories Health and Social Services

OFFICE OF THE CHIEF PUBLIC HEALTH OFFICER

Public Health Advisory

YELLOWKNIFE (February 9th, 2012) – Dr. Lorne Clearsky, Chief Public Health Officer, is advising residents of the Northwest Territories of elevated mercury levels in fish from one lake. Thereby, a public health notice is in effect, recommending people limit the quantity of pike and walleye they eat from the following lake:

Ekali Lake (also known locally as Kelly Lake) – Dehcho

Generally, fish is considered to be a good source of nutrition and high in protein, Vitamin B and omega-3 fatty acids. The health benefits of eating fish are thought to outweigh the potential risks presented by some contaminants. Mercury is a contaminant that can be found in almost all fish. Levels of mercury differ from lake to lake and from fish species to species and can be due to human activities or to natural causes. For retail fish, Health Canada has established guidelines on what levels of mercury are acceptable to consume. To reduce exposure, it is recommended that people adhere to the following recommendations:

- Eat smaller fish
- Eat more fish that are lower in the food chain, such as whitefish or grayling and eat less that are higher in the food chain such as walleye, northern pike or lake trout

Based on Canada's Food Guide, one serving of fish is considered to be 75g, basically a deck of cards. Below are recommendations specific to Ekali Lake (Kelly Lake in the Deh Cho region) which is located on the Mackenzie Highway 30 Kilometres from the town of Jean Marie River. Compared to 1996 levels, there has been a significant change in the levels of mercury in the following fish muscle.

Please note that this advice applies only to those individuals who eat northern pike or walleye on a regular or weekly basis for a number of months from this lake. An occasional large fish meal especially if consuming smaller fish would not pose any health risk. Although mercury can accumulate through regular fish consumption, the body is able to slowly eliminate mercury. The key is to balance consumption with this natural elimination process. White fish can be consumed without any restrictions.

Northern Pike

The mean mercury level is 0.62 ppm for northern pike. This is above Health Canada's recommendations.

The general population should consume no more than 150 grams (0.3 lbs) per week. This is equally to 2 servings a fish per week. Pregnant or breastfeeding mothers should eat no more than 150 grams (0.3lbs) per month. This is equal to 2 servings of fish per month. Children between five and 11 years of age can eat up to 125 grams (0.276 lbs) per month. This is equal to 1 and ¾ servings a month. Young children between one and four years of age should eat no more than 75 grams (0.165 lbs) per month. This is equal to 1 serving a month.

Walleye

The mean mercury level is 0.54 ppm for walleye. This is slightly above Health Canada's recommendations.

The general population should consume no more than 150 grams (0.3 lbs) per week. This is equally to 2 servings a fish per week. Pregnant or breastfeeding mothers should eat no more than 150 grams (0.3lbs) per month. This is equal to 2 servings of fish per month. Children between five and 11 years of age can eat up to 125 grams (0.276 lbs) per month. This is equal to 1 and ¾ servings a month. Young children between one and four years of age should eat no more than 75 grams (0.165 lbs) per month. This is equal to 1 serving a month.

Lake Whitefish

Levels of mercury in lake whitefish muscle are well below Health Canada's retail fish consumption guidelines. This fish can be eaten in unrestricted amounts.

For a complete list of lakes with elevated mercury levels please visit:

http://www.hlthss.gov.nt.ca/english/services/environmental_health/food_safety/contaminants/mercury/default.htm

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Evaluation of Hydro-Climatic Drivers of Contaminant Transfer in Aquatic Food Webs in The Husky Lakes Watershed

(Inuvialuit Settlement Region, Northwest Territories)

Évaluation des facteurs hydro-climatiques favorisant l'apport de contaminants dans les chaînes alimentaires aquatiques du bassin hydrographique des lacs Husky

(Région désignée des Inuvialuit, Territoires du Nord-Ouest)

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Abstract

Mercury can accumulate in apex-predator fish muscle to concentrations exceeding those considered safe for subsistence consumption by humans. Fish species such as Lake Trout are typical apex-predators of Arctic lakes and can be a significant source of food for local indigenous peoples. The influence of abiotic factors and biological parameters on Hg accumulation in apex-predators is not well understood. Further,

Résumé

Le mercure peut s'accumuler dans les muscles des poissons prédateurs de niveau trophique supérieur dans des concentrations qui dépassent celles jugées sécuritaires pour la consommation humaine chez les poissons de subsistance. Certaines espèces des lacs de l'Arctique, comme le touladi, sont des prédateurs types de niveau trophique supérieur et peuvent être une source importante de nourriture pour les peuples

a good understanding of sources of Hg to and processes within water column and food webs is still lacking. Our study aims to investigate the interactions of water column, food webs and Hg transfer in four freshwater systems in the Inuvialuit Settlement Region (Canada). The selected Big, Yaya, Noell, and Husky Lakes systems represent a range of water column and ecological characteristics, as well as Hg delivery (marine-, riverine- or freshwater-derived). We investigate how those characteristics affect Hg transfer and fractionation. All lakes are frequented by people from the Inuvialuit communities of Inuvik and Tuktoyaktuk for subsistence fishing. Sampling includes surface water, benthic and pelagic invertebrates, tissues from harvested fishes, and non-target fishes. Biological parameters of fishes (age, length, weight, diet) are recorded and invertebrates separated by species. Sample analysis includes total Hg (THg), monomethylHg (MeHg), and stable isotopes of carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$), and Hg ($\delta^{x}Hg$) and otolith microchemistry. Hg isotope ratios (IRs) are analyzed by multi-collector inductively coupled plasma mass spectrometry (MC-ICP/MS). Hg mass independent fractionation (MIF; $\delta^{199}Hg$) and mass dependent fractionation (MDF; $\delta^{202}Hg$) will be calculated and evaluated against conditions in the water column, food web transfer and the potentially difference in Hg delivery. [THg] detected in harvested fishes will be compared to consumption guidelines.

autochtones locaux. On comprend encore mal l'incidence des facteurs abiotiques et des paramètres biologiques sur l'accumulation du mercure (Hg) dans les prédateurs de niveau trophique supérieur. De plus, il est nécessaire d'avoir une bonne compréhension des sources de mercure et des processus dans la colonne d'eau et les réseaux trophiques. Nos travaux s'intéressent donc aux interactions entre la colonne d'eau, les réseaux trophiques et les apports de mercure dans quatre réseaux d'eau douce de la Région désignée des Inuvialuit (au Canada). Les lacs Big, Yaya, Noell et Husky ont été retenus aux fins de l'étude parce qu'ils sont représentatifs des diverses caractéristiques de l'écologie et de la colonne d'eau, ainsi que du passage du mercure d'un milieu à l'autre (marin, riverain ou dulcicole). Nous étudions la façon dont ces caractéristiques influent sur les apports de mercure d'un milieu à l'autre et sur le fractionnement du mercure. Tous les lacs sont fréquentés par les habitants des collectivités inuvialuites d'Inuvik et de Tuktoyaktuk qui y pratiquent une pêche de subsistance. Des échantillons d'eau de surface, d'invertébrés benthiques et pélagiques, de tissus de poissons pêchés et de poissons non ciblés y sont prélevés. Les paramètres biologiques des poissons (âge, longueur, poids, régime alimentaire) sont notés, et les invertébrés sont répartis par espèce. L'analyse des échantillons comprend la détection du mercure total (THg), du mercure monométhylé (MeHg), des isotopes stables de carbone ($\delta^{13}C$), d'azote ($\delta^{15}N$) et de mercure ($\delta^{x}Hg$) et la microchimie des otolithes. Les rapports isotopiques de mercure sont analysés par spectrométrie de masse à source à plasma inductif et collection d'ions multiples (MC-ICP-MS). Le fractionnement indépendant de la masse de mercure (FIM; $\delta^{199}Hg$) et le fractionnement dépendant de la masse de mercure (FDM; $\delta^{202}Hg$) seront calculés et évalués par rapport aux conditions dans la colonne d'eau, aux apports de mercure dans le réseau trophique et à la différence potentielle dans les apports de mercure. Le mercure total [THg] détecté dans les poissons pêchés sera comparé aux lignes directrices en matière de consommation.

Keys Messages

- We are aiming to provide the communities of Tuktoyaktuk and Inuvik with baseline information on contaminants (e.g., mercury) in fishes harvested from four local lakes, with a focus on Husky Lakes.
- Throughout our project, we continuously interact with both communities through public meetings, Traditional Knowledge interviews, and expert consultations. The results of the interviews were used to direct sampling in May 2012. We continuously interact with the Tuk HTC, report on our progress, and hire local field assistance for our field work through the HTC.
- We conducted an initial field trip to the Husky Lakes during November 2011 under-ice fishing efforts by local residents, collected several species of fishes, water samples and sediment samples with the help of 4 local people.
- Mercury concentrations in surface sediments decreased with greater salinity (the salinity gradient) in the Husky Lakes.
- Preliminary results of our mercury analysis indicate that mercury in Lake Trout from Husky Lakes are generally low, and seem lower than in nearby Noell Lake.

Messages clés

- Nos travaux visent à fournir aux collectivités de Tuktoyaktuk et d'Inuvik une information de référence sur les contaminants (p. ex. le mercure) dans les poissons pêchés dans quatre lacs locaux, en particulier les lacs Husky.
- Dans le cadre de notre projet, nous interagissons continuellement avec les deux collectivités par le biais de rencontres publiques, d'entrevues axées sur le savoir traditionnel et de consultations d'experts. Les résultats des entrevues ont servi de base à l'échantillonnage direct qui s'est déroulé en mai 2012. Nous avons maintenu des communications avec les comités de chasseurs et de trappeurs de Tuktoyaktuk, nous avons fait part des progrès réalisés et nous avons recruté, par l'entremise des comités de chasseurs et de trappeurs, des membres de la collectivité pour les travaux sur le terrain.
- Nous nous sommes rendus pour la première fois sur les lacs Husky en novembre 2011 lors d'une expédition de pêche sur la glace avec des résidents locaux et avons recueilli plusieurs espèces de poissons, ainsi que des échantillons d'eau et de sédiments avec l'aide de quatre résidents locaux.
- Les concentrations de mercure dans les sédiments de surface diminuent à mesure que la salinité (gradient de salinité) augmente dans les lacs Husky.
- Les résultats préliminaires de nos analyses indiquent que les concentrations de mercure dans le touladi des lacs Husky sont généralement basses, et semblent inférieures à celles mesurées dans le lac Noell, situé à proximité.

Objectives

- Characterize the lake-ice conditions and associated lake productivity and aquatic food webs along a hydroclimatic/salinity gradient within the Husky Lakes Watershed (HLW);
- Use the characterized food webs to explain uptake of Hg including isotopes as tracer/markers through a comparison of: i) spatial comparison of Hg bioaccumulation in food webs; ii) Hg stable isotope ratios in biota along a salinity gradient in the HLW and with lakes outside the HLW.

- Investigate Lake Trout patterns of movement to aid the interpretation of mercury concentration.

- Review of existing and new documentation of Traditional Knowledge (TK) on historical and present ice and climate conditions and fish biology and subsistence fisheries.

- Combine both knowledge bases to help develop future strategic monitoring of locally relevant sites.

Introduction

Local people of Inuvik and especially Tuktoyaktuk utilize the Husky Lakes Lake Trout extensively for subsistence hunts as a country food resource. Many families from Tuktoyaktuk spend the spring on the lakes to collect Lake Trout for subsistence consumption (jigging through the ice), while some families use nets under the ice in the fall to, in part, collect food for their dogs. All other lakes in this study (Noell, Yaya and Big lakes) are currently frequently utilized by members of both communities, while lakes along the proposed road connecting Inuvik and Tuktoyaktuk could become of interest, once they are more easily accessible. Mercury concentrations in fish from the lakes that are commonly used for subsistence fishing by community members are mostly unknown.

We are studying hydro-climatic effects on food webs and related contaminants transfer to top predators of lakes near the communities of Inuvik and Tuktoyaktuk using a mixed methods approach. Sample collections for this project are conducted following TK interviews and in conjunction with fall/spring fishing by residents of Tuk/Inuvik. Local people will be hired for this work and will be trained in relevant methods for future work on lakes. We will compare sites in the Husky Lakes Watershed (along a local salinity gradient) with Big Lake and Yaya Lake. This project will allow us to better understand the effects of marine and fresh waters entering Husky Lakes, controlled by changes in climatic conditions, guided by the existing TK on the systems. The research will establish a baseline against which the future changes of climate and land use in the ISR can be assessed, 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 general movement patterns of Lake Trout within the Husky Lakes. We will also use a method that could allow us to track the 'fingerprint' of mercury through the food web (Gantner et al 2009). 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 the study lakes (Mills et al. 2008). This project could aid in the future design of a community-based monitoring plan of the fisheries in the area and is linked to other environmental assessments underway on the Inuvik-Tuk road corridor.

Activities in 2011-2012

Fieldwork (2011-2012)

The initial fall field campaign was a multi-purpose trip that included helicopter-supported work, land-based work, and additional outreach/consultation. The timing for the fall/winter work was suggested to us by the Tuk HTC and during the review by the Regional Contaminants Committee in the proposal stage of this study. We were asked to join fishermen when they set fishing nets under the ice and to conduct sampling of fish and other parameters at that time, thereby limiting helicopter use and our scientific fishing efforts in the ecologically and culturally sensitive ecosystem. Prior to arranging flights to Inuvik, we communicated with ARI Inuvik and Tuk HTC to assure the ice on the lakes was safe to travel on. We spent 3 weeks in the ISR, split between Inuvik and Tuktoyaktuk; we meet with local partners (Aurora Research

Institute, Fisheries Joint Management Committee, Fisheries and Oceans Canada, Tuk HTC) and the public in Tuktoyaktuk to discuss project details and future directions. We visited all four study lakes to develop methods related to sample collections for both MSc projects. The field crew at all sites consisted of Donald Ross, Shannon McFadyen (U Victoria, MSc student) and Nikolaus Gantner, with 4 local people helping in Tuktoyaktuk.

Inuvik-based sampling

With the support of our Inuvik based co-lead ARI and PCSP/Canadian Helicopter's, and despite the limited available daylight (~11am-4pm) in November, our field crew was able to access all large lakes via helicopter, drill up to 3 holes per site in the ~15 inch thick lake ice using an auger and ice-saw and to collect abiotic data/samples (ice thickness, salinity measurements, water chemistry, surface grabs of lake sediments). Our attempts to collect zooplankton through/under the ice were of limited success, as biomass appeared extremely low. Our time at each site was limited due to the daylight. Dissolved oxygen, conductivity and temperature profiles in the lake water columns were obtained on site using YSI probes through the ice at 1-3 holes per site. Limnological parameters (e.g., secchi depth; ~2x2m snow cleared off around the ice) were characterized and water chemistry samples were obtained using standard methods of collection (water samples - about 2 L per lake). Water samples were kept cold and shipped to DFO Freshwater Institute (FWI Winnipeg) laboratories for analysis. We did not fish during this week, with exception of a few minutes of jigging while other work was being completed at a given site. Keeping the minimal effort in mind, our fishing resulted in one Fourhorn Sculpin ('Gannyuk') collected by means of scientific sampling. We had Inuvialuit representative Donald Ross (technician at ARI) with us for much of the work. Donald was aboard to provide the support in the field that we have grown accustomed to and to help us 'getting the message across' during meetings with local organizations and the public. We plan additional public presentations in Inuvik in the future.

Tuktoyaktuk-based sampling

Donald, Shannon and Nikolaus flew to Tuk to access the Husky Lakes sites via snowmobile. We hired 2 persons locally in Tuk, Charles Pokiak and Chris Felix, to take us out to meet with two fishermen, Rex Noksana and John Tedjuk (youth), at a fishing camp. We joined these two fishermen, who spent the month on the land, when they checked the nets set under ice to fish for 'crooked back' (Whitefish) for dog food during winter. Lake Trout were caught as 'edible by-catch' and several other fish species were also caught in the nets. The fishermen allowed us to take samples of specimens we selected together. Obtaining samples of fishes that are already caught has reduced the number of fish we need to catch ourselves for this study. We camped at the cabin and collected abiotic samples during the day via snowmobile. The meat of Lake Trout was either returned to the fishermen or provided to Elders in Tuk. Once we returned to Tuk, we were notified that other fishermen (e.g., James Keevik) had collected fishes from a second location and we were able to collect samples of these fishes as well (numbers included in the total above).

Fish processing for analysis:

In total, tissue samples were collected from 58 fishes caught by 'traditional fishing': (29 Lake Trout; 20 Lake Whitefish; 5 Blue Herring; 2 Broad Whitefish; 2 Fourhorn Sculpin) from two locations at the Husky Lakes. A range of sizes (ages) of each species was selected for tissue sampling. Fish size (fork length) and weight were recorded. Samples of fish muscle (~20 grams) and liver (~5 grams) were obtained from fish caught by fishermen via dissection in the field or at the accommodations. Sub-samples/tissue samples of all species were collected and preserved for trophic analysis (stable isotopes C, N and S) and contaminants (all ongoing). Ageing structures (otoliths) were removed from all fish sampled (see pictures section). Fish stomachs were either kept whole or opened and stomach contents recorded. This was necessary to characterize the food web including dietary preferences of fish at several life stages. Once samples were obtained, these were preserved (frozen). All samples obtained were brought back to the laboratories of the University of Victoria. No unexpected fish species was collected.

Capacity Building

In the North: Field work in November included 5 Inuvialuit and 2 southern researchers, TK work in February involved 14 local experts in Tuktoyaktuk and 2 southern researchers. We demonstrated our sampling procedures and provided training to those with us in the field, with particular focus on fish dissections, otolith extractions, and overall 'clean' handling of tissues. We also demonstrated our tentative field collection methods, equipment used, and fish dissections during our public meeting to all 20 attendees.

In the South: *Shannon McFadyen, University of Victoria:* Since September, Shannon completed required courses and thesis proposal for the University of Victoria's MSc degree (Geography). She worked as TA for 50 students in two classes. Shannon participated in the preliminary sampling trip to collect samples, spend time in the communities, hosted the public meeting in Tuktoyaktuk to discuss the project. Once samples were prepared for contaminants analysis in our lab at University of Victoria under the guidance of Dr Gantner, she traveled to Ontario to process samples in the laboratories of our collaborators (Dr H Hintelmann, Trent and Dr Muir, CCIW Burlington). To date, Shannon presented her project plans at the 19th NCP Results Workshop in Victoria BC (September 2011, winner of the poster award) and at the APECS DOM Limnology Webinar virtual poster presentation (online). Shannon published a description of her project in the WDCAG spring Newsletter and attended the PEEC 2012 in Bamfield, BC.

Benjamin Kissinger, University of Manitoba: Ben is the second MSc student using otolith microchemistry to determine the extent of movement of fishes amongst lakes/basins. Ben has started his MSc in the Department of Biological Sciences at University of Manitoba and has been conducting preliminary work towards method development. This work may be expanded to include physiological parameters in fishes. Ben has recently moved to Winnipeg to begin his degree and will be part of 2012 field work. Additional samples for his work are available from the past sampling trips.

Communication

While working out of ARI Inuvik, Shannon and Nikolaus gave a presentation to ARI staff and management, with a number of other researchers in the audience. On Nov 28 2011 we held a public meeting at Kitti Hall in Tuktoyaktuk, which was announced for about one week via community radio, our facebook group, and posters around town. The feedback was impressive as ~20 local residents attended and showed interest in what we had to present, while the attendees also made suggestions on the project, which we are currently including in our preparation for TK work (see pictures below). We were subsequently invited to the HTC board meeting to present the project to the board. We accepted the invitation, explained our project and discussed ways to make the project better. We met with ILA and TCC staff about the project on Nov 29. In Inuvik, we met with FJMC and DFO members to discuss next steps regarding the postponed September sampling. An overview poster was printed and displayed at ARI Inuvik; We have generated 'IPY frostbytes', short video clips related to the project, which are available via YouTube (see links below). We submitted our report to ARI regarding our NT license, which has been approved in March 2012. We submitted our progress report with our renewal application to NCP, supplied confirmations of community consultation in late March, and are awaiting results regarding the renewal. We submitted our harvest report related to our DFO license.

Related summaries and online sources: http://banting.fellowships-bourses.gc.ca/about-a_propos/gantner-eng.html; IPY Frostbyte McFadyen: www.youtube.com/watch?v=Gce-A7t3QZs; IPY Frostbyte Gantner: www.youtube.com/watch?v=RpdZY02KpAc; Facebook group (22 members): www.facebook.com/groups/105659876193939/; Website: http://csihusky.geog.uvic.ca (coming soon); E-mail: csihusky@uvic.ca (active).

Traditional Knowledge
Inuvialuit communities have a deep and thorough understanding of their local aquatic ecosystem and fish biology that has developed over many centuries. Extensive knowledge about subsistence fisheries and ice conditions resides with hunters and fishers in the communities of Tuktoyaktuk and Inuvik (Carmack et al. 2008). This TK based understanding of the local environment can provide expert information for the study of environmental conditions and northern species (Riedlinger and Berkes, 2001; Furgal et al., 2006). A mixed methods approach (Creswell 2009) is used in this project to bring together both quantitative (instrumental western science) and qualitative (TK as gathered and analysed through social science methods) information.

Semi-directed interviews on Inuvialuit Knowledge (IK) of fish and ecology of the Husky Lakes were completed with 14 local experts in the community of Tuktoyaktuk, NT in the last two weeks in February 2012. Topics covered in the interviews included fish species composition, fish health and fish habitat as well as knowledge about the aquatic ecosystems, food webs and lake ice conditions. The geographic focus of the interviews was on the Husky Lakes watershed and locations in the Beaufort Sea near the community. These topics were also covered for smaller lakes near the community of Tuktoyaktuk. Over 24 hours of interviews were audio recorded and are in the process of being transcribed verbatim. Once the transcriptions are complete, the qualitative analyses of the interviews will be conducted to identify common and emerging themes in the knowledge shared by the local experts. Participant mapping of local fishing locations and areas of significance to study the Husky Lakes food webs and ecosystem in relation to Lake Trout and other fish species was also completed in association with the interviews. These maps will be digitally scanned and entered into a GIS database for future use by the researchers and the communities. Once the interview qualitative analyses are complete, verification meetings will take place in Tuktoyaktuk to ensure that the knowledge has both been documented accurately and that the interpretations of the knowledge are correct from the perspectives of participants. These meetings are planned for early summer and late fall (2012) in Tuktoyaktuk. As this is a mixed methods project, IK will be used to inform sampling locations and parameters within the scientific sampling efforts.

Figure 1. Gordon Gordon Anaviak (l.) of Tuktoyaktuk marks fishing locations on a map during an Inuvialuit Knowledge interview with Jennie Knopp (r.). Photo credit J. Knopp.

Results

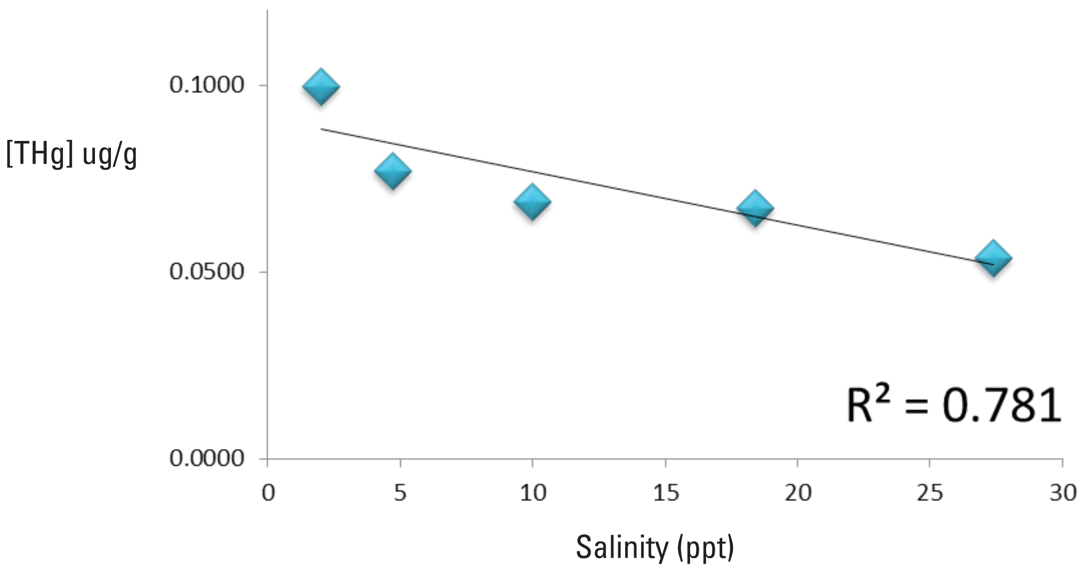
This project started in September 2011, field work was conducted in November 2011 and TK work in late February 2011. Analysis of all aspects is ongoing and results and discussion presented here are preliminary (as per March 2012).

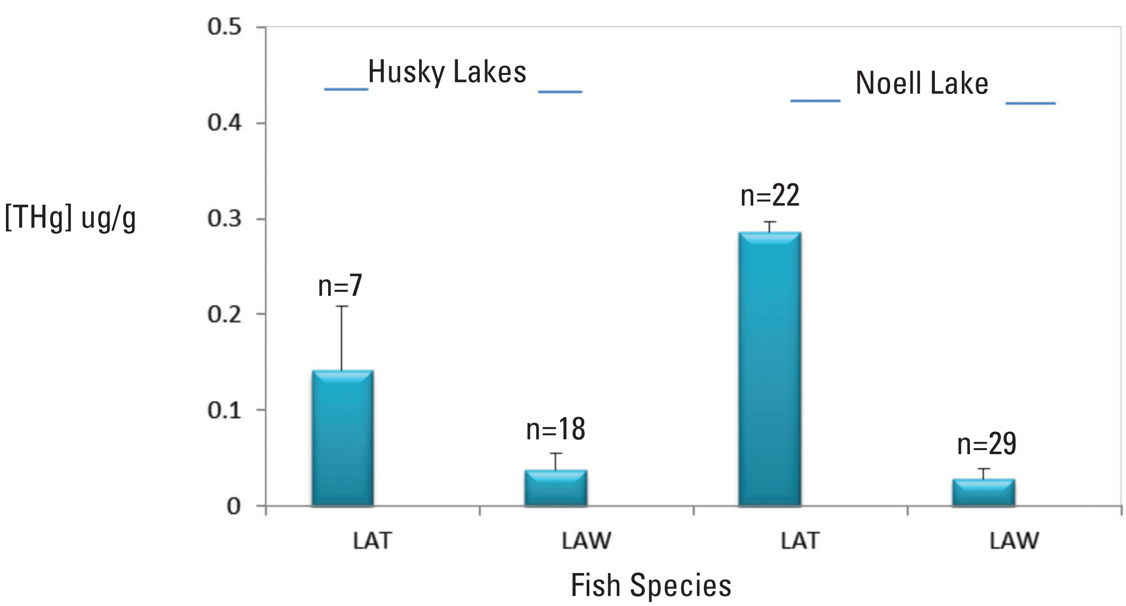
- A significant negative relationship (R2 = 0.78) was found between Total Hg concentrations in surface sediments ([THg], ug/g, uncorrected for organic matter content) and salinity (ppt) measured across a salinity gradient (<2 to 27.4 ppt) in Husky Lakes.

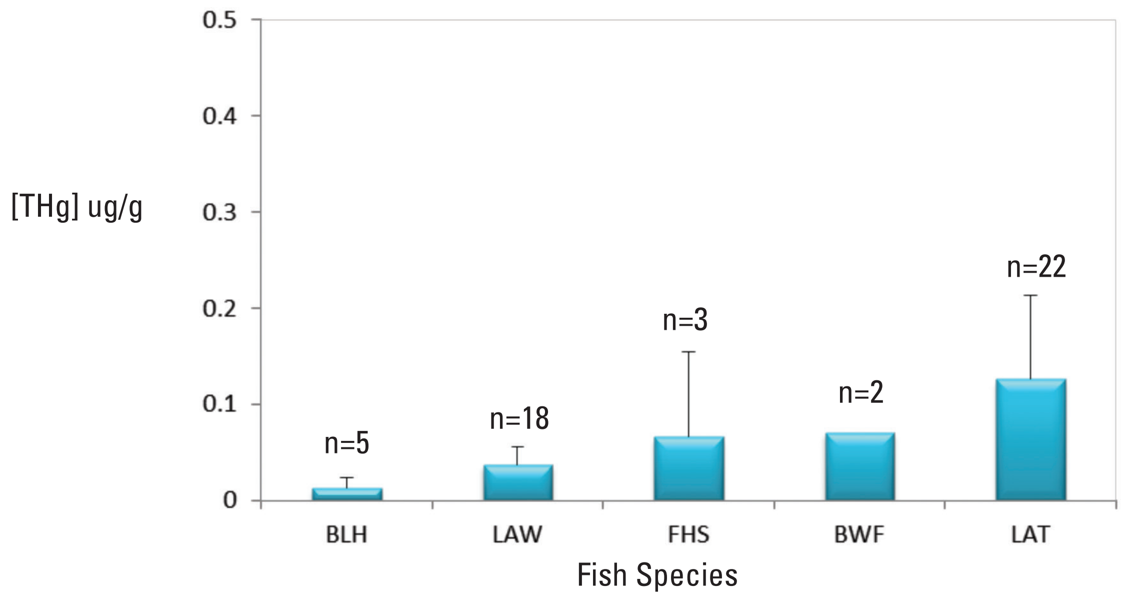
- Mercury in muscle ([THg], ug/g, geomean +/- SD) of Lake Trout (LAT) and Whitefish (LAW) was higher in samples from Noell Lake (2009) than in Husky Lakes (2011).

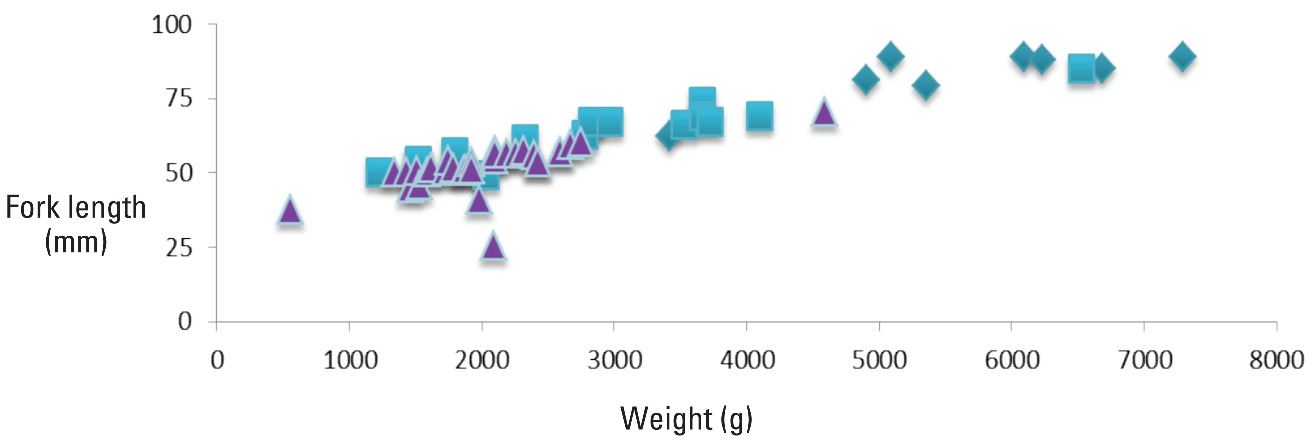
- [THg] (ug/g) in muscle from Broad Whitefish (n=2), Lake Whitefish (n=18), Blue Herring (n=5), Fourhorn Sculpin (n=3) and Lake Trout (n=22) from the Husky Lakes Basin 2/3 (2011) were low in all species measured, falling below consumption guidelines (0.5 ug/g).

- Weight (g) and fork length (mm) were measured for Lake Trout (LTR) caught from three sites: HLB-3 (n=8) and HLB-2/3 (n=15) in 2011, and Noell Lake (n-32) in 2009 and 2010 (Wrona et al. *submitted*). There is a positive relationship between fork length (mm) and weight (g), and fish from Noell Lake (freshwater, purple triangles) were found to be, on average, smaller than those from Husky Lakes (marine access, squares and diamonds).









- Mercury 'fingerprint': the extraction of selection samples for mercury stable isotope analysis was completed in January, while results of the analysis will be available soon.

Discussion and Conclusions

The inclusion of stakeholders from both communities' throughout the research process, via consultations, meetings, training, TK interviews proved highly useful in preparation for and during the field work of this project, making this first year of the study a step towards a community-based project. Analysis of the TK interviews is still on-going and/or preliminary findings are not yet verified, thus we limit our data presentation here to initial results of limnological aspects, abiotic and biotic compartments of the lakes and total mercury results.

An interesting preliminary result is the inverse relationship of total mercury in surface sediment and salinity shortly after freeze up (R^2=0.78). This relationship indicates that there might be less or less bioavailable, mercury in areas of greater salinity of the Husky Lakes. Mercury concentrations in sediments still need to be adjusted for organic matter and additional samples analysed to confirm this trend. Repeat salinity measurements will be conducted in the spring and during open water season to get a better picture of the seasonal variability of this gradient. The lower mercury concentrations in the larger Lake Trout from Husky Lakes (vs Noell Lake) indicate an effect of the saline condition, could be the result of movement, or difference in diet. Noell Lake Trout are thought to be landlocked and Noell Lake is a freshwater system. Previous comparisons of chars have shown that landlocked populations tend to have higher contaminant concentrations (Swanson et al. 2011). The extent of movement of Lake Trout in Husky Lakes is currently under investigation through Ben Kissinger's MSc project. Otolith microchemistry, paired with other lines of evidence (e.g., $\delta^{34}S$ in muscle) will be used to describe the habitat use of Lake Trout. It remains to be seen whether the trout in Husky Lakes are salt water trout, as they are often referred to by community members.

In 2012/2013, we will again join local fishermen during their May fishing at Husky Lakes to increase our spatial coverage and sample sizes. We are aiming to collect additional biota samples (benthic and pelagic invertebrates) during open water season (August) to aid our characterization of the lakes food webs. Statistical adjustments of fish mercury concentrations for co-variants will be conducted using ANCOVA, and resulting adjusted mercury concentrations compared among and within lakes. TK interview results will be verified with interviewees. Results of both TK, biological and contaminants work of this study will be reported to and discussed with the community in early 2013, in order to together determine parameters of interest for continued, community based monitoring.

Expected Project Completion Date

March 2014

Acknowledgments

We would like to thank the Northern Contaminants Program and the Cumulative Impacts Monitoring Program (both AANDC) for generous funding and the Aurora Research Institute in-kind support. PCSP and Aklak-Canadian Helicopters provided invaluable and safe logistical support. Cathy and Don Ross allowed us to stay at their home in Inuvik in November. Collections at Noell Lake in 2009 and 2010 were supported by DFO, EC, NSERC, Government of Canada IPY progarm and ArcticNet. Thanks to all staff at UVic, among much support, for timely review of Animal Use and Ethics protocols. Support for laboratory work was gratefully provided by Amy Sett (EC Burlington) and Brian Dimock (TrentU). We

NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	5 (field) + 14 (TK)	D. Ross (ARI), J. Tedjuk, C. Pokiak, C. Felix, R. Noksana; 14 local experts (TK interviews)
number of project–related meetings/workshops held in the North (April 1, 2011 – March 31, 2012)	3	HTC Board meeting x 2, Public meeting/workshop in Nov
number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	3	Shannon McFadyen Ben Kissinger Jennie Knopp
number of citable publications (e.g., in domestic/ international journals, conference presentations, book chapters, etc)	2011:1 2012:	NCP workshop, poster, Victoria

thank all interview participants in Tuk, Charles Pokiak, Chris Felix, John Tedjuk, and Rex Noksana for their help in the field. John Russel and staff at the TCC, staff at the Inuvialuit Land Administration and the Tuk HTC board members provided helpful advice during field work and TK work in Tuk.

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Įhdak'èt Aquatic Ecosystem Monitoring Project

Projet de surveillance des écosystèmes aquatiques Įhdak'èt

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Abstract

The project builds on community-driven and community-based fisheries and monitoring work carried out in 2010 and is the first of a multi-phase program to share and document Tłı̨chǫ knowledge and western scientific knowledge on the aquatic environment in Russell Lake. The project engaged local community members to collect samples and record a standard set of observations using both Tłı̨chǫ and western scientific knowledge. As a community-initiated and community-driven project, it involved community members in a meaningful manner in all aspects of conducting contaminants related research, including in the actual pursuit of monitoring and research objectives.

A monitoring camp was held on Russell Lake; a location that supports a strong aboriginal subsistence fishery. Water, sediment and fish were sampled by Elders, youth and fisheries scientists. Elders were asked to provide assessments of fish health and to describe the indicators they use to identify fish health. Scientists sampled fish tissues and demonstrated

Résumé

Le projet se fonde sur les activités de pêche et de surveillance axées sur les collectivités qui ont été réalisées en 2010. Il s'agit de la première phase d'un programme à plusieurs étapes visant à mettre en commun et à documenter les connaissances Tłı̨chǫ et les connaissances scientifiques occidentales sur l'environnement aquatique du lac Russell. La participation de membres des collectivités locales a été sollicitée dans le cadre du projet pour prélever des échantillons et consigner un ensemble standard d'observations au moyen des connaissances Tłı̨chǫ et scientifiques occidentales. Comme le projet est communautaire, il implique la participation significative de membres des collectivités à tous les aspects des travaux de recherche sur les contaminants, y compris l'atteinte des objectifs de surveillance et de recherche.

Un camp de surveillance a été mis sur pied au lac Russell, un lieu fortement utilisé par les Autochtones pour la pêche de subsistance. L'eau, les sédiments et les poissons ont été

to Elders and youth the methods for collecting fish tissues for analysis. A results workshop was held in Behchokǫ̀ to present the results of the fish tissue analysis, water and sediment quality sampling. Community members were informed and educated on the status of contaminants in the fish they may be eating and that these foods remain healthy choices perhaps within certain limits.

The fish tissue analysis showed that mercury levels are relatively low except in very large and very old individuals of walleye and northern pike. Pike and walleye are predatory fish and as such bioaccumulate mercury as they consume prey. Small to moderate sized pike and walleye were within Health Canada guidelines for Commercial Sale of Fish and do not pose a health risk. All samples of Lake Whitefish tissue had very low amounts of mercury.

Annual implementation of the program through the consistent use of the monitoring protocols developed this year will be key in achieving the main goals of long-term monitoring: detecting change over time and space.

échantillonnés par des aînés, des jeunes et des spécialistes des sciences halieutiques. On a demandé aux aînés de fournir des évaluations de la santé des poissons et de décrire les indicateurs qu'ils utilisent pour déterminer celle ci. Les scientifiques ont échantillonné les tissus des poissons et montré aux aînés et aux jeunes les méthodes employées pour la collecte de tissus à des fins d'analyse. Un atelier a été organisé à Behchokǫ̀ pour présenter les résultats de l'analyse des tissus des poissons ainsi que des échantillons d'eau et de sédiments. En outre, les membres des collectivités ont reçu de l'information sur l'état des contaminants dans les poissons qu'ils consomment, et on leur a expliqué que ces aliments demeuraient sains, mais dans certaines limites.

L'analyse des tissus des poissons a indiqué que les concentrations de mercure étaient relativement faibles, sauf dans le cas du doré jaune et du grand brochet, chez les individus très gros et très âgés. Ces poissons sont des prédateurs, et les proies qu'ils consomment entraînent chez eux une bioaccumulation du mercure. Les concentrations relevées chez les dorés jaunes et les grands brochets de taille moyenne étaient conformes aux lignes directrices de Santé Canada pour la vente commerciale de poisson, et ne posaient donc pas de risque pour la santé. Tous les échantillons de tissus de grand corégone contenaient de très faibles quantités de mercure.

La mise en œuvre annuelle du programme, par l'utilisation soutenue des protocoles de surveillance élaborés cette année, constituera un élément clé dans l'atteinte des objectifs de la surveillance à long terme, soit la détection des changements dans le temps et l'espace.

Keys Messages

- The fish tissue analysis showed that mercury levels are relatively low except in very large and very old individuals of walleye and northern pike.

- The water and sediment quality sampling results show that Russell Lake is typical of other lakes in the area; low levels of

Messages clés

- L'analyse des tissus des poissons a indiqué que les concentrations de mercure étaient relativement faibles, sauf dans le cas du doré jaune et du grand brochet, chez les individus très gros et très âgés.

- Les résultats de l'analyse des échantillons d'eau et de sédiments indiquent que le lac nutrients, dissolved metals and moderate suspended sediment.

- The traditional knowledge forms an invaluable baseline against which we can measure change. Behchokǫ̀ elders have observed many changes in water quality, temperature, flow and levels as well as changes in fish texture, size, shape and taste.

Russell est comparable aux autres lacs de la région : présence de faibles quantités de nutriments et de métaux dissous ainsi que de quantités modérées de sédiments en suspension.

- Les connaissances traditionnelles constituent de précieuses données de référence qui nous permettent de mesurer le changement. Les aînés de Behchokǫ̀ ont observé bon nombre de changements en matière de qualité de l'eau, de température, de débits et de niveau d'eau ainsi qu'en ce qui a trait à la texture, à la taille, à la forme et au goût des poissons.

Objectives

- Document and combine traditional knowledge of fish in the Behchokǫ̀ area with conventional fish sampling methods;
- Obtain baseline data on mercury levels and contaminants in fish consumed by local communities in the Tłı̨chǫ area of the NWT (Marian and Russell Lake).
- Evaluate mercury levels found in fish in terms of species and size/age relationships,
- Long-term objective is to establish a monitoring program to identify contaminant levels and changes in levels through time for fish in the Tłı̨chǫ region.

Introduction

There is a paucity of traditional knowledge and science on the aquatic ecosystems that supports subsistence fisheries in the Tłı̨chǫ region. There are many historic and proposed developments in the region and there is concern in the communities that contamination of downstream aquatic ecosystems may occur or has already occurred. Tłı̨chǫ elders and community members expressed interest in an up-to-date study documenting contaminant levels to determine whether stocks are healthy and safe to eat. 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.

Results from our 2010 monitoring project on fish health in Marian Lake showed that mercury levels, although currently not likely posing a health risk, should be monitored for trends through time. Lockhart[1] et al also reports elevated mercury in fish collected in Marian River and Slemon Lake in 1979 and 1983, respectively. Given these current and historic results, examination of mercury at additional locations in the Tłı̨chǫ region is warranted. While Water Resources, Aboriginal Affairs and Northern Development Canada's single water quality sampling station at Frank Channel does not detect mercury, additional water sampling locations throughout the Tłı̨chǫ region would broaden the geographic coverage for this parameter as recommended in the INAC State of Knowledge Report[2].

1 Lockhart, W., G.Stern. G. Gow, M. Hendzel, G. Boila, P. Roach, M. Evans, B. Billeck, J. DeLaronde, S. Fiesen, K. Kidd, S. Atkins, D. Muir, M. Stoddart, G. Stephens, S. Stephenson, S. Harbicht, N. Snowshoe, B. Grey, S. Thompson, N. DeGraff. 2005. A history of total mercury in edible muscle of fish from lakes in northern Canada. Science of the Total Environment www.sciencedirect.com vol. 351-352 pp. 427-463.

2 A Preliminary State of Knowledge of Valued Components for the NWT Cumulative Impact Monitoring Program (NWT CIMP) and Audit – FINAL DRAFT – Prepared by Indian and Northern Affairs Canada (INAC) for the NWT CIMP and Audit WorkingGroup. Updated November 2009. (original version February 2002, updated 2007)

Activities in 2011-2012

The project focused on the fisheries, water and sediment components of the aquatic environment. It developed Tłı̨chǫ measures of healthy fish as well as a scientific sampling protocol for the community collection of data on contaminants in key fish species to help better understand the state of the aquatic environment in the Tłı̨chǫ region.

Introductory Workshops

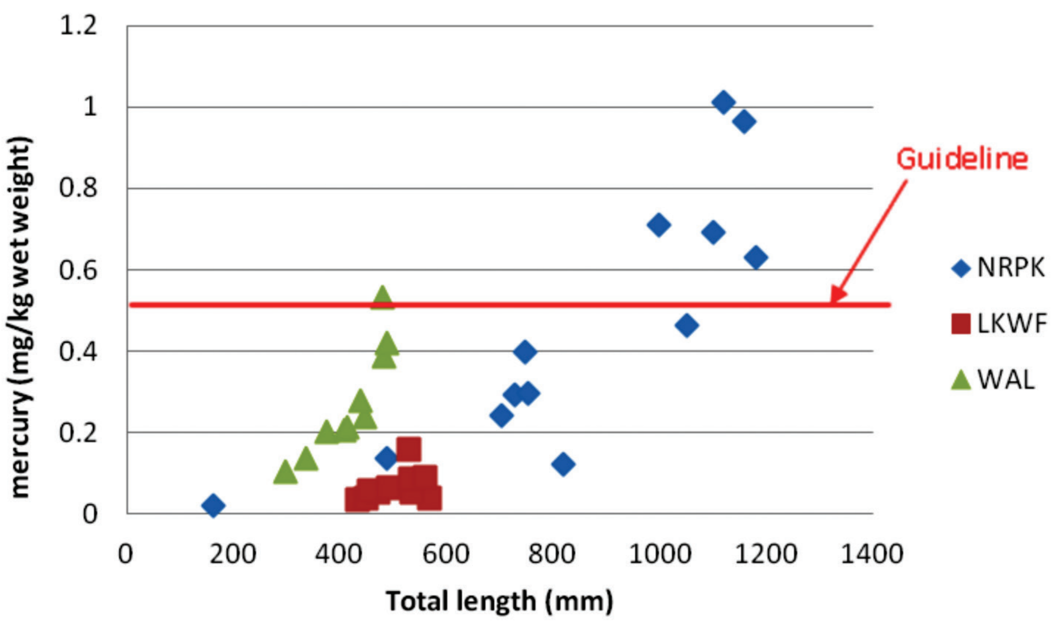
Workshops were held in spring and summer of 2012 to talk with the elders about the project, select an appropriate location and to plan for a monitoring camp. Russell Lake was selected due to concerns of contamination coming downstream from an old minesite in the watershed. Elders also discussed the concept of indicators and how they assess the health of the ecosystem.

Monitoring Camp

A four-day camp was held which provided a valuable experiential learning opportunity in Tłı̨chǫ ways of understanding the aquatic ecosystem, assessing the health of the ecosystem and catching, preparing and preserving fish. It was an opportunity for all participants to observe and learn about Tłı̨chǫ methods of resource management and working together to combine this knowledge with scientific fish-monitoring methods.

To determine current levels of contaminants in fishes regularly consumed by Behchokǫ̀ community members, fish tissue samples were collected from three fish regularly consumed (Lake Trout, Inconnu and Northern Pike). These samples were collected under the guidelines established by Environment Canada for sampling for metals on Great Slave Lake and the Golder technical protocol ‘Fish Health Assessment-Metals’. Mercury was elevated in the larger, older predatory fish (Figure 1).

Figure 1. Mercury levels in Lake Whitefish, Northern Pike and Walleye fish tissue sampled from Russell Lake. Ten samples of Whitefish tissue, 13 Northern Pike and 12 Walleye were analysed.



All fish captured were identified to species, measured (fork length to the nearest millimeter), and weighed (grams) (Figure 2). Additional data collected included gender, stage of maturity, and a general description of the contents of the stomach. Samples of ageing structures (otoliths and fin rays) were also collected.

Water quality indicators included standard physical and chemical parameters: temperature, pH, conductivity, clarity, turbidity, Total Suspended Solids, Total Dissolved Solids, alkalinity, dissolved Oxygen, major nutrients, ions and trace metals (Table 1). These parameters are comparable to INAC Water Resources datasets for Frank Channel of Great Slave Lake, the closest water quality monitoring

Figure 2. Species and number of fish captured on Russell Lake

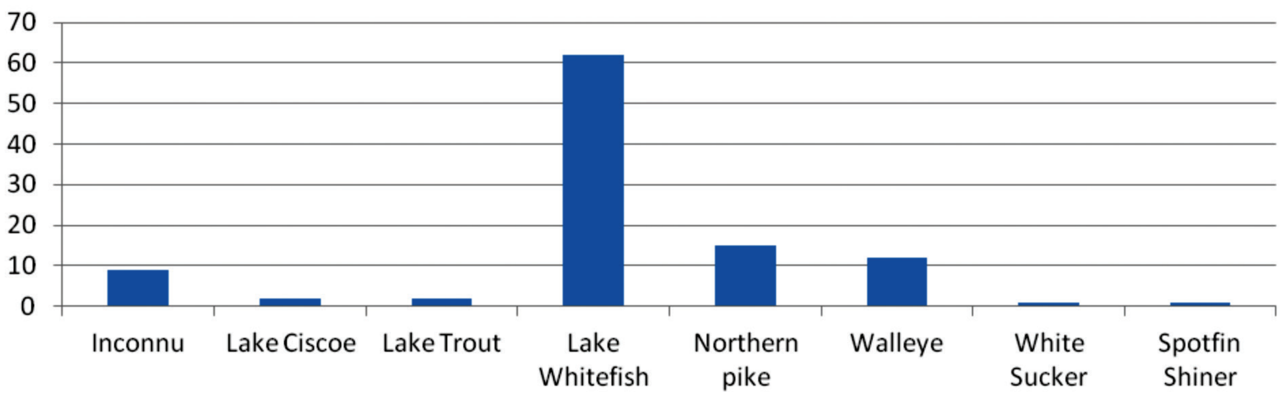
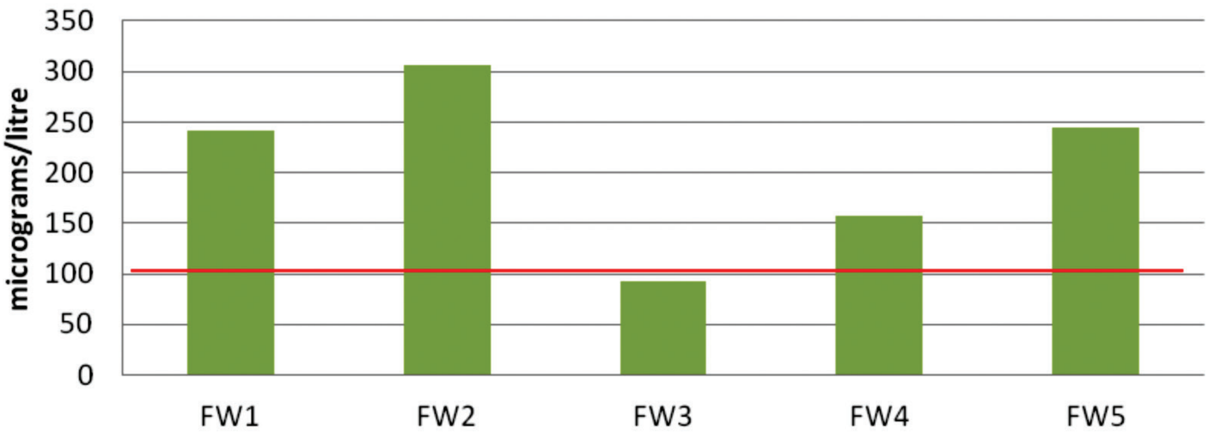


Table 1 – Selected Nutrient and Physical Parameters of Water Samples

	FC3	FC4	FC1	FC5	FC2
Total P (mg/L)	0.01	0.01	0.01	0.01	0.01
Dissolved P (mg/L)	<0.01	0.02	<0.01	<0.01	0.02
DOC (mg/L)	5.1	5	5	4.8	5
TOC (mg/L)	5	4.9	4.8	4.7	4.8
TSS (mg/L)	<3	<3	6	<3	<3
TDS (mg/L)	<10	<10	<10	<10	10
Hardness (mg/L)	16.3	16.5	16.9	16.6	17.6
Conductivity (µS/cm)	36.8	37.2	38	37.7	37.6
Alkalinity (mg/L)	12.7	12.7	13.7	12.9	13.3
Calcium (mg/L)	4.2	4.3	4.4	4.2	4.5
Magnesium (mg/L)	1.4	1.4	1.5	1.5	1.6
Sulphate (mg/L)	2	2	2	2	2
Chloride (mg/L)	0.8	0.8	0.8	0.8	0.9
Reactive Silica (mg/L)	0.471	0.455	0.406	0.67	0.434
pH	7.37	7.37	7.34	7.18	7.37
Turbidity (NTU)	2.42	3.11	5.79	5.74	6.89

Figure 3. Aluminum concentrations in water samples



station. Of note was that aluminum was elevated in four of the five samples (Figure 3)

Sediment sampling used methods outlined in the Metal Mining Guidance Document for Aquatic Effects Monitoring[3] and analysed for standard physical and chemical properties as well as trace metals. Lake sediments were sampled using an Ekman grab sampler which is suitable for collecting soft, fine grained sediment that is typically observed throughout the watershed.

Results Workshop
A workshop was held in early April 2012 to report the results back to all project participants.

Capacity Building
Tłı̨chǫ Government staff was a key driver in the implementation of the project, meeting on a regular basis with WRRB staff, planning logistics for elder workshops and the monitoring camp.

Elders and youth were exposed to scientific methods of sampling and monitoring the aquatic ecosystem including sediment and water quality sampling as well as fish tissue sampling for contaminant analysis. Scientists and youth were exposed to traditional knowledge approaches to understanding and interacting with the aquatic environment.

Youth were trained by a professional videographer in video filming and editing as a method of archiving traditional and scientific knowledge and to make a series of videos related to traditional ecological knowledge and the aquatic environment throughout the project.

Communications
Communication was achieved primarily through workshops and meetings with project participants. The project also developed monitoring protocols for use in future years as well as a Tłı̨chǫ fish guide for the more common fish species found in the Tłı̨chǫ region.

Traditional Knowledge Integration
Traditional knowledge research was conducted during two workshops and at the monitoring camp to document knowledge on aquatic ecosystems and how Tłı̨chǫ elders monitor the "health" of the ecosystem. This research resulted in a Tłı̨chǫ Aquatic Ecosystem Monitoring Protocol that will be used in future years of the program.

Under the guidance of Tłı̨chǫ Government traditional knowledge researchers, youth worked with Elders to learn about traditional ways of assessing water quality, sediment quality and fish health. These indicators include measures of fish fatness, taste, form, water clarity, levels, flows as well as proper behavior of people indicative of knowledge and respect.

[3] Environment Canada. 2011. Metal Mining environmental Effects Monitoring Technical Guidance Document

NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	37	
number of project–related meetings/workshops held in the North (April 1, 2011 – March 31, 2012)	4 workshops 6 meetings	Workshops included Tłı̨chǫ elders Meetings included Tłı̨chǫ Government staff
number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	4	Tłı̨chǫ high school students
number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	2011: 2012:	none

Expected Project Completion Date

Completed

Acknowledgments

This project has been guided by many elders from the community of Behchokǫ̀: Harry

Apples, Adele Camille, Eddie Camille, Jonas Football, Nick Football, Robert Mackenzie, Harry Mantla, Elizabeth Michel, Dora Migwi, Bernadette Naskin, Elizabeth Rabesca, Celine Tatzia and Francis Williah. We give many thanks for their dedication to the project and their patience in sharing advice over the past two years.

The Wek'èezhìi Renewable Resources Board and Tłı̨chǫ Government thank those organizations that have provided technical support on this project: Thorpe Consulting Ltd., Fisheries and Ocean Canada (DFO) and Golder Associates. We also thanks those agencies that generously provided financial support: DFO, Aboriginal Affairs and Northern Development (AANDC), Northern Contaminants Program (NCP), Cumulative Impact Monitoring Program (CIMP), Government of Northwest Territories and Tłı̨chǫ Government

Environmental Monitoring and Research

Tendances Environnementales Surveillance et de Recherche

Northern Contaminants Air Monitoring for Organic Pollutants and Data Interpretation

Surveillance des contaminants atmosphériques dans le Nord : mesure des concentrations de polluants organiques et interprétation des données

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Abstract

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

Résumé

L'atmosphère est le principal chemin emprunté par les contaminants organiques pour pénétrer dans les écosystèmes de l'Arctique. Le présent projet, qui fait partie d'un programme continu de surveillance ayant débuté en 1992, porte sur la mesure de ces contaminants dans l'atmosphère de l'Arctique. La mesure des quantités et des types de contaminants exige la collecte de volumes importants d'air par l'entremise de filtres. Les échantillons filtrés sont ensuite analysés en laboratoire. Les résultats de ce projet en cours servent à négocier et à évaluer l'efficacité des accords internationaux de lutte contre les contaminants, et à faire l'essai de modèles atmosphériques qui expliquent le déplacement des contaminants à partir de points d'origine situés au sud de l'Arctique. À ce stade du projet, des échantillons sont prélevés chaque semaine au site de référence d'Alert, au Nunavut, mais seulement un échantillon

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. A flowthrough air sampler has been deployed at the Yukon station of Little Fox Lake starting in August 2011 to monitor for trans-Pacific transport of organic pollutants.

hebdomadaire sur quatre sera analysé afin d'établir une tendance. Les échantillons restants seront extraits et conservés en vue d'études futures portant sur des épisodes importants de transport de polluants et sur les nouveaux produits chimiques prioritaires. À partir de décembre 2005, nous avons élargi le programme pour étudier dans l'atmosphère de l'Arctique canadien, à Alert, les nouveaux produits chimiques, tels que les pesticides d'usage courant, les produits ignifuges bromés et les composés perfluorés utilisés comme antitaches. À partir d'août 2011, un échantillonneur d'air à écoulement continu a été déployé à la station Little Fox Lake, au Yukon, afin de surveiller le transport transpacifique de polluants organiques.

Keys Messages

- The arctic warming and sea ice retreat due to climate change have induced the re-release of persistent organic pollutants (POPs) trapped in environmental sinks, e.g. water, ice, snow and soil.
- Three new brominated flame retardants, namely 1,2-bis(2,4,6-tribromophenoxy) ethane (BTBPE), 2-ethyl-1-hexyl-2,3,4,5-tetrabromobenzoate (EHTeBB) and bis(2-ethyl-1-hexyl)tetrabromophthalate (TBPH) were detected at relatively high concentrations at both Canadian High Arctic and Tibetan Plateau.
- Inter-laboratory comparison analysis showed inconsistent data comparability between the two laboratories that analyse air samples from this monitoring project before and after 2002. These inconsistencies can complicate abilities to discern long-term trends of pollutants in a given sampling site. It is advisable to maintain long-term measurements with minimal changes in sample analysis.

Messages clés

- Le réchauffement de l'Arctique et le retrait de la glace de mer dans l'Arctique à cause des changements climatiques ont entraîné le rejet de polluants organiques persistants (POP) qui étaient emprisonnés dans des puits environnementaux (p. ex. eau, glace, neige, sol).
- Trois nouveaux produits ignifuges bromés, soit 1,2-bis(2,4,6-tribromophénoxy) éthane (BTBPE), 2-éthyl-1-hexyl-2,3,4,5-tétrabromobenzoate (EHTeBB) et bis(2-éthyl-1-hexyl)tétrabromophthalate (TBPH), ont été décelés en concentrations relativement élevées dans l'Extrême Arctique canadien et sur le plateau tibétain.
- Des analyses comparatives interlaboratoires indiquent des incohérences dans la comparabilité des données entre les deux laboratoires qui analysent les échantillons d'air dans le cadre du présent projet de surveillance avant et après 2002. Ces incohérences peuvent compliquer l'établissement des tendances à long terme des polluants pour un site d'échantillonnage donné. Il est recommandé de maintenir l'intégrité des mesures à long terme en réduisant le plus possible les changements liés à l'analyse des échantillons.

Objectives

- To determine whether atmospheric concentrations and deposition of priority pollutants in the Arctic are changing in response to various national and international initiatives by:

    a. continuing to measure the occurrence of selected organochlorines and polycyclic aromatic hydrocarbons in the Arctic atmosphere at Alert (measurements started in 1992).

    b. analyzing and reporting data from Alert to provide insight into pollutant trends and sources.

- Ensuring the effective usage of information at the international negotiating table in order to achieve the appropriate restrictions on release of pollutants of concern for the Arctic environment by:

    a. having contributed to the assessment arising from the second phase of the Northern Contaminants Program and specifically, the revised Assessments on POP's and Heavy Metals as part of the Arctic Monitoring and Assessment Program [AMAP] Work Plan.

    b. contributing information for the evaluation of the overall effectiveness of provisions outlined in the Stockholm Convention on POPs and the LRTAP Convention Protocols on POPs.

    c. advising Canadian negotiators in preparing reasonable and practical strategies of control (consistent with the way contaminants move through the north).

- To enable validation of models of toxic chemicals in the Arctic environment with atmospheric observations.

Introduction

Atmospheric measurements of polybrominated diphenyl ethers (PBDEs) have been conducted at Alert, Nunavut, since 2002. In this report, time trends of PBDEs measured in air at Alert are reported up to 2009.

Trend analysis of atmospheric POPs from Alert and Zeppelin (Norwegian-operated station) has shown evidence of revolatilization of POPs from environment sinks due to artic warming and sea ice retreat. An article has been published in the journal *Nature Climate Change* and results are summarized here.

The atmosphere is considered the major and fastest route of transport for many priority pollutants to the remote Arctic. New and emerging chemicals that are detected in Arctic air may indicate long-range transport potential which is one of the criteria for classifying chemicals as persistent organic pollutants (POPs) that may be considered for control. Current-use pesticides (CUPs) and non-PBDE flame retardants (FRs) were included in Arctic air measurements at Alert since mid-2006 and 2007, respectively. Air concentration measurement results up to 2009 for these compounds are reported here.

Chemical analysis of the super-HiVol air samples from Alert was transferred from the Freshwater Institute (FWI) to the National Laboratory for Environmental Testing (NLET) in 2002. An interlaboratory comparison has been conducted and results are reported here.

Activities in 2011-2012

Measurements and Analysis
Regular ground level atmospheric measurements of OCs (PCB congeners, chlordane, DDT, chlorobenzenes and selected herbicides) and PAHs (20 priority ones) are being made at Alert, Nunavut, using a custom-made super-high-volume air sampler (super-HiVol). Measurements involve routine weekly sample collection, extraction, analysis as well as archiving. Samples are currently being analyzed in NLET (Burlington). From 2002-2006, the

particle and vapour phase fractions of each weekly sample were combined for analysis to reduce cost. Relative concentrations on the particle and gas phases can be estimated from historical results. Since PBDEs have only been added to the chemical list after 2002, no information with regard to their distribution between the particle and gas phases in Arctic air were available. To explore this distribution, additional funding has been obtained from NCP to perform gas- and particle-phase separate analysis on all 2006/07 samples. For 2007/08 and 2008/09 samples, we have separately analyzed the gas and particle phases every other week. Starting from 2009/10, only one out of four weekly samples were analyzed to maintain the long-term temporal trend. The samples that are not analyzed were routinely extracted and the extracts were archived, giving us the opportunity to analyze the skipped weeks if necessary. Analysis of 2010/11 samples from Alert is currently ongoing.

PBDE air measurements continued at Alert. Most congeners showed steady trends with no significant increasing or decreasing trends. The penta- and octa-BDE technical mixtures have been included in the Stockholm Convention on POPs for global control as of May 2009. DecaBDE (BDE 209) is currently not under global control by the Stockholm Convention on POPs. BDE 209 increased continuously at Alert until 2005 with a doubling time of 3.5 y. Unfortunately, vapour-phase blank concentrations of BDE 209 were found to be high in 2006; rendering the continuation of the time trend impossible at this time. Fortunately, the blank issue did not affect 2007- 2009 samples. Since BDE 209 is mostly associated with the particle phase at low temperatures and its particle phase blank concentrations were low at Alert, the temporal trend of BDE 209 can be rebuilt using particle phase concentrations only. Since the gas and particle phases were combined for analysis between 2002 and 2005, the particle extracts need to be reanalyzed before the time trend can be reported in the future.

We have also started to screen for new non-PBDE FRs, including 13 other brominated FRs: BTBPE, EHTeBB, TBPH, pentabromotolune (PBT), hexabromobenzene (HBB), pentabromobenzene (PBB), allyl 2,4,6-tribromophenyl ether (ATE), 2-bromoallyl-2,4,6-tribromophenyl ether (BATE), tetrabromo-o-chlorotoluene (TBCT), 2,3-dibromopropyl-2,4,6-tribromophenyl ether (DPTE), 2,2',4,5,5'-pentabromobiphenyl (BB-101), pentabromobenzyl acrylate (PBBA), octabromotrimethylphenylindane (OBIND)), and two highly chlorinated FRs (syn-dechlorane plus (syn-DP) and anti-dechlorane plus (anti-DP)). The results were compared with those measured at another remote location on the Tibetan Plateau in an article published in the journal of Environmental Pollution.

A separate high volume air sampler (PS1 sampler), sampling with 1 glass fiber filter followed by a PUF-XAD sandwich, has been installed at Alert in November 2005 which is operating in parallel with the routine air monitoring sampler. Weekly integrated air samples have been collected to analyze for new and emerging chemicals, including perfluorinated compounds (PFCs) and current-use pesticides (CUPs). Sampling generally occurred once per month from October to February and once every other week from March to September. Since this sampler could only collect approximately one third of the air volume normally collected with the routine super Hi-Vol, sample extracts have not been archived. After extraction, half of the extract for each sample was sent to Drs. Derek Muir and Camilla Teixeira's laboratory at the National Water Research Institute (NWRI, EC) in Burlington for analysis of CUPs and the other half to Drs. Mahiba Shoeib and Tom Harner's laboratory at Environment Canada (Downsview) for analysis of PFCs.

As funding becomes available in mid-2011, a FTS was installed at Little Fox Lake in August 2011 and started monthly-integrated sampling for the determination of OCs, FRs and selected CUPs. Sampling at this location allows for the continual investigation of trans-Pacific transport of contaminants to the western Canadian Arctic.

Related Work under IPY – the Intercontinental Atmospheric Transport of Anthropogenic Pollutants to the Arctic (INCATPA) project

1. The Little Fox Lake station in Yukon has been restarted in August 2007 and super-HiVol sampling ended October 2009. Flowthrough air sampling started August 2011 under NCP.

2. Chemical analysis of the super-HiVol air samples collected at Little Fox Lake has been completed. Two papers had been presented at the IPY 2012 Conference in Montreal:

    a) Hung, H., Steffen, A., Su, Y., Li, Y.-F., Ma, J., Dastoor, A., Cole, A., Durnford, D., Sverko, E., Sofowote, U., Westgate, J., McCarry, B., Wania, F., Xiao, H., Roach, P., Konoplev, A., Feng, X., Qi, H., Ren, N., Zhou, L., Viet, P. H., Harner, T., Fellin, P. Studying Atmospheric Input of Organic Pollutants and Mercury to the Arctic: Overview of the IPY Project of Intercontinental Atmospheric Transport of Anthropogenic Pollutants to the Arctic (INCATPA)

    b) Westgate, J., Hung, H., Sofowote, U. M., Su, Y., Sverko, E., D'Sa, I., Roach, P., Fellin, P., Wania, F. Short Scale Variations and Potential Sources of Brominated Flame Retardants in Air at a Remote Site in the Yukon Territory, Canada

3. Project P.I. Hayley Hung was the Lead Convenor of Session 1.3.4 Contaminants in Polar Regions at the IPY 2012 Conference in Montreal.

Data Analysis

A paper titled "Revolatilization of persistent organic pollutants in the Arctic induced by climate change" was published in the journal Nature Climate Change (Ma et al. 2011, Nature Climate Change 1: 255-260, DOI:10.1038/NCLIMATE1167). The paper uses air monitoring data of POPs from Alert and the Norwegian-operated AMAP station of Zeppelin to reveal for the first time evidence that arctic warming and sea ice retreat due to climate change have induced the re-release of POPs trapped in environmental sinks, e.g. water, ice, snow and soil. This paper highlights the importance of assessing climate change impacts on POPs measured in the environment; and how these impacts may interfere with evaluating the effectiveness of domestic and international control initiatives for these chemicals, such as the UNEP Stockholm Convention on POPs.

Chemical analysis of the super-HiVol air samples from Alert was transferred from the Freshwater Institute (FWI) to NLET in 2002. A paper documenting three rounds of intensive interlaboratory comparisons between FWI and NLET conducted in 2004, 2005 and 2008 after the laboratory change was published (Su, Y., Hung, H., Stern, G., Sverko, E., Lao, R., Barresi, E., Rosenberg, B., Fellin, P., Li, H., Xiao, H. (2011) Bias from two analytical laboratories involved in a long-term air monitoring program measuring organic pollutants in the Arctic: a quality assurance/quality control assessment. *J. Environ. Monitor.* 13: 3111-3118). Analysis was compared for OCs, PCBs and PAHs in standards, blind samples of mixed standards and extracts of real air samples. It was shown that the analytical differences for standards (<30%) and samples (<70%) were generally less than or comparable to those reported in the IPY INCATPA inter-laboratory study with 21 participating laboratories. Variation in accuracy over time was found for some OCs and PCBs on a random and non-systematic manner. It was concluded that inter-laboratory differences can complicate abilities to discern long-term trends of pollutants and it is advisable to maintain the scientific integrity of long-term atmospheric POPs measurements, with minimal changes in sample analysis.

The atmospheric time trend of β-HCH measured at Alert was used in a paper titled "Comparative assessment of the global fate of α- and β-hexachlorocyclohexane before and after phase-out" published in *Environmental Science and Technology* by Henry Woehrnschimmel, a

Ph.D. student at the Swiss Federal Institute of Technology Zurich under the supervision of Dr. Matthew MacLeod (Stockholm University). Dr. Hung is a co-author of this paper. Using a global fate and transport model (BETR Global multimedia contaminant fate model) coupled with emission inventories and environmental measurements in air and water, it was shown that β-HCH is declining more slowly than α-HCH in the atmosphere due to its higher persistence and it will eventually become the predominant isomer of HCH in the environment.

For legacy chemicals, data analysis has been completed up to the end of 2009. In terms of CUPs and PFCs, samples were analyzed up to the end of 2010. It is intended that the time trends of CUPs and PFCs measured at Alert (2006-2010) be published in winter 2012, representing the first record of atmospheric time trends of such chemicals in Arctic air.

The abovementioned results plus additional information on new chemicals measured at Alert (PBDEs, new flame retardants, CUPs and PFCs) and Little Fox Lake (PBDEs and new FRs) will also be included in the upcoming Canadian Arctic Contaminants Assessment Report III (CACAR III) to be published later in 2012.

Dr. Hung and Dr. Yushan Su (previously EC) collaborate with NILU and the Ontario Ministry of the Environment team that is coordinating the NCP Phase III interlaboratory comparison to operate an Interlaboratory study for EMEP/ AMAP/ CAMP (Comprehensive Atmospheric Monitoring Programme)/HELCOM (Helsinki Commission)/NCP specifically designed for atmospheric samples. A draft report is being compiled in collaboration with Drs. Martin Schlabach and Wenche Aas (NILU).

Outreach Accomplishments

Outreach and communication under this project is conducted in conjunction with that of the project "Air Measurement of Mercury at Alert and Little Fox Lake" (P.I. Alexandra [Sandy] Steffen) and the IPY INCATPA project.

- Hayley Hung and Sandy Steffen conducted an open lunchtime seminar on December 7, 2011, at the Yukon College, Whitehorse, to students and lecturers of the College and the general public. The seminar was given upon the invitation of the Yukon Research Centre (YRC) at the College which partners with Environment Canada in the operation of the Little Fox Lake station where monitoring of atmospheric mercury and POPs are conducted under NCP and IPY. Hayley and Sandy provided an overview of NCP's research on the monitoring, transport and transformation of atmospheric mercury and POPs in the North and showcased results obtained from the Little Fox Lake station. The lecture was covered by CBC North Television, Yukon community radio and the Yukon News.

- Sandy and Hayley met with the Director and staff of the Cold Climate Innovation and Technology Innovation Programs of the Yukon College to discuss potential partnership in developing a passive mercury air sampler suitable for use under remote Arctic environment for future community-based and ecosystem studies, as well as the use of the Little Fox Lake station as a combined monitoring, research and educational station for undergraduate and high school students.

- 100 English, 50 Inuktitut and 15 French Alert brochures have been sent to the NAC upon request from Sabrina Sturman and Natalie Plato.

- The article published in *Nature Climate Change* has garnered strong media interest internationally. Hayley Hung has conducted interviews with the following reporters/ writers which highlighted atmospheric contaminant studies under NCP and AMAP:

    – Lauren Morello of ClimateWire for New York Times
    – Damian Carrington, The Guardian, U.K.
    – Katherine Bagley, SolveClimate News

– Kristy Kirkup, Parliamentary Bureau
Margaret Munro, Postmedia News (interview)
– Ita Kendall, Radio Canada International
– Andrew Purcell, New Scientist Magazine
– Tyler Irving, Canadian Chemical News
– Michelle McCaw, CBC Radio Regina
Lesley Evans Ogden, Natural History Magazine
– Diana Vargas, CKLB Radio, Yellowknife

The reports were also translated to different languages for broadcasting:

In Chinese: http://article.yeeyan.org/view/239427/208605

In Portuguese: http://ecosfera.publico.clix.pt/noticia.aspx?id=1504574

In Spanish: http://www.vistaalmar.es/15/medio-ambiente/cambio-climatico/1706-deshielo-artico-esta-liberando-peligrosas-toxinas.html

In Italian: http://www.zeroemission.tv/Ambiente/Emissioni%3A-DDT-e-altri-inquinanti-rilasciati-anche-dai-ghiacci-artici/news/13481.phtml

Capacity Building: As in previous years, the NCP atmospheric organic pollutants and mercury monitoring projects have joined forces for communication and capacity building activities because they are closely related in terms of goals, facilities and technical support.

We have set our main focus on the communication aspect of our program. Since Alert is isolated, not near any community and restricted by the military we have been challenged, in the past, to meet our capacity building and training expectations. To address these challenges we continue to work with members of the NCP management committee, the NAC and ITK to develop ideas and strategies for training and capacity building within the Alert projects. We feel that we have made considerable progress over the years in our abilities to communicate our work and have begun to disseminate this information and, in this manner build capacity, in some northern locations including Whitehorse, Skagway, Yellowknife, Anchorage and Barrow, Alaska. We welcome any recommendations as to where our communication abilities may fit within capacity building and training initiatives led by the NAC, ITK and ICC programs.

We are currently working with the Yukon College to make the Little Fox Lake station into a combined monitoring, research and educational station for undergraduate and high school students. Project P.I.s Hayley Hung and Sandy Steffen are planning to conduct a lecture at the college for students of the B.Sc. and Renewable Resource programs (which use NCP-based curriculum) followed by a field trip to Little Fox Lake in September 2012.

Data collected from Little Fox Lake (and once interpreted) will be distributed to the CYFN and the Ta'an Kwach'an First Nation, in whose traditional territory the sampler site is located. The data generated can be used by CYFN in local, national and international issues. The Ta'an Kwach'an can use the information to keep their community informed of local effects from airborne contaminants. The applications would include their work with COP meetings and new initiatives related to POPs, mercury and climate change.

Communication: We have been continuously working on improving our communication skills to better convey research results to non-scientists. In the past, we have attended a valuable workshop on communicating complex science, giving talks at Environment Canada for non-researchers, presented results to a high school and elementary school students in the Toronto area and in Whitehorse, have been interviewed by the local and northern media and even had a spot on a children's show on the Aboriginal Television Network. We have taken media training and tried to implement these skills at the NCP annual meeting. Please also see the Outreach Accomplishment section above.

Traditional Knowledge Integration:
At this time, TK is only indirectly related to this project. As mentioned in previous proposals, when on board the Amundsen Icebreaker,

Figure 1. Seasonal variations and long-term trends of selected PBDEs total air concentrations at Alert. Black crosses indicate measured values; pink lines are long-term time trends and blue lines are seasonal cycles. For BDE 209, red crosses indicate particle phase concentrations only.

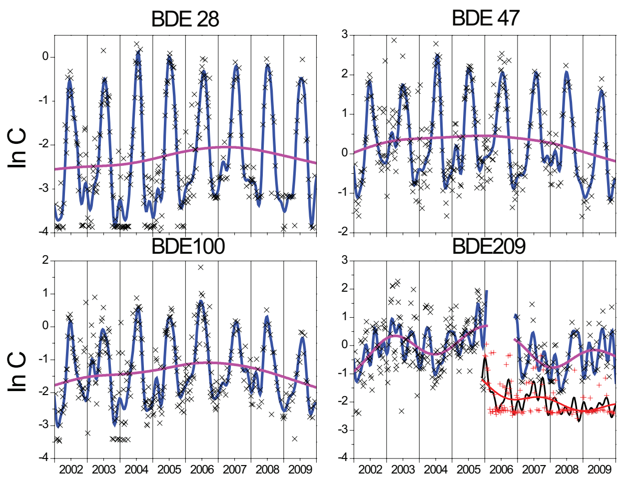


Figure 2. Seasonality of dacthal (A), tefluthrin (B), and trifluralin (C) and their temperature dependency at Alert. Black circles indicate air concentrations; blue solid lines represent temperatures; and black solid lines are significant linear regressions. Green lines indicate the average field blank levels.

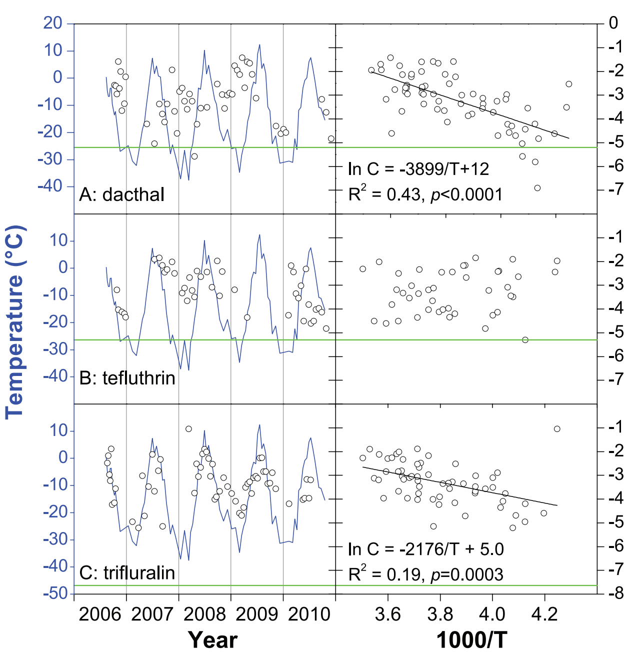
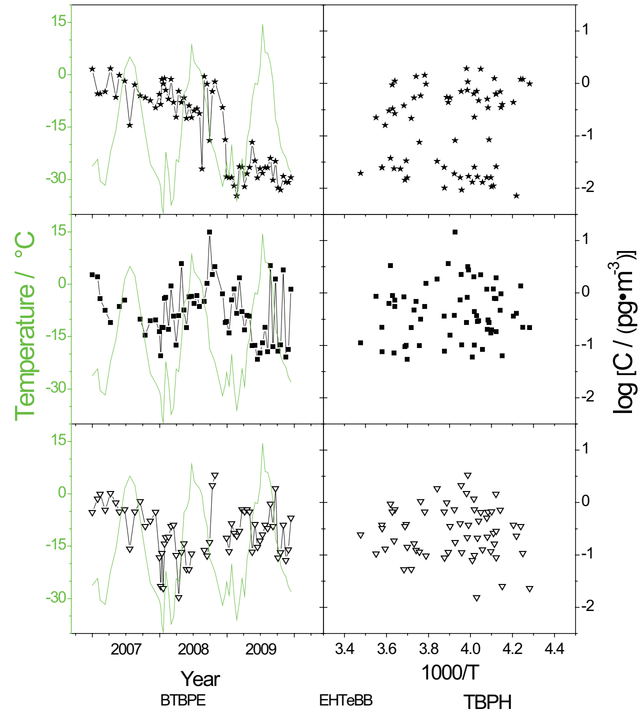


Figure 3. Seasonality of BTBPE, EHTeBB and TBPH and their temperature dependency at Alert. No obvious seasonality or temperature dependency was founded. Black markers indicate concentrations; green line represents temperature.



Hayley Hung participated in a Traditional Knowledge Workshop. This meeting provided insight on pollutant movement between air and open seawater.

We welcome ideas where TK could become applicable to the baseline monitoring at Alert and Little Fox Lake. The P.I.s would also appreciate any opportunity to meet with elders to discuss the application of TK to these programs.

Results

Long-term time trends measured at Alert for PBDEs are updated (Figure 1). Trends and seasonal cycles are derived using the digital filtration method (Hung et al., 2010).

Samples were analyzed for 22 CUPs since 2006 and 13 FRs were added into the screening chemical list from 2007. Seasonal cycles and temperature dependence of 3 CUPs, namely dacthal, tefluthrin and trifluralin, are shown in Figure 2; and similar plots for the three FRs, namely BTBPE, EHTeBB and TBPH are shown in Figure 3.

Through analyzing the bias from the two analytical laboratories involved in the NCP program, good measurement accuracy was observed when standards were analyzed; and the measurement accuracy varied over time for some OCPs and PCBs in standards on a random and non-systematic manner. Figure 4 shows the linear regressions between results from the two laboratories for different rounds of comparison.

A trend and modeling analysis of atmospheric POPs at the Norwegian-operated Zeppelin Mountain station and Alert implies

Figure 4. Correlations between analytical results of NLET and FWI for standard compared in 2005 (black square), standard compared in 2008 (red circles), air extract from Alert 2004 (blue triangles), air extract from Alert and blind sample compared in 2005 (purple diamonds), and blind sample compared in 2008 (green circles). Panel A: a-HCH; Panel B: PCB-52; and Panel C: fluoranthene.

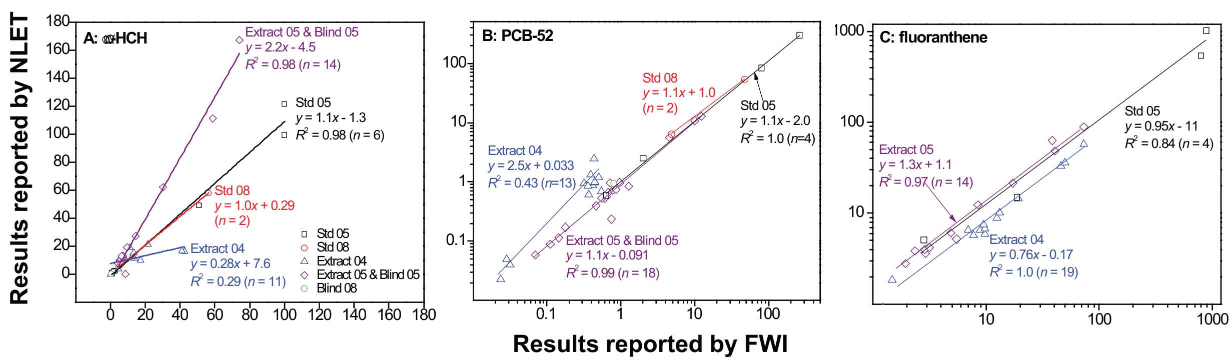
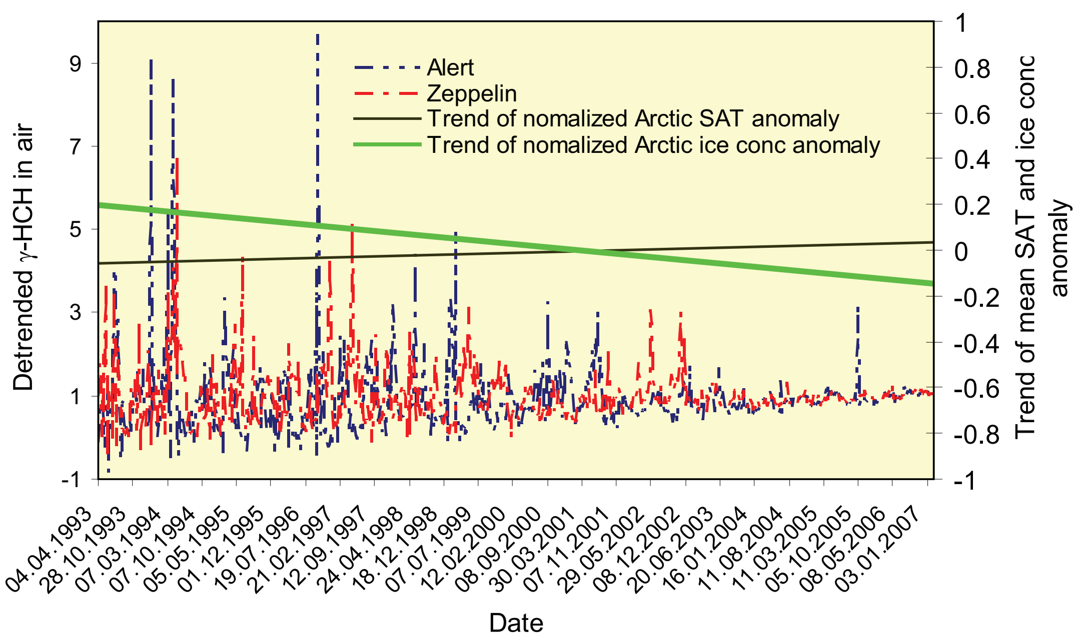


Figure 5. Detrended (residual) and normalized (by the standard deviation) time series of weekly sampled air concentration of g-HCH at Alert (dashed blue line) and Zeppelin Mountain (dashed red line) from 1993 through 2007. The linear trend of the normalized mean surface air temperature (SAT) anomaly (solid brown line) and the normalized mean ice concentration (solid green line) over the Arctic are also presented.



revolatilization of POPs previously trapped in environment sinks due to a warming Arctic and increased sea ice retreat. Figure 5 shows the detrended and normalized anomaly of weekly sampled air concentrations of γ-HCH from 1993 to 2007 at Zeppelin Mountain (Svalbard) and Alert. Also shown are the mean air temperature and sea ice concentration anomalies. It can be seen that after 2000 the detrended time series of γ-HCH show an increasing tendency corresponding to increasing temperature and decreasing sea ice concentrations.

Discussion and Conclusions

Atmospheric concentrations of BFRs at Alert
Atmospheric PBDE levels have been monitored at Alert started from 2002; and since 2007, a series of "new" BFRs were also added into the list of screened chemical. Figure 1 gives the atmospheric concentrations, seasonal variations and long-term trends for selected PBDEs up to the end of 2009. For these dominant PBDE congeners, obvious seasonality and temperature dependence were observed. For most of the PBDE congeners, their long-term trends are relatively steady, i.e., no significant increasing or decreasing trends were observed. The overall estimated halflife ($t_{1/2}$) or doubling time (t_2), which is the time required to decline to half or increase to double of the original concentration, are generally longer than 15 years.

Xiao et al. (2012) reported that three new BFRs were detected at Alert at relatively high concentrations, similar to those of the PBDEs. Measurement results from 2009 further confirm this observation. Unlike PBDEs, no obvious seasonality nor temperature dependence were observed for these three chemicals. BTBPE shows significantly lower concentrations in 2009 than previous years. Continuous monitoring of this compound in Arctic air is required to determine whether this trend persists.

CUPs atmospheric concentrations at Alert
CUPs analysis results generally show very low atmospheric concentrations at Alert. For the most dominant CUPs, no decreasing trends were observed during 2005-2009. Some CUPs demonstrate a significant temperature dependence, e.g. dacthal and trifluralin (Figure 2).

Quantifying the bias from inter-laboratory comparison between FWI and NLET
Initiated in 1992, air monitoring of organic pollutants in the Canadian Arctic provided spatial and temporal trends in support of Canada's participation in the Stockholm Convention of Persistent Organic Pollutants. The specific analytical laboratory charged with this task was changed in 2002 from FWI to NLET while field sampling protocols remained unchanged. Three rounds of intensive comparison studies were conducted in 2004, 2005, and 2008 to assess data comparability between the two laboratories. Analysis was compared for OCPs, PCBs and PAHs in standards, blind samples of mixed standards and extracts of real air samples. Good measurement accuracy was achieved for both laboratories when standards were analyzed. Variation of measurement accuracy over time was found for some OCPs and PCBs in standards on a random and non-systematic manner. Relatively low accuracy in analyzing blind samples was likely related to the process of sample purification. Regression analysis showed inconsistent data comparability between the two laboratories during the initial stages of the study. These inter-laboratory differences can complicate abilities to discern long-term trends of pollutants in a given sampling site. It is advisable to maintain long-term measurements with minimal changes in sample analysis.

Evidence of revolatilization of POPs in the Arctic induced by climate change
The concentrations of many POPs have decreased in Arctic air over the past few decades owing to restrictions on their production and use. As the climate warms, however, POPs deposited in sinks such as water and ice are expected to revolatilize into the atmosphere, and there is evidence that this process may have already begun for volatile compounds. Figure 5 shows the weekly time series of detrended (removal of an underlying upward or downward trend to present a normalized baseline view) γ-HCH from 1993 – 2007 at Zeppelin Mountain,

Svalbard and Alert. The linear trends of weekly moving averaged mean surface air temperature (SAT) and sea ice concentration anomalies, normalized by their respective standard deviation, averaged over the Arctic, are also plotted in the figure. It can be seen that detrended γ-HCH atmospheric concentrations at both monitoring sites underwent an increasing trend, corresponding nicely to an increasing trend of Arctic mean air temperature and a decreasing trend of sea ice concentration, especially since the late 1990s. This suggests the likelihood of an influence of Arctic warming and ice melt on the atmospheric cycling of γ-HCH. Detrended time series of other POPs [including hexachlorocyclohexanes (HCHs), dichlorodiphenyltrichloroethanes (DDTs) and chlordanes] in air measured at Zeppelin Mountain show similar increasing trends but such trends were not significant in most atmospheric POPs measured at Alert, except for cis-chlordane. This was likely partly due to the discrepancies caused by changing laboratories for chemical analysis of POPs samples in 2002.

NCP Perfomance Indicator

Performance Indicator	Number	Detail / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	3	Pat Roach (AANDC, Yukon) coordinate Little Fox Lake station deployment; Cindy Dickson and Bob van Dijken (CYFN) assisted with outreach in the Yukon.
number of project-related meetings/workshops held in the North (April 1, 2011 – March 31, 2012)	1	December 7, 2011, Yukon College lunchtime seminar (see Outreach Accomplishments above)
number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	1	John Westgate, University of Toronto, analyses IPY data from Little Fox Lake
number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	2011: 6 2012: 3	4 journal publications + 2 conference presentations 1 journal publication + 2 conference presentations

Expected Project Completion Date

On-going

Acknowledgments

We would like to acknowledge the Northern Contaminants Program (NCP) for funding the atmospheric measurements at Alert and the FTS deployment at Little Fox Lake. We would also like to thank Environment Canada's Chemical Management Plan for co-funding the new chemical measurements at Alert with NCP, as well as the Government of Canada Program for IPY for supporting IPY INCATPA. Also, thanks to NCP and NSERC for supporting the development of the FTS. We would like to thank Len Barrie and Derek Muir for initiating the air monitoring program of organic pollutants under NCP and their continuous support.

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Mercury Measurements at Alert and Little Fox Lake

Mesure du mercure à Alert et à Little Fox Lake

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Abstract

Mercury (Hg) is a global priority pollutant and continues to be of concern in Arctic regions. The longest Arctic record of atmospheric mercury concentrations have been collected in the Canadian high Arctic at Alert, Nunavut. This time series shows distinct repeatable seasonal and annual patterns in the gaseous elemental mercury (GEM). Trend analysis reveals there to be less of a decreasing trend in the high Arctic than at more southerly locations. Trend analysis on the atmospheric mercury species including Reactive Gaseous Mercury (RGM) and Particle Associated Mercury (PHg) was undertaken for the fist time and compared to data collected from lower latitude sites. This analysis showed that there are increasing trends of some species over time during certain months of the year. GEM measurements continued to be collected in the Yukon at Little Fox Lake but more years of data are still required to produce a valid trend.

Résumé

Le mercure (Hg) est un polluant prioritaire à l'échelle mondiale qui continue de soulever des préoccupations dans les régions arctiques. La plus longue période de collecte de données sur le mercure atmosphérique a été réalisée dans l'Extrême Arctique canadien, à Alert (Nunavut). Cette série chronologique indique des tendances saisonnières et annuelles distinctes et reproductibles en ce qui concerne le mercure élémentaire gazeux (MEG). L'analyse des tendances révèle que la tendance à la baisse est moins importante dans l'Extrême-Arctique que dans les régions situées plus au sud. En outre, une analyse des tendances concernant les espèces de mercure atmosphérique, soit le mercure gazeux réactif (MGR) et le mercure particulaire (Hgp), a été entreprise pour la première fois. Les résultats de cette analyse ont été comparés aux données recueillies dans des sites situés à des latitudes plus basses. Cette nouvelle analyse a permis d'établir des tendances temporelles à la hausse pour certaines espèces au cours de certains mois de l'année. La collecte de mesures du MEG s'est poursuivie à Little Fox Lake, au Yukon, mais il faudra encore attendre plusieurs années pour disposer des données nécessaires à l'établissement d'une tendance valable.

Key Messages

- Seventeen years of atmospheric mercury measurements have been made at Alert, Nunavut.
- Time trends of this data are reported
- Four years of atmospheric mercury measurements have been collected at Little Fox Lake, Yukon to establish baseline levels, assess long range transport events from the Pacific Rim and the impact of regional forest fires to this area.

Messages clés

- Des mesures du mercure atmosphérique ont été recueillies sur une période de dix sept ans à Alert, au Nunavut.
- Les tendances temporelles issues de ces données sont présentées dans l'étude.
- Des mesures du mercure atmosphérique ont été recueillies sur une période de quatre ans à Little Fox Lake, au Yukon, afin d'établir les concentrations de référence et d'évaluer les épisodes de transport sur de grandes distances à partir du littoral du Pacifique ainsi que les répercussions des incendies de forêt régionaux dans cette région.

Objectives

The objectives of this project are to establish long term baseline concentrations of mercury in the Arctic atmosphere and to study the behaviour of mercury in the Canadian high Arctic. By collecting this information on concentrations of atmospheric mercury, temporal variability, transport events and trends can be established. This information will be crucial in the development of Canadian strategies for national and international pollution control objectives. For instance, this data will be part of Canada's strategy on the current UNEP global negotiations on a legally binding agreement for mercury. Currently, Alert is an external partner for the Global Mercury Observation System (GMOS) program for the evaluation of the effectiveness of the UNEP agreement. Through the NCP, the transport of atmospheric mercury to the Arctic, the cycling of mercury in the atmosphere and the subsequent deposition of mercury from the atmosphere to the arctic environment has been studied at Alert since 1995. This long term record is advantageous to elucidate changes to and properties of atmospheric deposition after polar sunrise and the resulting potential link to enhanced Hg concentrations in the Arctic environment. Understanding these processes will help us to predict the effects that a rapidly changing Arctic climate will have on mercury deposition. The impact of mercury emissions from areas in the Pacific Rim to the Canadian western Arctic have become a concern over the past several years. To address this, measurements continue in the Yukon at the Little Fox Lake site to measure the transport of mercury to this area.

Introduction

Mercury (Hg) continues to be a priority pollutant of concern in Arctic regions. This project, within the NCP, provides long term data on the temporal trends and contributes to understanding the spatial variability of mercury in the High Arctic air as well as how the behaviour of Hg may impact the pristine Arctic. Changes in the global atmospheric pool of Hg over time and the resulting concentration changes in particular regions are poorly defined. Thus, areas like the Arctic are a good place to assess such trends. Further, with global climate change expected to occur at a rapid pace in Arctic regions, the atmospheric dynamics and the impacts of pollutants such as Hg to this environment have to be well understood. Pollution of Hg in the Arctic has mainly occurred after industrialisation (*Steffen et al.*, 2008). While European and North American emissions of gaseous elemental mercury (GEM) have decreased since 1995, emissions in other regions such as Asia and Africa have increased

(Pacyna *et al.*, 2006). Circulation patterns show that air masses originating in Asia can enter the Canadian Arctic (Dastoor and Larocque, 2004; Durnford *et al.*, 2010) and thus the increase in Asian emissions are particularly important to the Canadian north. It has been established by modellers that the Little Fox Lake site in the Yukon is an ideal location to measure such input from these sources (Durnford *et al.*, 2010).

The annual time series of GEM at Alert shows a repetitive distinct seasonal cycling of this pollutant. This same pattern is not evident at Little Fox Lake. Alert is a coastal site and thus is subject to intense atmospheric chemical reactions in the springtime that convert Hg in the air that can deposit to the surfaces. Alert also reports increased levels of GEM in the summer season (a unique feature to the high Arctic). Neither one of these phenomena are measured inland at the high altitude site in the Yukon. It is known that the Arctic Ocean plays a strong role in the atmospheric transformation and deposition of mercury, thus it is not surprising that the cycling of mercury in the Yukon interior is different from Alert.

The data collected by this NCP program serves to monitor long term and seasonal trends of mercury in the high and sub arctic and provides a voice to this contaminant that circulates in these regions. It provides important information on the atmospheric transport, transformation and deposition processes of this priority pollutant throughout the Polar Regions. The data collected from this program is used by chemists, modellers and those influencing policy decisions on mercury.

Activities in 2011/2012

Research activities
Ground-based continuous atmospheric measurements of GEM, Reactive Gaseous Mercury (RGM) and Particulate Mercury (PHg) continued at Alert. RGM and PHg concentrations were collected and the data has been quality assured to the end of 2011. The GEM data from Alert and Little Fox Lake for 2011 have been collected and processed through the quality control program. A statistical analysis of monthly trends in RGM and PHg at Alert, St Anicet, Quebec and the Experimental Lakes Area was conducted to compare trends at different latitudes. Snow samples continued to be collected on weekly samples (ground) and on a per event basis (table).

Capacity Building
In keeping with past years, the NCP-funded air research projects for POPs and Mercury have combined communication and consultation activities because they are so closely related in terms of facilities and technical support.

We are working with the Yukon College in Whitehorse to have the data from Little Fox Lake downloaded and kept on their server so they can access the data on site. This would allow students at the college remote access to the data and raise interest in scientific research and local environmental issues. We went to the Yukon College in December 2011 and gave a seminar to students and faculty on the NCP and IPY work that we are undertaking at Little Fox Lake. We are working with the college to help with guest lecturing for one of their environmental courses which will include a site visit to Little Fox Lake.

Communications
When possible, our work is disseminated to the media and others as requested.

Traditional Knowledge
At this time, TK is indirectly related to this NCP project through work undertaken in Barrow Alaska. This work was funded by Environment Canada but the TK gathered in this project can be applied to understanding the data collected in this project. We worked in the community of Barrow and with hunters from the area on the sea ice. They provided us with TK on the condition of the ice, predicting movements and recommended safe places to set up our equipment based on their many years of knowledge on this sea ice. This information was invaluable to the project and it is used to understand the data about sea ice surface exchange processes of mercury.

Results

Figure 1a shows the GEM measurements at Alert from 1995 to 2011 and Figure 1b shows the RGM and PHg concentrations from 2002 to 2011. Figure 2 shows the monthly trends of RGM and PHg at Alert and GEM at Alert, St. Anicet and E.L.A. Alert, St. Anicet and E.L.A are represented by data from 2002-2010, 2003-2010 and 2005-2010, respectively. The trends are shown as change in concentration per year and if the change is above zero it indicates and increasing trend for that month and if it is below zero it indicates a decreasing trend for that month. Figure 3 shows the GEM measurements collected at Little Fox Lake from 2007 to 2011.

Figure 1a

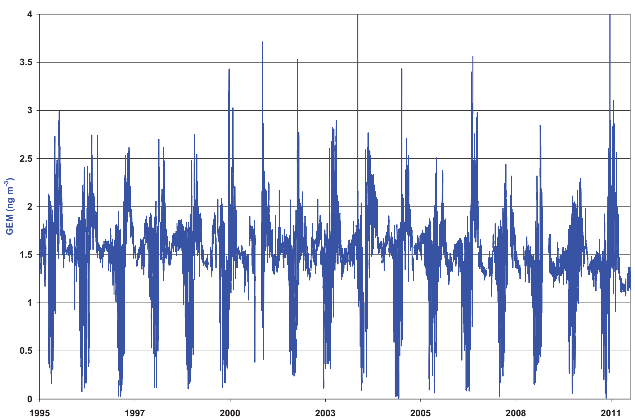
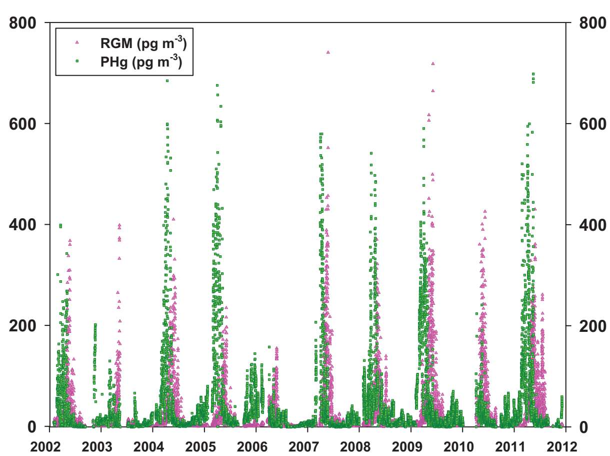


Figure 1b



Discussion and Conclusions

Seventeen years of GEM data and have been collected at Alert and the data is shown in Figure 1a. Three time trend analyses of this data set have been done and have shown that there is a stronger decreasing trend in more recent years. From 1995 to 2002 and 1995-2005, there were no statistically significant trends in the annual median concentration (Steffen *et al.*, 2005; Temme et al., 2007). The most recent trends from 1995-2007 and 1995-2009 indicate decreasing trends of 0.6 and 0.7% per year, respectively (Cole and Steffen, 2010) and Cole et al., in prep). These findings indicate that, while slight, the decreasing trends recently reported are likely occurring in the latter years.

The distinct seasonality of GEM remains evident at this location. Considerable studies have been undertaken to investigate the springtime chemistry that results in the low concentrations shown from March to May but few have focussed on the summertime elevated concentrations. In 2005, an analysis of the elevated summer concentrations in relation to the springtime lows showed that the mercury measured in the summer months was more than that lost from the atmosphere in the spring (Steffen *et al.*, 2005). This study did not go in depth to suggest the source of the elevated summer mercury. In 2012, a study was undertaken to try and explain the elevated summer concentrations using the GEOS-Chem model and assessing if it could explain the measurement data reported from high Arctic sites including Alert (Fisher *et al.*, 2012). This study concluded that rivers are large sources of mercury to the Arctic Ocean and subsequently to the atmosphere that have been previously not considered. This result is significant as the changes in the Arctic due to a changing climate will directly affect the behaviour of the rivers in this region. It is recommended that measurements be undertaken in the summer to investigate this very high source of mercury to the atmosphere.

Figure 1b shows the atmospheric concentrations of reactive gas phase mercury (RGM) and particulate mercury (PHg) from 2002 to 2011, inclusive. For the first time, the same method used to investigate the GEM trends previously mentioned was used to investigate trends in these atmospheric species at Alert over this time period. Daily mean concentrations of RGM, TPM and GEM were used to calculate seasonal trends at these sites in months with sufficient valid data. The results are shown in Figure 2 and also show a comparison of this analysis with concentration measurements from the Experimental Lakes Area (ELA) in northern Ontario and from St. Anicet, a rural location affected by activities from Montreal. A positive trend indicates a year-to-year increase in concentration for that month. While the concentrations are very low, the results show that there is an increasing trend in RGM concentration March and May at Alert (almost 10% per year in this month); May in St. Anicet and no other significant trends for the other months. Higher concentrations of PHg are measured at theses site and the results show that there are significant increasing trends at Alert in February, March (17%), April (8%) and November and significant decreasing trends in January. The lower latitude locations do not show the same trends during the same time periods. Finally, the bottom plot shows an increasing trend in GEM at Alert in February, April and August whereas the other months and sites predominantly show decreasing trends. The springtime trends in speciated mercury at Alert are of interest because of their link to atmospheric photochemistry and ocean conditions at this time of year. An increase in RGM and TPM during the AMDE season could indicate an overall increase in the amount of oxidation of GEM by halogen radicals. However, trends in GEM over the same period are not consistently decreasing (GEM decreased in March and May but increased in April) as would be expected from an increase in the oxidation rate. Also, these trends are still qualitatively uncertain due to the short time period and the fact that RGM and TPM measurements are still not well-calibrated.

Figure 2

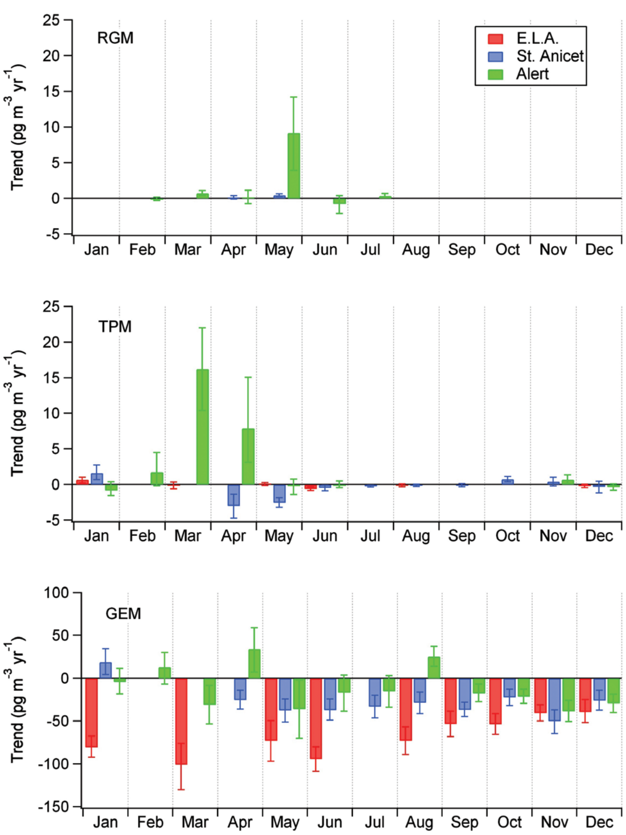
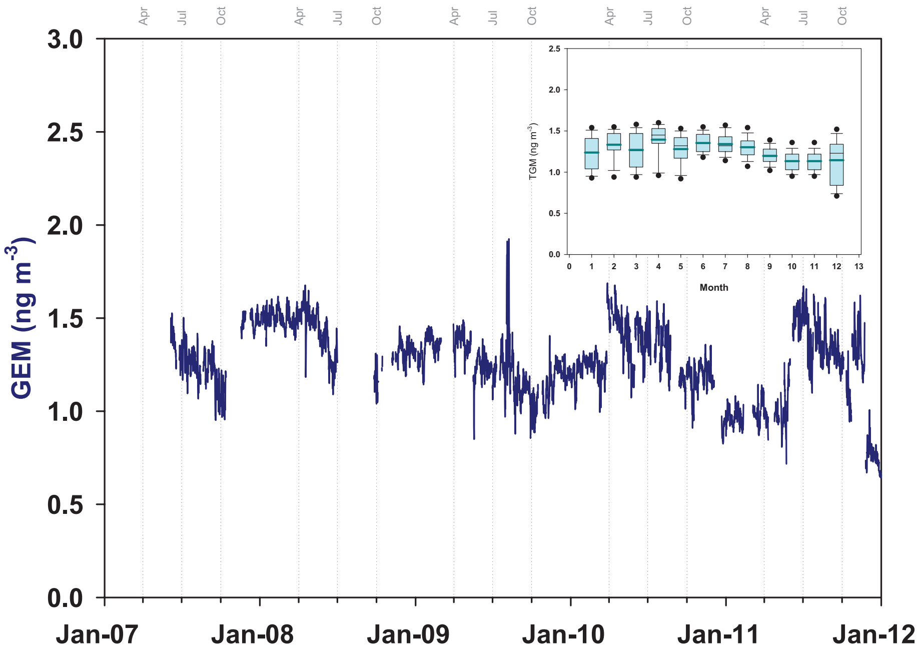


Figure 3 shows the concentration time series of GEM from Little Fox Lake and the monthly concentrations between 1997 and 2011. The data has been collected for just over 4 years which is not enough to investigate a trend with time. However, upon observation of the time series, it appears that each year from April to October there is a decrease in the concentration of GEM followed by an increase. This is reflected in the box and whisker plot inset into Figure 3. The dark blue line represents the mean concentration, the black line the median and the outliers as the 5th and 95th percentiles. At this time, we will not speculate on this trend but suffice it to say that patterns tend to emerge in Arctic mercury data with time. A further analysis into this is warranted. In the summer of 2009 there was a sharp increase in July that was previously attributed to the impact of forest fires in northern Yukon.

Overall, atmospheric mercury measurements continue at Alert and Little Fox Lake. These data sets are rich with information and provide tremendous insight into the fate and transport of mercury in the Canadian Arctic.

Figure 3



Expected Project Completion Date

Ongoing

Acknowledgements

The project team would like to thank the Global Atmospheric Watch program at Alert for supplying facilities, assistance and personnel. We would like to thank Joshua Benmergui for collecting the 2010/2011 GEM data at Alert. Much appreciation to Greg Skelton for the ongoing work on compiling this large data set! As always, we thank the NCP for their continued support for this work.

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NCP Performance Indicators

Performance Indicator	Number	Detail / Description
number of northerners engaged	0	
number of meetings/workshops held in the North	1	
number of students involved in project	1	(plus rotating students at Alert)
Number of citable publications	3	

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

Tendances temporelles des polluants organiques persistants et des métaux chez le phoque annelé de l'Arctique canadien

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Abstract

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. All sampling is done with the help of hunter and trapper committees in each community who are supplied with sampling kits and instructions. In 2011 samples were collected by local hunters in

Résumé

Le présent projet a pour but de déterminer, chez le phoque annelé, les changements de concentrations de mercure, d'anciens contaminants, comme les BPC et d'autres polluants organiques persistants (POP), ainsi que de nouveaux contaminants. Tout l'échantillonnage est effectué avec l'aide de comités de chasseurs et de trappeurs dans chacune des collectivités visées, auxquelles

the communities of Arviat, Resolute and Sachs Harbour and additional samples were received from Pangnirtung. Chemical measurements were combined with results from previous years, including samples archived from the 1970s to examine the trends over time and geographical differences. In this report, trends in concentrations of mercury, PCBs, brominated flame retardants (BFRs) and perfluorinated chemicals in ringed seals are discussed in detail. Average mercury concentrations in seal muscle collected in 2011were similar to measurements made in previous years and show no indication of an increase. Legacy POPs, such as PCBs, DDTs, chlordane and toxaphene, which were all banned in the 1970s and 80s are declining slowly in seals, with faster changes seen in Hudson Bay than in the central or western Arctic. The "penta" and "octa"brominated diphenyl ether (PBDE) flame retardants as well as PFOS are declining in seals following their bans/phase outs in Canada and elsewhere. However another BFR, hexabromocyclododecane is increasing in ringed seals, possibly because it is being used more now as a replacement for the banned chemicals.

on remet des trousses d'échantillonnage et des instructions à cet égard. En 2011, des chasseurs locaux ont prélevé des échantillons dans les collectivités d'Arviat, de Resolute et de Sachs Harbour, et des échantillons additionnels ont été récoltés à Pangnirtung. Des mesures chimiques ont été combinées aux résultats d'années antérieures, incluant des échantillons prélevés à partir des années 1970, pour examiner les tendances au fil du temps et les différences géographiques. Dans le présent rapport, nous traitons en détail des tendances des concentrations de mercure, de BPC, d'agents ignifuges bromés et de composés chimiques perfluorés chez le phoque annelé. En 2011, les concentrations moyennes de mercure dans les muscles des phoques étaient semblables aux mesures prises les années précédentes; il n'y a donc aucune indication d'augmentation. Les concentrations de POP anciens, tels que les BPC, le DDT, le chlordane et le toxaphène, qui ont tous été interdits dans les années 1970 et 1980, diminuent lentement chez les phoques. Nous notons des changements plus rapides dans la baie d'Hudson que dans le centre ou l'ouest de l'Arctique. Les concentrations de produits ignifuges de type pentabromodiphényléther et octabromodiphényléther (PBDE) ainsi que les perfluorooctanesulfonates (PFOS) sont en déclin chez les phoques en raison de leur interdiction ou de leur élimination progressive au Canada et dans d'autres pays. Cependant, la concentration d'un autre BFR, l'hexabromocyclododécane, est en hausse chez le phoque annelé, possiblement parce qu'on l'utilise maintenant en remplacement des produits chimiques interdits.

Key Messages

- Average mercury concentrations in seal muscle were similar to measurements made in the period 1999-2010.
- PBDEs and PFOS, as well as legacy POPs such as DDT, are declining steadily in seals with greatest declines seen in Hudson Bay animals

Messages clés

- Les concentrations moyennes de mercure dans les muscles des phoques étaient semblables aux mesures prises au cours de la période de 1999-2010.
- Les concentrations de PBDE et de PFOS, de même que celles de POP anciens comme le DDT, diminuent constamment chez les phoques, les plus grandes diminutions étant observées dans la baie d'Hudson.

Objectives

1. Determine temporal trends of persistent organic pollutants (POPs) and new organic chemicals of potential concern, as well as mercury and other metals in ringed seals using annual collections at 3 communities using previous data from the 1970s, 1980s and 1990s as well as archived samples if available.

2. Identify and prioritize other new contaminants that are entering the Arctic environment and contribute information to Canadian and International assessments of new candidate POPs.

3. Provide the information on levels and temporal trends of these contaminants to each participating community and to the Territorial contaminants committees.

Introduction

The ringed seal is the most abundant Arctic pinniped with a circumpolar distribution and has been a key biomonitoring animal for examining spatial and temporal trends of persistent organic pollutants (POPs) and mercury in the Arctic since the 1970s. This project began in April 2004 under NCP Phase III and follows up earlier projects on ringed seals (Muir and Lockhart 1994; Muir et al. 1999; Muir et al. 2001; Muir et al. 2003; Muir 1996; Muir 1997). Results for POPs and heavy metals including mercury are available going back to the 1980s, and earlier in some cases. This ringed seal contaminants project now has a very large database consisting of results for about 680 samples for PCBs and organochlorine pesticides (OCPs) and about 700 samples for mercury in muscle. Biological data including age and carbon and nitrogen stable isotope data are available for about 550 individual seals collected in the past 10 years.

Because ringed seals are an important species harvested by hunters each year in almost all communities in Nunavut, Nunavik, and the Inuvialuit Settlement Region, this project provides an opportunity to involve the communities in the scientific program of the NCP. Participation of hunters in each community has been consistent and the quality of the hunter based collection has generally been high.

In 2009-10 we reported on polychlorinated naphthalenes (PCNs) in seal blubber and on mercury in muscle (Muir et al. 2010). Our 2010-11 report focused on temporal trends of mercury and cadmium in seal liver and on perfluorinated chemicals (PFCs) in seal liver (Muir et al. 2011). This year we've returned to reporting on trends of "legacy POPs", mercury in muscle, as well as trends of BFRs and PFCs.

Activities in 2011-12

Sample collection: In 2011 ringed seal samples were successfully collected with the help of hunters in the communities of Arviat (N=30), Sachs Harbour (11), Resolute Bay (N=16). The collection at Resolute was partially lost during summer 2011 due to failure of the community freezer. However additional samples were collected in Nov-Dec 2011. In collaboration with Dr. Aaron Fish and PhD student Dave Yurkowski at University of Windsor we received ringed seal samples from Pangnirtung and Jordan Matley a PhD student with Terry Dick (University of Manitoba) provided additional samples from Resolute collected in fall 2010. Prof. S. Tanabe (Ehime University) also provided samples of muscle and liver from ringed seals collected in 1999 at Pangnirtung by Dr. Takashi Kunito.

- Collections consisted of blubber, liver, muscle, kidney, tooth/lower jaw (for aging). Essential data on length, girth, blubber thickness at the sternum, and sex was provided for almost all animals for all locations. Samples were stored at -20^{o}C and then shipped frozen to Burlington for processing. Large subsamples of all tissues were archived in walk-in freezers at -20^{o}C in sealed plastic bags (double bagged).

- In 2011 all tooth aging was conducted by Matson Labs (Milltown, MT). Muscle samples were sent to Wildlife Genetics International (Nelson BC) for gender confirmation using a DNA marker and to the University of Waterloo (Environmental Isotope Lab) for C and N stable isotope analysis.

- Short reports (in English and Inuktitut) on the results of the study to date were faxed to the Hunters and Trappers committee offices of each community in April 2012 as part of communication and consultations. In February 2012, project summaries were also sent to the Chairs of the Nunavut Niqiit Avatitinni Committee and the NWT Environmental Contaminants Committee.

Chemical analyses: Methodology for organochlorine pesticides (OCPs), PCBs, polybrominated diphenyl ethers (PBDEs) and PCNs and coplanar PCBs in seal blubber was unchanged for all samples reported here. Details were given in Muir et al. (2005) and in our 2010-11 Synopsis report (Muir et al. 2011) . Similarly methodology for or total mercury in muscle, and PFCs, mercury and multi-element analysis in seal liver has been reported previously and remained unchanged.

Quality assurance and statistical analysis: All organic analyses except for PFCs were conducted by the National Laboratory for Environmental Testing (NLET) Organics Analysis Laboratory using established protocols (NLET 2007a; NLET 2007b). Multielement analyses using ICP-MS and CV-AAS were conducted by the NLET inorganics lab. Both labs are certified by Canadian Standards Association and have participated in the NCP Interlab comparisons.

PFCs were determined in the Muir lab at Environment Canada Burlington. During 2010-11 the laboratory participated in an interlab comparison of PFCs in reference materials from the National Institute for Standards and Technology (NIST) which is now published (Reiner et al. 2012).

- QA steps included the analysis of reference materials for heavy metals and POPs and reagent blanks with each batch of samples. All results were blank subtracted. Further details are given in previous synopsis reports (Muir et al. 2008; 2009; 2010; 2011).

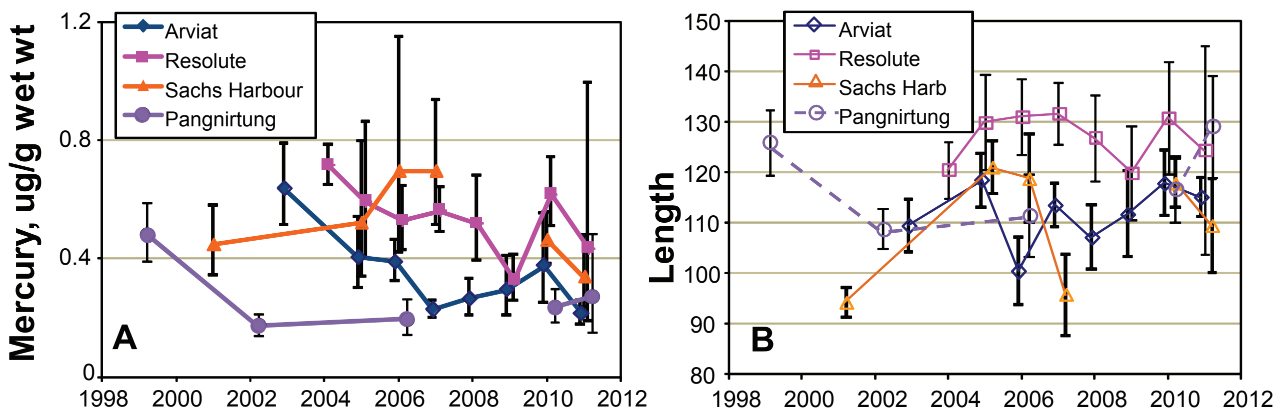
- Basic statistics, correlations and frequency distributions were determined using Systat Version 12 (Systat Software Inc, Chicago IL). Organohalogen concentrations in ringed seals were normalized to 100% lipid. For temporal trend comparisons results for both mercury, cadmium, and POPs were first tested for normality the Shapiro-Wilk test. All contaminants data were $\log_{10}$ transformed to give coefficients of skewness and kurtosis <2 and geometric means (back transformed log data) were calculated. Temporal trends of PCBs and OCPs in the data for female ringed seals were analysed using the statistical program PIA (Bignert 2007).

Results and Discussion

Sample collection and hunter observations: In 2011 requested information on gender, girth, length, blubber thickness was provided for 55 of 57 animals. The identification of the gender of the seals by hunters in the field was in agreement with results for DNA markers in 43 out of 46 samples (11 remain to be analysed). Overall the information provided by the hunters was excellent considering the logistical challenges they face in having to harvest and dissect the animals in the field. Hunters in Sachs Harbour are reporting more bearded seals and fewer ringed seals while in Arviat more Harbour Seals are being hunted. Harp seals are reported more frequently now at Resolute.

Trends of mercury in seal muscle: We have previously report trends in concentrations of mercury in ringed seal muscle from Arviat, Sachs Harbour and Resolute to 2009 (Muir et al. 2010). Concentrations in seal muscle continue to vary within a relatively narrow range and show no significant trends over time (Figure 1). This is also true in ringed seals from Pangnirtung for which results from samples collected in 2010 and 2011 were combined with older data from previous NCP funded collections. There are advantages in using muscle instead of liver for assessing temporal trends because mercury

Figure 1. Time trends of (A) mercury in seal muscle and (B) length of the seals from Arviat, Pangnirtung, Sachs Harbour, and Resolute. Symbols represent geometric mean concentrations and vertical lines are 95% confidence limits for animals ≥5yrs of age.



concentrations appear to less variable from year to year as shown by Gaden et al (2009) for ringed seals at Ulukhaktok. The results in Figure 1 are for adult seals (>5 yrs) based on observations that mercury in seal liver increases with age up to about age 5 years (Muir et al. 2011). However, there we actually found only weak relationships of muscle mercury with age (Figure 2). The relationship of log mercury versus age was significant only at Arviat (r^2=0.1, P=0.01, N=105) for seals ≥ 3 years but it was not significant at Sachs Harbour or Resolute for any age group.

Trends of Legacy POPs: Measurement of all organic contaminants continued in 2011-12 but

Table 1. Results of analysis of time trends of the ringed seal data using the PIA program

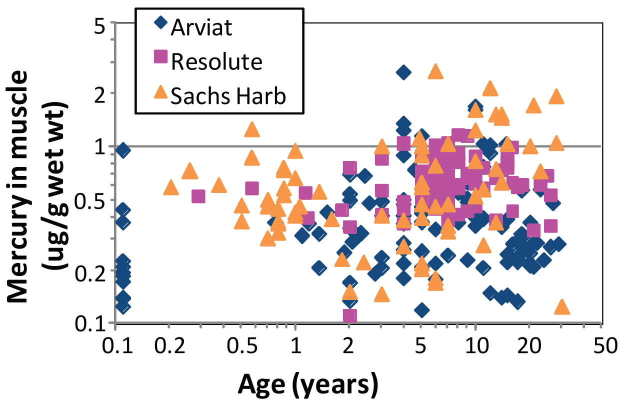
Region[1]	Hudson Bay	1986 - 2010	Lancaster	1972-2010	Beaufort	1972-2010	East Baffin	1986-2006
Years of sampling	12		16		7		6	
Total samples	147		207		91		68	
Parameter	% decline or increase	LDC (%)	% decline or increase	LDC (%)	% decline or increase	LDC (%)	% decline or increase	LDC (%)
α-HCH	-9.40%	12	-3.90%	6.9	-1.50%	32	-6.20%	19
β-HCH	-3.40%	20	4.90%	8	5.10%	25	1.00%	40
HCB	-3.00%	6.4	-0.74%	4	-0.90%	11	-1.60%	18
Σ_{10}PCB	-4.90%	11	-2.00%	4.9	-0.83%	24	-1.80%	35
ΣDDT	-7.20%	11	-2.80%	4.4	-3.30%	35	-3.10%	21
ΣCHL	-8.20%	12	0.89%	5.3	-0.11%	41	-4.30%	17
Toxaphene	-7.20%	28	0.35%	37	-1.80%	33	Not analysed	

[1] Hudson = Arviat + Inukjuaq; Lancaster = Resolute Bay + Gjoa Haven+Arctic Bay + Grise Fiord

Beaufort= Sachs Harbour and Ulukhaktok; East Baffin = Pangnirtung + Qikiqtarjuaq

[2]LDC = Lowest detectable change at Power of 80%

Figure 2. Relationship of mercury in muscle of ringed seals from Arviat, Resolute and Sachs Harbour with age of the animals. A log scale is used to make it easier to view the data



results for PCBs and other chlorinated organics including organochlorine pesticides, toxaphene, endosulfan, chlorinated paraffins and PCNs are pending. Temporal trends of legacy POPs to 2010 were analysed after combining results from nearby communities because most PCB/OCs concentrations were similar for nearby communities while differing significantly among regions. For example, results from Resolute were combined with those from Arctic Bay and Grise Fiord. In the case of PCBs we used the sum of 10 major congeners (Σ10PCB) for compatibility with results from the 1970s and 80s. Overall, there are declining trends of POPs in ringed seals with the relative magnitude of ΣDDT > α-HCH > Σ10PCB ≈ ΣCHL ≈ toxaphene. DDT declined significantly in ringed seals from all 4 regions (Table 1). Chlordane-related compounds declined in the East Baffin and Hudson Bay regions (Table 1). However, the declines of Σ10PCB and ΣCHL in the Beaufort and Lancaster regions, were not statistically significant despite the relatively large numbers of sampling years now available, suggesting continued inputs. HCB declined significantly only in Hudson Bay.

Trends in New POPs: Other contaminants determined in ringed seal blubber include those listed in the Stockholm Convention (Penta- and Octa-brominated diphenyl ethers) and PFOS, as well as a large suite of brominated flame retardant (BFR) chemicals and PFCs. Analyses of current use pesticides dacthal and chlorthalonil in seal blubber from Resolute have also been conducted by graduate student Adam Morris (Morris et al. 2010).

BFRs routinely analysed in the project include the hexabromo-cyclododecane (HBCD), allyl 2,4,6-tribromophenyl ether, 2,3,5,6-tetrabromo-p-xylene, pentabromobenzene, pentabromotoluene, 2,3,4,5,6-pentabromoethylbenzene, 2,3-dibromopropyl 2,4,6-tribromophenyl ether, hexabromobenzene (HBB), 1-bromomethyl-2,3,4,5,6-pentabromobenzene, bis(2-ethyl-1-hexyl)tetrabromophthalate, and 1,2-Bis(2,4,6-tribromophenoxy)ethane (BTBPE). Most of these BFRs have not been detected except for HBB, BTBPE and HBCD. HBB has have been detected in some seal blubber samples but concentrations are near detection limits. Consistent detections of HBCD and BTBPE have been made since 2005. Overall, concentrations of HBCD have increased from 25 to 171% during the period 2001-2010 (Table 2). ΣPBDEs (sum of congeners 47, 99, 100, 153, 154) have generally increased in the southern Beaufort (Sachs Harbour and Ulukhaktok) and in Lancaster Sound but in Hudson Bay ΣPBDEs have declined from 2002 t0 2010 at 7% per year, although the trend is not statistically significant (Table 2).

PFOS concentrations have declined in seals from Lancaster Sound and Hudson Bay over the period 2003 to 2011 after previous rapid increases (Table 2). ΣPFCAs (sum of perfluorononanoic acid to perfluorodecanoic acids) are also declining in Lancaster Sound (16%/yr) and in Hudson Bay (8.7%/yr; not statistically significant). In the southern Beaufort Sea locations both PFOS and ΣPFCAs continue to increase (Table 2) although at slower rates than found in the 1990s-early 00s in Lancaster Sound and Hudson Bay.

Discussion and Conclusions

This study has provided new information on the temporal trends of mercury in ringed seal muscle, on PCBs and other POPs including

Table 2. Percent annual increase to or decreases for PBDEs, HBCD, PFOS and PFCAs in ringed seals

Location	Parameters	Beaufort	Lancaster Sound		Hudson Bay	
ΣPBDEs	#Years & range	7, 91-10	5, 92-10	–	8, 02-10	–
	% dec or inc /yr1,2	9.2	7.4	–	-7.0 NS	–
HBCD	#Years & range	4, 01-10	5, 06-11	–	4, 07-10	–
	% dec or inc /yr	+25 NS	+171 NS	–	+38 NS	–
PFCAs	#Years & range	6, 72-11	3, 93-03	8 03-11	7, 92-07	4, 07-11
	% dec or inc /yr	4.1	14	-16	9.5	-8.7 NS
PFOS	#Years & range	6, 72-11	3, 93-03	8 03-11	3, 92-03	8, 02-11
	% dec or inc /yr	3.8 NS	20	-19	14	-8.6

[1]% decrease from maximum or % increase over the period indicated

[2]NS = no statistically significant change in mean concentrations over time (P <0.05) using the PIA program (Bignert 2007) ringed seals

NCP Performance Indicators

Performance Indicator	Number	Detail / Description
Number of northerners engaged in your project	25	This project involves the hunters and trappers committee in each community who approve participation, the HTC manager who distributes sample kits and makes payments, and the individual hunters. In Sachs Harbour, Jeff Kuptana was hired to do sample processing. In total an estimated 25 people participated based on 8-10 hunters in Arviat and Resolute and three HTC managers. In previous years the numbers were much higher when 5 communities per year were being sampled.
number of meetings/workshops held in the North	1	Extensive communication by phone and E-mail with Resolute, Sachs Harbour, and Arviat HTC Managers. Invited participant in the workshop on ìRinged seal contaminants and traditional knowledge project in Nunatsiavutî, Nain NL January 26, 2012.
number of students involved in project	2	PhD student Adam Morris has contributed samples and visited Resolute in March 2011 where gave a presentation at the school and spoke with the Manager of the HTC. Randi Anderson (MSc University of Manitoba) is looking at chronic stress (cortisol hormones) in ringed seals from a number of the communities (Arviat, Holman, Pang).
Number of citable publications	0	Contributed data to the CACAR Mercury assessment and the CACAR POPs assessment. Co-authored presentations at IPY (Montreal April 2012). Krey et al.Concentrations of Neurotoxic Metals in Ringed Seal (Phoca hispida) Brain.

brominated flame retardants in seal blubber and on PFCs in ringed seal liver. Average mercury concentrations in muscle vary year to year but typically by <30% and no statistically significant trend is evident. Hunters are reporting earlier ice breakup and this may be influencing the diet of the seals. As annual sampling continues it may be possible to examine the effect of ice out time (annual data on ice thickness is available for Resolute Bay) along with dietary indicators such as carbon and nitrogen isotope ratios and fatty acids to see if there is an influence on mercury in seals.

The results are show that BFRs, which are replacements for "penta" and "octa" PBDEs (banned under the Stockholm Convention and phased out in North America by 2005), are increasing in ringed seals. This demonstrates again the importance of wildlife monitoring for contaminants in the Arctic. The results also show the effect of bans and phase outs of the PBDEs and PFOS, which are both declining in Hudson Bay. The lack of decline in these groups in the Beaufort Sea ringed seals illustrates the wide variation in timing of exposure to contaminants across the Canadian arctic. Differences between the Beaufort Sea, Hudson Bay and East Baffin sites are also seen for other POPs such as β-HCH which continues to increase at Sachs Harbour/Ulukhaktok and Resolute while declining in East Baffin and Hudson Bay locations. This may reflect the importance of ocean transport not only for HCHs but also for PFCs and possibly other contaminants.

Expected Project Completion Date

The project is ongoing with annual sampling at 3 locations planned under the NCP 2012-13 "Blueprint".

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Temporal and Spatial Trends of Legacy and Emerging Organic and Metal/Elemental Contaminants in Canadian Polar Bears

Tendances temporelles et spatiales des contaminants organiques et métalliques/élémentaires classiques et émergents chez l'ours blanc du Canada

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Abstract

The polar bear *(Ursus maritimus)* is the apex predator of the Arctic marine ecosystem and an integral component of Inuit and northern culture in Canada. Due to its position at

Résumé

L'ours blanc *(Ursus maritimus)* est un prédateur supérieur de l'écosystème marin de l'Arctique ainsi qu'un élément intégral de la culture inuite et du Nord au Canada. En raison de la position

the top of the marine food web, levels of persistent organic pollutant (POP) and metal contaminants in polar bears are among the highest observed in the Arctic. Results to date for 2011-2012 focused on investigating the influence of carbon and lipid sources on regional differences in liver trace element (As, Cd, Cu, total Hg, Mn, Pb, Rb, Se and Zn) concentrations in polar bears (*n*=121) from ten Alaskan, Canadian Arctic and East Greenland subpopulations. Carbon and lipid sources were assessed using carbon isotope ratios ($\delta^{13}C$) in muscle tissue and fatty acid (FA) profiles in subcutaneous adipose tissue as chemical tracers. A negative relationship between total Hg and $\delta^{13}C$ suggested polar bears feeding in areas with higher river inputs of terrestrial carbon accumulate more Hg than bears feeding in areas with lower freshwater input. Hg concentrations were also positively related FAs that are biosynthesized in large amounts in Calanus copepods. This result raised the hypothesis that *Calanus glacialis* are an important link in the uptake of Hg in the marine food web and ultimately in polar bears. Unadjusted total Hg, Se and As concentrations showed greater geographical variation among polar bear subpopulations compared to concentrations adjusted for carbon and lipid sources. Based on these findings it was suggested that carbon and lipid sources for polar bears should be taken into account when assessing spatial and temporal trends of long-range transported trace elements. This work is of significant value to northerners, whose cultural lifestyle depends on subsistence foods that polar bears prey on, as well as polar bears in the Inuit diet.

de cette espèce au sommet du réseau trophique marin, les concentrations de polluants organiques persistants (POP) et de métaux chez l'ours blanc figurent parmi les plus élevées qui ont été observées dans l'Arctique. Les résultats à ce jour pour l'exercice 2011-2012 sont centrés sur l'examen des effets des sources de carbone et de lipides sur les différences régionales relatives aux concentrations d'éléments traces (As, Cd, Cu, Hg total, Mn, Pb, Rb, Se et Zn) détectées dans le foie des ours blancs (*n* = 121) issus de dix sous populations de l'Alaska, de l'Arctique canadien et de l'est du Groenland. Les sources de carbone et de lipides ont été évaluées au moyen des rapports isotopiques du carbone ($\delta^{13}C$ dans les tissus musculaires et des profils d'acides gras dans les tissus adipeux sous cutanés, utilisés comme traceurs chimiques. Une relation négative entre le Hg total et le $\delta^{13}C$ donne à penser que les ours blancs qui se nourrissent dans des zones recevant des apports fluviaux de carbone terrestre très importants accumulent une quantité plus élevée de Hg que ceux qui se nourrissent dans des zones où les apports en eaux douces sont plus faibles. Les concentrations de Hg ont aussi été positivement liées aux acides gras biosynthétisés en grandes quantités chez les copépodes du genre Calanus. Ce résultat soulève l'hypothèse voulant que le Calanus glacialis constitue un lien important dans l'absorption de Hg dans le réseau trophique marin et, à terme, chez les ours blancs. Les concentrations non ajustées de Hg total, de Se et d'As ont affiché une variation géographique plus forte parmi les sous-populations d'ours blancs que les concentrations ajustées en fonction des sources de carbone et de lipides. D'après ces constats, nous recommandons de tenir compte des sources de carbone et de lipides pour les ours blancs dans l'évaluation des tendances spatiotemporelles des éléments traces transportés sur de grandes distances. Ces travaux sont importants pour les habitants du Grand Nord, parce que leur mode de vie culturel dépend des espèces de subsistance dont se nourrissent les ours blancs et des ours blancs eux mêmes qui font partie de l'alimentation des Inuit.

Key Messages

- Unadjusted total Hg, Se, Cd and As concentrations in livers showed greater geographical variation among polar bear subpopulations compared to concentrations adjusted for carbon and lipid sources.
- A negative relationship between total Hg and carbon isotope ratios suggested polar bears feeding in areas with higher river inputs of terrestrial carbon accumulate more Hg than bears feeding in areas with lower freshwater input.
- Total Hg concentrations were positively related fatty acids that are biosynthesized in large amounts in *Calanus* copepods, which may be an important link in the uptake of Hg in the marine food web and ultimately in polar bears.
- MeHg in water column and food web length may also play an important role in total Hg concentrations in apex predators like polar bears.
- Stable nitrogen isotope ratios, which are a measure of feeding position in the marine food chain, were positively correlated with the concentrations of total Hg, Se and As in polar bears. This suggested that regional differences in polar bear food web length play a role in explaining subpopulation differences in trace element concentrations.

Messages clés

- Les concentrations non ajustées de Hg total, de Se et d'As dans les foies échantillonnés ont affiché une variation géographique plus forte parmi les sous-populations d'ours blancs que les concentrations ajustées en fonction des sources de carbone et de lipides.
- Une relation négative entre le Hg total et les rapports isotopiques du carbone donne à penser que les ours blancs qui se nourrissent dans des zones recevant des apports fluviaux de carbone terrestre très importants accumulent une quantité plus élevée de Hg que ceux qui se nourrissent dans des zones où les apports en eaux douces sont plus faibles.
- Les concentrations de Hg total ont été positivement liées aux acides gras biosynthétisés en grandes quantités chez les copépodes du genre *Calanus*, qui pourraient constituer un lien important dans l'absorption de Hg dans le réseau trophique marin, et, à terme, chez les ours blancs.
- Le MeHg dans la colonne d'eau et la longueur du réseau trophique pourraient jouer un rôle important dans les concentrations de Hg total chez les prédateurs supérieurs comme l'ours blanc.
- Les rapports d'isotopes stables de l'azote, qui constituent une mesure de la position dans le réseau trophique marin, ont été positivement corrélés aux concentrations de Hg total, de Se et d'As chez l'ours blanc. Ce résultat indique que des différences régionales dans la longueur du réseau trophique pourraient expliquer, en partie, les différences observées dans les concentrations d'éléments traces entre les sous populations.

Objectives

Overall

To determine and monitor the spatial and temporal trends (e.g., concentrations and congener patterns), bioavailability, fate, and toxicokinetics (e.g., biotransformation and tissue distribution) of legacy and new/emerging POPs (chlorinated, brominated and fluorinated), their persistent degradation products, precursors and/or isomers, as well metal and other elements, in polar bears from Canadian Arctic management zones.

Specific and shorter term

- To determine the spatial and ongoing temporal trends of legacy and emerging POPs (e.g., brominated flame retardants (BFRs) and perfluorinated compounds (PFCs)) and degradation products, precursors and/or isomers, and metals/elements (e.g., Hg) in polar bears using the appropriate tissues collected in communities within the western and southern Hudson Bay management zones in the Canadian Arctic, using appropriate tissues (fat or liver).

- To use carbon and nitrogen SIs and FAs as ecological tracers of trophic levels and diet, and determined in polar bear tissues (muscle or fat) from selected management locations (assessed in (1)) to examine the influence of diet and trophic level as confounding factors on POP spatial and temporal trends, in addition other influential factors such as sex, age, time of collection, and lipid content.

- To identify and determine emerging chlorinated, brominated and fluorinated POPs that may persist in the tissues of polar bears, are not necessarily listed as a NCP, LRTAP or Stockholm Convention priority POP, and can be monitored for as part of or with little deviation from analytical methods applied for determination of the NCP priority POPs.

- To provide information in a timely manner to each Inuit community participating in the study, on the levels and trends of POPs in polar bears. This would include translation of documentation and deliverables into Inukituk.

- To archive the remaining polar bear tissue samples that were collected as part of this project, in Environment Canada's National Wildlife Specimen Bank (EC-NWSB) located at the NWRC, Carleton University, Ottawa.

Introduction

The polar bear *(Ursus maritimus)* is an apex predator of circumpolar arctic marine ecosystems. Due to its trophic position, and through the process of biomagnification, it continues to be shown that polar bears achieve some of the highest (legacy and emerging) contaminant concentrations in their tissues of any arctic species or any species on the planet (Letcher et al. 2010; Riget et al. 2011). These contaminants include trace elements such as mercury (Hg), but also essential (As, Cu, Mn, Se, Zn) and non-essential (Cd, Hg, Pb, Rb) elements of both natural and anthropogenic origin, many of which are toxic at elevated concentrations (Routti et al. 2011). Hg and Cd have been detected at high concentrations in species occupying the top of the arctic marine food webs including polar bears (Dietz et al. 1996, 2000; Muir et al. 1999; Routti et al. 2011). Toxicological effects of these trace element contaminants in the Arctic have been of concern in species such as polar bears, seals, beluga whales *(Delphinapterus leucas)* and bowhead whales *(Balaena mysticetus)* (Basu et al. 2009; Dietz et al. 2011; Sonne et al. 2007; Sonne-Hansen et al. 2002; Rosa et al. 2007; Woshner et al. 2002). Of the different chemical forms of Hg, the most important from an environmental toxicology perspective is methylmercury (MeHg). MeHg biomagnifies through food chains and more than 95% has been shown to be absorbed from the diet in exposed mammals (Berlin et al. 1986). In recent years, increasingly subtle but important biological effects have been documented, including behavioral, neurochemical, hormonal, and reproductive changes in predatory fish and wildlife exposed to environmentally relevant levels of MeHg (Scheuhammer et al. 2011).

Trace element concentrations show wide geographical variation between polar bear subpopulations. Studies published over the last 25 years have documented the highest concentrations of total Hg, Se and As in polar bears from the Beaufort Sea and lowest in southern and western Hudson Bay and the Chukchi/Bering Sea (Braune et al. 1991; Dietz et al. 2000; Norstrom et al. 1986; Routti et al. 2011; Rush et al. 2008). In contrast, Cd concentrations in polar bears and ringed seals generally increase from the western to eastern Arctic (Braune et al. 1991; Dietz et al. 2000; Norstrom et al. 1986; Routti et al. 2011; Rush et al. 2008; Wagemann et al. 1996). Trace element concentrations in arctic biota are influenced by physical factors including riverine output and geology, as well as biological factors such as underlying food web structure that are manifested in the diet of higher trophic level wildlife (Douglas et al. 2011; Munthe et al. 2011; Wagemann et al. 1996). The relative importance of these underlying factors in modulating geographical differences in trace element concentrations in polar bears and other marine mammals is not completely understood.

The food web length and diet composition of polar bears are known to vary considerably between Arctic subpopulations (McKinney et al. 2011a, 2011b; St. Louis et al. 2011; Thiemann et al. 2008). For example, polar bears feed predominantly on ringed seals *(Pusa hispida)*, but depending on the subpopulation, bearded seals *(Erignathus barbatus)*, harp seals (Phoca groenlandica), harbor seals *(Phoca vitulina)*, hooded seals *(Cystophora cristata)*, walruses *(Odobenus rosmarus)*, narwhals (Monodon monoceros), belugas, bowhead whales and sperm whales *(Physeter macrocephalus)* may also form part of their diet (Derocher et al. 2002; Thiemann et al. 2008). It is, however, unclear how such trophic factors may influence spatial variation in trace element levels.

Chemical tracers, such as nitrogen and carbon stable isotope (SI) ratios ($\delta^{15}N$, $\delta^{13}C$) and fatty acid (FA) composition, have been used to elucidate trophic relationships and food web structure (Hobson, 1999; Iverson et al. 2004). $\delta^{15}N$ is frequently used to estimate relative trophic positions of animals within a food web, while $\delta^{13}C$ delineates the major carbon sources of an organism i.e. benthic/pelagic, marine/terrestrial and freshwater/marine (Hobson, 1999). FAs may be used to assess individual diet composition of animals (Iverson et al. 2004). In addition, transfer of energy from phytoplankton and zooplankton to top predators may be traced using FAs (Falk-Petersen et al. 2009), since characteristic FAs synthesized in primary and secondary producers are transferred through food webs (Dalsgaard et al. 2003). Carbon and nitrogen SIs have become powerful tools to study dietary exposure and biomagnification of persistent contaminants in marine ecosystems (Jardine et al. 2006), while FA composition has been used in contaminant studies only recently including studies of persistent organic pollutant variation among polar bear subpopulations (Loseto et al. 2008; McKinney et al. 2009, 2010, 2011a, 2011b).

We reported in 2010-2011 that concentrations of major bioaccumulative trace elements showed significant variation among subpopulations of polar bears spanning from Alaska, Canada and East Greenland (Routti et al. 2011). In 2011-2012, we completed a follow-up study that used SI and FA chemical tracers to test the hypothesis that among these same polar bear subpopulations, differences in trace concentrations of essential and non-essential elements are affected by variation in carbon and lipid sources, and also as a function of trophic position. Prior to combining the information of trace elements and carbon and lipid sources, we investigated subpopulation differences in carbon and lipid sources assessed using $\delta^{13}C$ ratio values and FA signatures, respectively.

Activities in 2011-2012

Sample collections and analyses

In late 2010, we successfully applied for and obtained a 2011 Nunavut Wildlife Research Permit (NWRP) polar bear samples collections during the harvests in western and southern Hudson Bay. The 2011 NWRP was evaluated in collaboration with communities and via the Nunavut Department of Environment (M. Dyck, S. Atkinson and A. Coxon). In late winter/early spring 2011, from the quota of permitted polar bear harvests, fat, liver and muscle tissue samples were obtained from n=17 southern Hudson Bay bears and n=23 western Hudson Bay (Coral Harbour and Rankin Inlet) bears. These samples had been collected by local hunters in participating communities via interaction with local HTAs and COs.

For the n=40 sample sets collected in 2011, we have completed all the targeted POP analyses (i.e. PCBs, DDTs, CHLs, ClBzs, HCHs, PBDEs, various other BFRs, PFCs and elements/ metals in fat or liver samples). FA analyses were completed (via Lab Services section, NWRC). The analysis of SIs of nitrogen and carbon for the 2011 collected liver and muscle samples are to be analyzed by the Environmental Isotope Laboratory (EIL) at the University of Waterloo (Waterloo, ON). Age determinations of all Hudson Bay bears from which a tooth was obtained are expected to be completed sometime in 2012, which is done by the Nunavut Department of Environment (A. Coxon, M. Dyck).

Capacity building, communications and traditional knowledge

In 2011-2012, this project cooperated in building expertise in scientific sampling during the late winter/early spring 2011 harvests in Hudson Bay. In this research year, the four participating communities and HTAs were directly involved and led in the organization and collection of fat, liver and muscle samples. As detailed in an approved 2011 Nunavut Wildlife Research Permit, and in cooperation with the Dr. Stephen Atkinson, Markus Dyck and Angela Coxon in the Department of Environment, Government of Nunavut, Dr. Letcher arranged and sent directly to the COs in each community a cooler complete with a suitable number of sampling kits that coincides with the number of bears required for these management zones and within the allowable hunting quota for that community. Also, Letcher had previously established with S. Atkinson (Government of Nunavut, Dept. of Environment) an Agreement of Cooperation and Contribution, which embodies this research Environment Canada-Government of Nunavut partnership. For the hunters in each community, each cooler contained simple and easy to read sampling instructions in both English and Inuktitut. Therefore, when the COs distributed the kits to the hunters, it was as easy as possible for them to sample correctly. Sampling instructions were also sent to the NAC who assessed whether the right questions being asked with regards to the traditional knowledge (e.g., sex, age and health).

For new POP data that had become available in 2010-2011, presentations and dissemination were made at the 2011 NCP Results Workshops held in mid-September in Victoria, B.C. (As well as at various other conference; see Performance Indicators section). With the completion of journal publications and reports, these documents were provided to Nunavut partners and the NAC for further distribution. Whenever it was necessary, the PI responded to any inquires or concerns of the participating communities. The PI also made every reasonable effort to communicate in person with the RCC representatives and COs and hunters in each participating community. AANDC was also informed as well as others associated with these participating departments. All publications that result from the NCP core-monitoring research are being provided to pscowen@ucalgary.ca for inclusion in the NCP Publications Database.

As in past sampling for this core monitoring project, the 2011-2012 collection of samples was carried out exclusively by hunters in the participating Hudson Bay communities and in coordination with the PI and involved agencies in Nunavut. This project worked within the guidelines of the allowable hunting quotas for each of the HTAs and communities. The project therefore relied heavily on the knowledge and experience of these hunters for the sampling and for the ecological information on behaviour, condition and population numbers they provide to wildlife COs and biologists. The traditional knowledge of polar bears and their food web continues to enhance and is critically needed for this monitoring and research initiative. Via the sampling exercise and the priority of the samples that are collected for the determination of contaminants, local communities are learning more about how contaminants are manifested in a top predator organism, which is representative of human exposure as polar bears are consuming country food at the same level of people in the communities.

Results

Regional variation in carbon and lipid sources and relationships with trace elements

$\delta^{13}C$ signatures were depleted in the Northern and Southern Beaufort Sea, Hudson Bay and East Greenland subpopulations compared to the remaining subpopulations (ANOVA, $F_{9,111}=40$, $p<0.001$, Table 1).

Concentrations of Hg, Se, As and Cd were related to FAs and/or $\delta^{13}C$ based on the ordination plot derived from the RDA (Figure 1a). Plotting sample scores revealed that the relationships between trace elements were mainly related to subpopulation differences (Figure 1b), while sex and season had minor influence on these relationships (Figure 1c-d).

Influence of carbon and lipid sources on subpopulation differences in trace element concentrations

It was investigated whether polar bear subpopulation differences in trace element concentrations are affected by variation in the carbon and lipid sources. Trace element

Table 1. Subpopulation and geometric mean of the number of individuals, age and stable isotope ratio of carbon a of polar bears investigated for the influence of dietary tracers, sex and age on trace element concentrations.

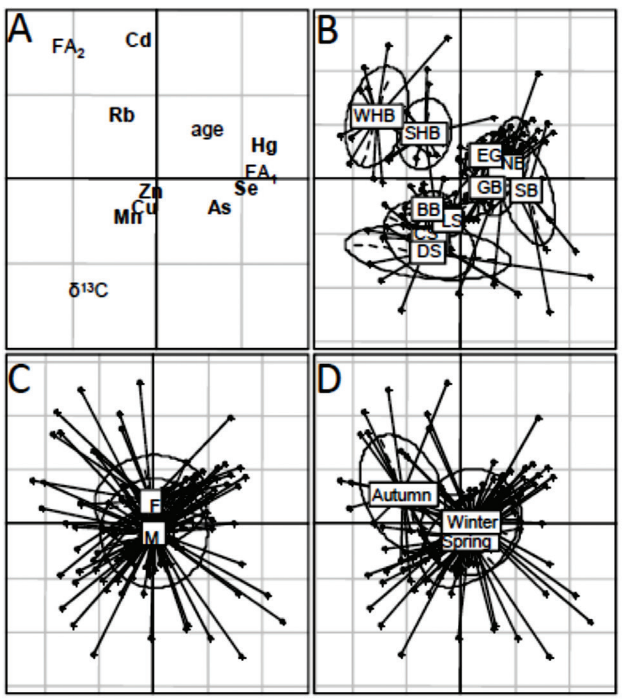
Subpopulation	*n* (males: females)	median age (range)	$\delta^{13}C \pm SD$ [a]
Alaska- Bering – Chukchi Sea (CB)	11 (7:4)	7.0 (2-22)	-16.8 ± 0.3
Southern Beaufort Sea (SB)	10 (7:3)	9.0 (4-20)	-19.1 ± 0.4
Northern Beaufort Sea (NB)	24 (17:7)	6.0 (3-24)	-19.2 ± 0.6
Gulf of Boothia (GB)	6 (4:2)	8.5 (3-24)	-17.5 ± 0.5
Lancaster/Jones Sound (LS)	12 (10:2)	6.0 (3-11)	-17.6 ± 0.5
Southern Hudson Bay (SHB)	12 (8:4)	9.0 (3-22)	-18.9 ± 0.3
Western Hudson Bay (WHB)	11 (8:3)	7.0 (3-29)	-18.8 ± 0.6
Baffin Bay – N.E. Baffin Island (BB)	10 (7:3)	5.0 (2-10)	-17.5 ± 0.6
Davis Strait – S.E. Baffin Island (DS)	5 (5:0)	4.0 (3-6)	-16.6 ± 0.7
E. Greenland – Scoresbysund (EG)	20 (14:6)	6.5 (3-19)	-18.7 ± 0.3
all females	34	7 (2-24)	-18.6 ± 1.0
all males	87	7 (3-29)	-18.2 ± 1.0

[a] (McKinney et al. 2011a)

Table 2. Explanatory variables included, degrees of freedom (d.f.) and R^2 for the most parsimonious linear models for $\log_e$-transformed trace element concentrations in polar bears.

	$\delta^{13}C$	$FA_{ind}1$	$FA_{ind}2$	age	d.f.	R^2
log(As)	x	x	x		3, 115	0.29
log(Cd)			x		1, 118	0.09
log(Hg)	x	x	x	x	4, 115	0.31
log(Se)	x	x	x	x	4, 115	0.28

Figure 1. Ordination plots from redundancy analysis (RDA) based on covariance matrix of log-transformed trace element concentrations in liver of polar bears. The relationships are shown between response variables (trace element concentrations) and explanatory variables (chemical tracers (stable carbon isotope and fatty acids) and age) (A). The sample scores are grouped by subpopulation (B), sex (C) and season (D). The first linear combination of the explanatory variables explained 33% of the response variables and the second, 16%. The first axis explained 89% of the variation and second axis, 8.7%.



concentrations were adjusted for the lipid and carbon source descriptors and other variables (sex and age), if these were included in the most parsimonious models (Table 2). Subsequently, adjusted element levels were compared to those reported previously for the unadjusted levels in the same individuals (Routti et al. 2011). Furthermore, the effect of carbon and lipid source variation on pair-wise differences between subpopulations was tested by running a *post hoc* Tukey's HSD test after and before adjusting the trace element concentrations for carbon and lipid source descriptors. After adjusting for carbon and lipid source descriptors, this meant that the trace element concentrations were adjusted according to all the variables included in the most parsimonious models (Table 2). Before adjusting for carbon and lipid source descriptors, this means that the trace element concentrations were adjusted only to other variables (age and sex) if these were included in the most parsimonious models (Table 2). Level of significance was set to $\alpha \leq 0.05$.

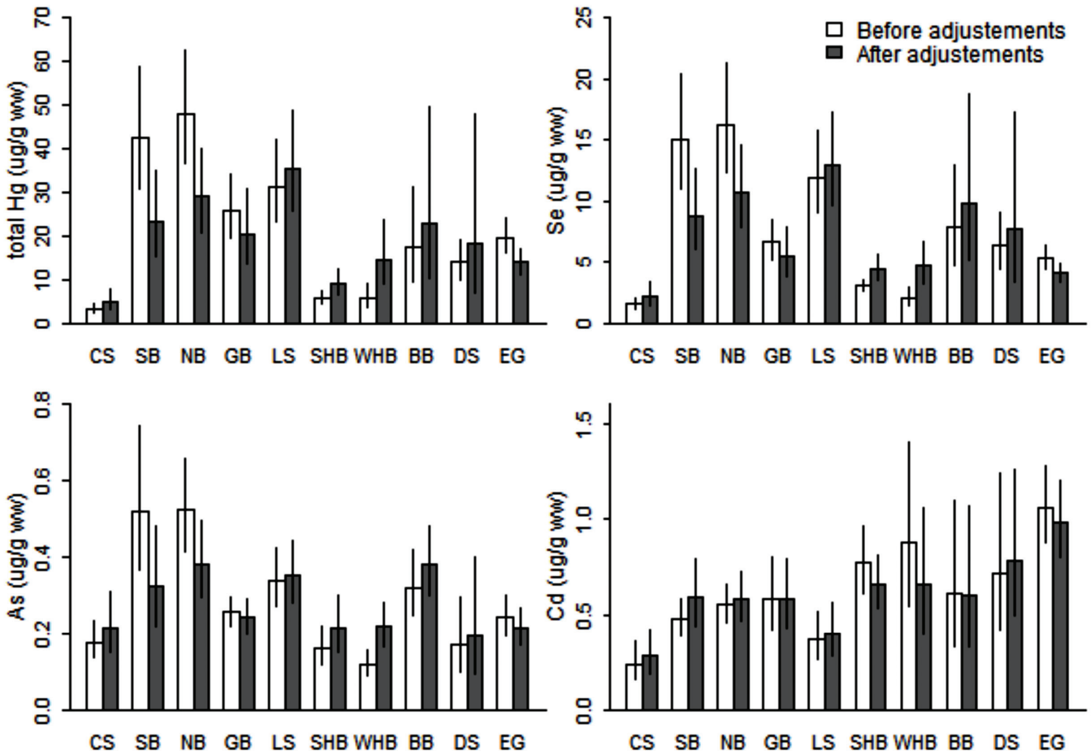
When adjusted for carbon and lipid sources as measured by $\delta^{13}C$ and FA tracers, total Hg concentrations were significantly different from concentrations that were not adjusted (Figure 2). Mean total Hg concentrations were higher in southern and western Hudson Bay polar bears and lower in southern and northern Beaufort Sea subpopulations when adjusted for $\delta^{13}C$ and FA tracers as compared to unadjusted concentrations.

Discussion and Conclusions

Regional variation in carbon and lipid sources

$\delta^{13}C$ values are enriched going from terrestrial/freshwater organic matter to pelagic phytoplankton to ice algae and benthos (Hobson 1999). The depleted $\delta^{13}C$ signatures in the polar bears from the Beaufort Sea and Hudson Bay (Table 1) may originate from input of terrestrial organic carbon by rivers including Mackenzie running in the Beaufort Sea and several rivers feeding Hudson Bay basin (Goñi et al. 2000; Mundy et al. 2010). Although Hudson Bay polar bears spend prolonged seasonal periods on land, incorporation of terrestrial-based carbon from feeding on berries has been suggested to be a minor part of their carbon bulk (Hobson and Stirling, 1997). The depleted $\delta^{13}C$ values in East Greenland polar bears (Table 1) may be related to the phenomena that freshwater from the Arctic Ocean originating mainly from Russian and Canadian river runoff is strongly confined nearly to the East Greenland coast, as the majority of the polar sea ice are transported southward along the East Greenland shores, where it melts as it meets with warmer ocean currents (Jones et al. 2008).

Figure 2. Geometric mean concentrations (µg•g^{-1} wet weight ± 95% confidence intervals) of total Hg, Se, As and Cd in liver of polar bears from ten subpopulations before (Routti et al. 2011) and after adjusting for lipid and carbon sources (see Table 2 for details).



Major FAs included 20:1n-9, 20:5n-3, 22:5n-3, 22:6n-3 and 18:2n-6 as presented in detail by McKinney et al. (2011a). These FAs originate from pelagic herbivorous plankton and phytoplankton such as *Calanus* copepods, diatoms, dinoflagellates and *Phaeosystis pouchetii* (Dalsgaard et al. 2003). The FA composition in polar bears thus suggests that polar bear diet is coupled mainly to the pelagic marine food web, which is in agreement with previous carbon SI estimations reported by Hobson et al. (2002). The first axis explaining 64% of the FA variation distinguished mostly between 20:1n-9 and 22:1n-9, and 20:5n-3 (figure not shown; see Routti et al. 2012). Correspondence analysis indicated that FA composition differed among the polar bear subpopulations, while the variation between seasons and sexes was minor. This is similar to previously results reported by McKinney et al. (2011a). In the present study, the bears from lower latitude Hudson Bay and Chukchi Sea populations had lower proportions of 20:1n-9 and 22:1n-9 compared to the polar bears from higher latitudes. The FAs 20:1n-9 and 22:1n-9 are biosynthesized by *Calanus* copepods and used as specific markers for this taxon (Dalsgaard et al. 2003), which is the major zooplankton taxa in the high Arctic (Hop et al. 2006; Hopcroft et al. 2005). The present results suggested that *Calanus* copepods are proportionally greater in the polar bear food webs in higher latitudes as compared to those from lower latitudes. This is in accordance with differences reported elsewhere in zooplankton composition between Hudson Bay, Chukchi Sea and the remaining areas (Harvey et al. 2001; Hopcroft et al. 2010; Leitch et al. 2007).

Relationships between carbon and lipid sources and trace elements

Total Hg concentrations were negatively related to $\delta^{13}C$ (Figure 1a; β= -0.27 [-0.45, -0.09]), which is in accordance with a previous report on Hg in polar bears from western Hudson Bay and southern Beaufort Sea (St. Louis et al. 2011). As mentioned earlier, depleted $\delta^{13}C$ signatures (Table 1) may originate from terrestrial organic carbon transported by rivers. Riverine transport is also a major source of Hg to the Arctic Ocean (Leitch et al. 2007). Thus, polar bear food webs rich in river-exported carbon may lead to elevated total Hg concentrations in polar bears. Concentrations of total Hg also showed positive relationship with $FA_{ind}1$ (Figure 1a; β=1.5 [0.9, 2]), which was positively loaded with the *Calanus* FA marker 20:1n-9. This raises the question whether food webs rich in *Calanus* accumulate more Hg compared to food webs deficient in *Calanus*. Previous studies on beluga whales found positive correlations between total Hg concentrations in liver and muscle and long chain monounsaturated fatty acids (20:1n-7, 20:1n-9, 22:1n-9 and 22:1n-11) (Loseto et al. 2008), which are biosynthesized in *Calanus*-copepods (Dalsgaard et al. 2003). After an extensive literature search, there is no comparative literature about Hg uptake by *Calanus* compared to the major zooplankton taxa from subarctic. *Calanus* may be exposed to relatively high Hg levels due to its foraging ecology. The key *Calanus*-copepod in Arctic shelf seas, C. glacialis, times its foraging to the ice algal bloom in April, while their offspring feeds on the phytoplankton bloom following the sea-ice break-up (Soreinde et al. 2010). Interestingly, Hg concentrations in sea-ice brines are highest in April and decrease with the progressing melting season when melt water flushes the brine into the underlying seawater (Chaulk et al. 2011). Hg concentrations were positively related with age (β= 0.0478 [0.016, 0.080], which is in accordance with previous studies on polar bears (Dietz et al. 1996; Douglas at al. 2011).

Se and As showed strong positive correlation with total Hg (r=0.97 [0.95, 0.98] and 0.80 [0.72, 0.85], respectively) and were thus positively related to $FA_{ind}1$ and negatively to $\delta^{13}C$ (Figure 1a). Se concentrations were also positively related to age. Strong correlations between Hg and Se have been reported by numerous wildlife studies, which is probably related to a detoxifying effect of Se on Hg (Dietz et al. 2011). Hg forms an equimolar inert tiaminite Se-complex Hg:Se (Gailer 2007) and the molar ratio of Hg:Se varied between 0.8 to 1.6 in the present polar bears which is at a similar range as previously observed in polar bears (Dietz et al. 2000). The underlying reason for the positive correlation of As with either Hg or Se is not clear. First, biomagnification potency of As has not been demonstrated in contrast to Hg (Anderson et al. 2010; Atwell et al. 1998; Barwick et al. 2003; Campbell et al. 2005). Second, although arsenite (As^{3}+) and Se may interact by forming an equimolar complex with glutathione (Gailer 2007), the major As form in marine mammals (seals) and birds is arsenobetaine (Fujihara et al. 2003), which is not known to interact with Se. However, different forms of As have not been investigated in polar bears, and further research is warranted to investigate the underlying reason for strong correlations of As with Hg and Se.

Cd concentrations were positively related to $FA_{ind}2$ (Figure 1a; β=1.5 [0.6, 2.3]), which loaded negatively with FA 20:4n-6. This suggests enrichment of Cd from near-shore to the pelagic environment, since 20:4n-6 is synthesized in macro-algae growing in shallow waters (<12m) (Graeve et al. 2002). This is in agreement with increasing Cd levels from inner fjord system towards open sea in e.g. the Greenland environment (Riget et al. 2004). In case of Cu, Mn, Rb and Zn, these were not related to carbon or lipid source descriptors (Figure 1a). Cu, Mn and Zn are all essential elements and their uptake is naturally regulated by organisms, while the role of Rb as a micronutrient has been discussed (Nielsen 1998).

Influence of carbon and lipid sources on subpopulation differences in trace element concentrations

In Routti et al. (2011), we recently reported that total Hg concentrations in polar bears from northern and southern Beaufort Sea were higher than in any other subpopulations except Lancaster/Jones Sound and the Gulf of Boothia, while total Hg concentrations were lower in southern and western Hudson Bay polar bears compared to any other subpopulation except Davis Strait and Chukchi Sea. The subpopulation differences of concentrations of total Hg adjusted for carbon and lipid sources were less pronounced than unadjusted trends among these subpopulations (Figure 2). Adjusted total Hg concentrations in southern and northern Beaufort Sea polar bears were generally not higher compared to other subpopulations ($0.12<p<1$; $p=0.06$ for northern Beaufort Sea – East Greenland; southern Beaufort Sea – southern Hudson Bay $p=0.001$) except Chukchi Sea ($p<0.001$). Total Hg concentrations adjusted for carbon and lipid sources in polar bears from western Hudson Bay were similar to all the subpopulations ($0.15<p<1$) and higher than in Chukchi Sea polar bears ($p=0.042$). Adjusted total Hg concentrations for southern Hudson Bay subpopulation were still lower compared to polar bears from northern Beaufort Sea and Lancaster/Jones Sound ($p\geq0.001$). Since Se and total Hg concentrations were strongly correlated, concentrations of Se adjusted for carbon and lipid sources were less pronounced compared to unadjusted trends among these subpopulations (Figure 2). Concentrations of As adjusted for carbon and lipid sources were, in general, similar between subpopulations ($p>0.095$; East Greenland – northern Beaufort Sea p=0.024). However, subpopulation differences were observed in the unadjusted As concentrations (Routti et al. 2011)(Figure 2). Prior to adjustments for lipid source, concentrations of Cd in polar bears generally increased from east to west (Routti et al. 2011). However, after adjustments this trend was less pronounced (Figure 2).

The present 2011-2012 results suggested that differences in Hg, Se, As and Cd concentrations among polar bear subpopulations are partly explained by variation in carbon and lipid sources. Low concentrations of total Hg concentrations adjusted for carbon and lipid sources in Chukchi Sea polar bears may be related to Hg concentrations in water. Dissolved gaseous Hg in surface waters from the Chukchi/Bering Sea has also been reported to be low compared to the remaining Arctic (Andersson et al. 2008). Chukchi/Bering Sea is influenced by inflow of water from the Pacific Ocean, where evasion of gaseous mercury is not blocked by ice cover (MacDonald et al. 2005).

Confounding factors – methylated Hg species in water column and food web length

A recent study comparing total Hg levels in hair of polar bears from western Hudson Bay and the southern Beaufort Sea concluded that the differences in total Hg levels between these two subpopulations may be related to both length of the food web and pelagic concentrations of MeHg concentrations (St. Louis et al. 2011). MeHg concentrations in the water column vary between the Canadian Arctic archipelago and Hudson Bay, while total Hg concentrations are similar in the different areas within the Canadian Arctic and sub-Arctic (Kirk et al. 2008; St. Louis et al. 2011). Monomethylated Hg is the toxic form of Hg accumulating in the food web, while elemental Hg has poor bioaccumulation potential (Mason et al. 1996). Although the present results suggested that total Hg variation among polar bear subpopulations is mainly explained by food web differences, the results for the Canadian subpopulations may be partly confounded by regional variation in MeHg species in the water column (Kirk et al. 2008; St. Louis et al. 2011). We had reported that the highest concentrations of total Hg (corrected for sex and age) were in polar bears from the Beaufort Sea, Lancaster Sound and Gulf of Boothia, followed by the Baffin Bay and Davis Strait, and Hudson Bay bears having the lowest Hg concentrations (Routti et al. 2011). Similarly, concentrations of MeHg in mid-depth and deep water column were reported to be highest in the southern Beaufort Sea and Lancaster Sound and lower for Davis Strait to Hudson Bay (Kirk et al. 2008; St. Louis et al. 2011). However, the geographical differences in MeHg concentrations in water column were smaller compared to differences that we observed among the polar bear subpopulations. Furthermore, the Beaufort Sea and Baffin Bay were shown not to have different MeHg concentrations in the water column (Kirk et al. 2008; St. Louis et al. 2011)as they did for total Hg concentrations in polar bears. Therefore, the difference that we presently observed in total Hg concentrations between Beaufort Sea and Baffin Bay subpopulations could be explained by differences in carbon and lipid sources between the Beaufort Sea and Baffin Bay.

Trophic biomagnification of Hg has been reported both in polar bears (Horton et al. 2009; Kirk et al. 2008) and marine food webs (Atwell et al. 1998; Rigét et al. 2007). We previously reported that $\delta^{15}N$ values varied among the polar bear subpopulations (McKinney et al. 2011a). As part of the present study, it was found that the $\delta^{15}N$ values were positively correlated with the concentrations of total Hg, Se and As. This suggested that regional differences in polar bear food web length play a role in explaining subpopulation differences in trace element concentrations. However, the trophic baseline of $\delta^{15}N$ values in Arctic marine food webs may vary significantly between geographical regions (Hobson et al. 1995; Pomerleau et al. 2011). Thus, the differences in $\delta^{15}N$ values among polar bear subpopulations do not necessary reflect their trophic position in food web. It is presently recommended that future studies will investigate the role of whole food web length in subpopulation variation of trace element concentrations in polar bears. This will require thorough investigation of $\delta^{15}N$ values at lower trophic levels in order to properly adjust polar $\delta^{15}N$ values to possible variation of $\delta^{15}N$ baseline.

Conclusions

The present study demonstrates the importance of including information of carbon and lipid sources when interpreting the spatial trends of certain trace elements in polar bears. Subpopulation differences are partly explained by variation in carbon and lipid sources, but MeHg in water column and food web length may also play an important role in total Hg concentrations in apex predators. It has been proposed that trace element concentrations in arctic apex predators may change during the next decades, as Hg and Cd emissions are expected to increase due to the increasing use of coal in Asia and worldwide. For POPs, this is also with for example the use of PBDE flame retardants deceasing and alternate flame retardants increasing. In another example, perfluorinated compounds such as PFOS are expected to decrease, but with shorter chain and branched sulfonate and carboxylic acids and precursors to be produced. Additionally, changing climate may be affecting the natural cycles and long-range transport of these elements and POPs, as well as access, abundance and distribution of polar bear prey. Frequent bioaccumulative element and POP monitoring, and identification of presently unknown POPs, of both polar bear food web structure and exposure to such contaminants is thus important to detect possible and rapid changes. Such work will be continued in 2012-2013 and beyond, with the focus being on polar bears from Hudson Bay.

Expected Project Completion Date

All aspects of the pan-Canadian spatial trends phase of this project and based on the 2007 and 2008 (IPY years) pan-Canadian/circumpolar sample collections (e.g., data generation, data compilation and interpretation, data interpretation and writing of papers) are expected to be fully completed by the end of 2012. The new and continuing phase of this core contaminant monitoring project began in 2009-2010 and will continue in this NCP 5 year cycle, with the collection of new polar bear (fat, liver and muscle) samples from individuals for longer-term and annual temporal trends assessments of bear in priority subpopulation in Hudson Bay.

Acknowledgments

We formally acknowledge and are thankful of the funding support provided by the NCP for this arctic core monitoring work, including the reviews and comments on the original proposal from the NCP Technical Review Teams, Regional Contaminants Committees and the Niqiit Avatittinni Committee (NAC). The PI and team members thank all individuals (e.g. northern peoples, field biologists and students) and agencies that have and will continue to participate in this ongoing project. The collection of polar bear tissues in Nunavut for contaminant analysis was initiated and carried out by the Department of Sustainable Development (Government of Nunavut), which was included as part of the normal sampling of all polar bear that are collected as part of the traditional hunt by northern peoples. Many thanks to the hunters and trappers organizations and conservation officers for coordinating sample collection.

NCP Performance Indicators (April 1, 2011 – March 31, 2012)

Performance Indicator	Number	Detail / Description
Number of northerners engaged in this project	22	The number of northerners (directly and indirectly) involved in or engaged in this project is large, including: NWT and Nunavut team members - 4 (Dyck, Atkinson, Coxon, Branigan) Community Conservation officers = 6; at least one for each of the 6 participating Hudson Bay (Sanikiluaq, Whale Cove, Rankin Inlet and Arviat) and Baffin Bay (Pond Inlet and Clyde River) communities HTA representatives = 6; at least one for each of the 6 participating Hudson Bay (Sanikiluaq, Whale Cove, Rankin Inlet and Arviat) and Baffin Bay (Pond Inlet and Clyde River) communities Community hunters = 6; at least one for each of the 6 participating Hudson Bay (Sanikiluaq, Whale Cove, Rankin Inlet and Arviat) and Baffin Bay (Pond Inlet and Clyde River) communities
number of meetings/workshops held in the North	0	Since early 2011, Dr. Letcher has been in communication with the polar bear biologists in the government of Nunavut, Atkinson and Coxon, as to the possibility of arranging a meeting and information exchange sometime in 2012. Discussions continued with Mr. Markus Dyck becoming the new polar bear biologist in 2012. With NCP support, Dr. Letcher is anticipating to visit Igloolik in conjunction with the NCP 2012 Results Workshop in Inuvik, NWT (in mid-Sept. 2012).
number of students involved in project	6	The students and Post Doctoral Fellows involved in this project in 2011-2012 have been southerners or international, and are presently listed: • Dr. Heli Routti: PDF, via Carleton University, Dr. Letcher as supervisor. • Ms. Alana Greaves: MSc candidate, Carleton University, Dr. Letcher as supervisor • Dr. Melissa McKinney: PDF, via Dalhousie University, Halifax, NS; Dr. Letcher as collaborator • Ms. T.Ø. Bechshøft: PhD candidate, via Aarhus University (Roskilde, Denmark), Dr. Rune Dietz as supervisor (Dr. Letcher, PhD thesis committee member) • Ms. Gro D. Villanger: PhD candidate, via Norwegian Science and Technology University (Trondheim, Norway), Dr. Bjorn Jenssen as supervisor (Dr. Letcher, PhD thesis collaborator) • Mr. Adam Morris: PhD candidate, via University of Guelph, Dr. Derek Muir and Dr. Keith Solomon as supervisors (Dr. Letcher, PhD thesis committee member)

NCP Performance Indicators (April 1, 2011 – March 31, 2012) continued

Performance Indicator	Number	Detail / Description
Number of citable publications	26	a) Domestic/international journals, book chapters, reviews, reports, etc. (n=11) • The number of citable publications, book chapters, reviews, etc. from or related to this project as of 2011-2012 is comprised of 3 review articles (Houde et al. 2011; Riget et al. 2011; Sonne et al. 2011) and 7 research articles (Bechshøft et al. 2012a, 2012b; McKinney et al. 2011a, 2011b, 2011c; Routti et al. 2011; Sonne et al. 2011; Villanger et al. 2011). One report to NCP-AANDC was submitted in 2011-2012 (Letcher et al. 2011). b) Conference and workshop presentations (n=15) Conference and workshop presentations made in 2011-2012 that were related to this project are listed below: Department of Biology Seminar Series, Université du Québec à Montréal (UQAM), Dec. 7, 2011, Montréal, QC, Canada. • INVITED ORAL: R.J. Letcher, *"Influence of diet and food web on spatial and temporal trends of organohalogen and mercury contaminants in polar bears (Ursus maritimus) from circumpolar subpopulations"*. 19th Biennial Conference on the Biology of Marine Mammals, Nov. 26-Dec. 2, 2011, Tampa, FL, U.S.A: • ORAL: T.Ø. Bechshøft, C. Sonne, R. Dietz, J. Jakobsen, J.S. Meyer, M.A. Novak, E. Henchey, F.F. Rigét, E.W. Born, I. Eulaers, V. Jaspers, A. Covaci, R.J. Letcher, *"Biomarkers of POP exposure in East Greenland polar bears (Ursus maritimus)"*. • ORAL: R. Dietz, F.F. Rigét, C. Sonne, E.W. Born, R. Bossi, K. Gustavson, T.Ø. Bechshøft, P. Grandjean, M.A. McKinney, D.C.G. Muir, R.J. Letcher, *"The East Greenland polar bear as a messenger of global temporal contaminant trends"*. 32nd Annual Society of Environmental Toxicology and Chemistry (SETAC) Meeting, Nov. 11-15, Boston, MA, U.S.A.: • POSTER: A.K. Greaves, R.J. Letcher, C. Sonne, R. Dietz, E.W. Born, *"Brain region and tissue distribution and patterns of bioaccumulative perfluoroalkyl acids (PFAAs) in highly exposed East Greenland polar bears"*. NKVet Symposium, Oct. 6-7, 2011, Helsinki, Finland: • ORAL: C. Sonne, R.J. Letcher, T.Ø. Bechshøft, F.F. Rigét, D.C.G. Muir, P.S. Leifsson, E.W. Born, L. Hyldstrup, N. Basu, M. Kirkegaard, R. Dietz, *"Two decades of biomonitoring polar bear health in Greenland: A review"*.

NCP Performance Indicators (April 1, 2011 – March 31, 2012) continued

Performance Indicator	Number	Detail / Description
Number of citable publications	26	International Symposium on Advanced Studies by Young Scientists on Environmental Pollution and Ecotoxicology, Aug. 4-7, 2011, Matsuyama, Japan.: • INVITED ORAL: M.A. McKinney, R.J. Letcher, R. Dietz, C. Sonne, S.J. Iverson, A.T. Fisk, B.C. McMeans, A. Morris, G.T. Tomy, D.C.G. Muir, S.A. Ferguson, E. Peacock, E.W. Born, M. Branigan, N.J. Lunn, I. Stirling, T.J. Evans, J. Aars, G.W. Gabrielsen, *"Using trophic tracers to interpret contaminant levels, patterns and trends in polar bears and arctic marine food webs"*. 19th Annual Results Workshop of the Northern Contaminant Program (NCP), Canadian Arctic Contaminants Assessment Symposium, Sept. 20-21, 2011, Whitehorse, Yukon, Canada. • ORAL: R.J. Letcher, H. Routti, M. Branigan, A. Coxon, A. Fisk, M.A. McKinney, E. Peacock, *"Mercury and other bioaccumulative metals: Spatial and temporal trends in polar bears from Canadian subpopulations"*. 31st International Symposium on Halogenated Persistent Organic Pollutants (DIOXIN 2011), Aug. 21-25, 2011, Brussels, Belgium: • PLENARY ORAL: R.J. Letcher, *"Current species models of wildlife toxicology and the effects of emerging organohalogen substances"*. Arctic Monitoring and Assessment Program (AMAP) conference, *"The Arctic as a Messenger for Global Processes – Climate Change and Pollution"*, May 4-6, 2011, Copenhagen, Denmark: • POSTER: R.J. Letcher, M.A. McKinney, G.T. Tomy, S.G. Chu, R. Dietz, C. Sonne, D.C.G. Muir, C.M. Butt, S. De Guise, *"Differential perfluorooctane sulfonate (PFOS) levels in Arctic marine top predators and the influence of biotransformation of PFOS precursors (or "PreFOS")"*. • POSTER: H. Routti, R.J. Letcher, E.W. Born, M. Branigan, R. Dietz, T.J. Evans, A.T. Fisk, M.A. McKinney, E. Peacock, C. Sonne, *"Selected trace elements in polar bears (Ursus maritimus) from Alaska, Canada and Greenland: Spatio-temporal trends and role of biological factors"*. • ORAL: C. Sonne, R.J. Letcher, M.A. McKinney, F.F. Rigét, P.S. Leifsson, L. Hyldstrup, T.Ø. Bechshøft, N. Basu, E.W. Born, D.C. G. Muir, R. Dietz, *"Monitoring the health of East Greenland polar bears (Ursus maritimus): 1999-2010"*.

NCP Performance Indicators (April 1, 2011 – March 31, 2012) continued

Performance Indicator	Number	Detail / Description
Number of citable publications	26	• POSTER: T.Ø. Bechshøft, C. Sonne, R. Dietz, J. Jakobsen, J.S. Meyer, M.A. Novak, E. Henchey, F.F. Riget, E.W. Born, A. Covaci, I. Eulaers, V. Jaspers, R.J. Letcher, *"Biomarkers of POP exposure in East Greenland polar bears (Ursus maritimus)"*. • ORAL: R.J. Letcher, M.A. McKinney, J. Aars, E.W. Born, M. Branigan, E. Choy, R. Dietz, T.J. Evans, G.W. Gabrielsen, D.C.G. Muir, E. Peacock, C. Sonne, *"Subpopulation-Specific Influence of Diet and Other Factors on the Spatial Trends of Chlorinated, Brominated and Fluorinated POPs in Polar Bears (Ursus maritimus)"*. • ORAL: R. Dietz, F.F. Rigét, C. Sonne, E.W. Born, R. Bossi, T.Ø. Bechshøft, P. Grandjean, D.C.G. Muir, R.J. Letcher, *"Temporal trends of chlorinated, brominated and fluorinated POPs and mercury, in East Greenland polar bears (Ursus maritimus) within the last four decades"*. • POSTER: M.A. McKinney, R.J. Letcher, I. Stirling, N. Lunn, E. Peacock, *"Sea-Ice conditions and the influence of diet and on temporal trends (1991-2007) of organohalogen contaminants in western Hudson Bay polar bears (Ursus maritimus)"*.

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Temporal Trends of Halogenated Organic Compounds in Canadian Arctic Beluga and Walrus

Tendances temporelles des composés organiques halogénés chez le béluga et le morse de l'Arctique canadien

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Abstract

The objectives of this on going study are to maintain current data on contaminant levels in marine mammals and to continue to assess the temporal trends of halogenated organic compounds (HOCs). This will allow us to determine whether the levels of these compounds 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 CFL (IPY & NSERC) and ArcticNet, to understand the effects that climate variation may have on these contaminant levels.

Résumé

La présente étude, qui est encore en cours, a pour but de tenir à jour les données sur les concentrations de contaminants chez les mammifères marins et de poursuivre l'évaluation des tendances temporelles des composés organiques halogénés (COH). Cela nous permettra de déterminer si les concentrations de ces composés chez les mammifères marins et, par conséquent, l'exposition des habitants de l'Arctique qui, traditionnellement, les consomment, changent au fil du temps. Ces résultats permettront aussi de vérifier l'efficacité des contrôles internationaux et, de concert avec des projets comme l'étude sur le chenal de séparation circumpolaire (Année polaire internationale et Conseil de recherches en sciences naturelles et en génie) et ArcticNet, de comprendre les effets que les variations climatiques peuvent avoir sur ces concentrations de contaminants.

Key Messages

- No trends were observed for major OC groups in the western Arctic beluga. In particular, HCHs levels are not showing the declines observed atmospherically and in the Arctic Ocean since the ban in the usage of the technical mixture by China in 1983 and followed by India in 1990.
- Since 2006, on average, only four beluga were collected and analyzed annually from Pangnirtung. Zero in 2011. Such a small sample size makes any interpretation of the results highly improbable. Conversely, through funding from NWMB (until 2009) and DFO, we have managed to accumulate an excellent series of samples from Sanikiluaq (1994, 1995, 1998, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011). As such, we propose, once again, that NCP consider switching our eastern Arctic temporal beluga monitoring location to Sanikiluaq. This will, however, entail additional retrospective analysis and costs to NCP.

Messages Clés

- Aucune tendance n'a été observée pour les principaux groupes de COH chez le béluga de la partie ouest de l'Arctique. Plus particulièrement, les niveaux d'hexachlorure de benzène (HCH) ne reflètent pas les baisses observées dans l'atmosphère et dans l'océan Arctique depuis l'interdiction des mélanges techniques par la Chine en 1983, puis par l'Inde en 1990.
- Depuis 2006, en moyenne, seulement quatre bélugas ont été capturés et étudiés annuellement à Pangnirtung, et aucun ne l'a été en 2011. Un échantillonnage de si petite taille rend l'interprétation des résultats très improbable. Cependant, grâce à un financement du Conseil de gestion des ressources fauniques du Nunavut (CGFN) (jusqu'en 2009) et de Pêches et Océans Canada, nous avons réussi à constituer une excellente série d'échantillons provenant de Sanikiluaq (1994, 1995, 1998, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011). D'ailleurs, nous proposons, encore une fois, que les représentants du Programme de lutte contre les contaminants dans le Nord (PLCN) examinent la possibilité de déplacer à Sanikiluaq la station de surveillance temporelle du béluga de l'est de l'Arctique. Cela engendrerait cependant des analyses rétrospectives et des coûts additionnels pour le PLCN.

Objectives

To continue to assess long term trends and to maintain the current data-base on levels of halogenated organic compounds (e.g. PCBs, DDT, toxaphene) in marine mammals (beluga, narwhal, walrus) from selected locations across the Canadian Arctic

Introduction

Marine animals accumulate (relatively) high concentrations of halogenated organic compounds (HOCs). The objectives of this project, therefore, are to maintain current data on contaminant levels in marine mammals and to continue to assess the temporal trends of 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 the IPY CFL (Circumpolar Flaw Lead) System Study and ArcticNet Phase 1 and II to understand the effects that climate variation may have on the contaminant levels in these animals and the health of the stocks.

The raw data and samples from previous and ongoing investigations are archived in the Freshwater Institute and represent about 2000 marine mammals, mostly beluga, ringed seals, narwhal and walrus from 23 different locations across the Canadian Arctic. DFO scientists concerned with stock management, animal health and climate change studies obtain various samples from hunter kills and those samples form the basis of most of our analyses. For example, tissues from eastern Arctic and Hudson Bay beluga have been collected and analyzed for HOCs as part of DFOs stock management studies since 1996. In the western Arctic the collections have been supported by FJMC since 2002. The accumulating data resulting from these studies offer the means to detect both spatial and temporal trends of HOCs and heavy metals in Arctic marine mammals and most importantly to try and link the observed variation to physical and biological process and carbon and contaminants cycling within the Arctic Ocean.

Activities In 2011/12

Samples collected and analysed to date are in Tables 1- 4. Since 2006, on average, only four beluga were collected and analyzed annually from Pangnirtung. None in 2011. Such a small sample size makes any interpretation of the results highly improbable. Conversely, through funding from NWMB and DFO, we have managed to accumulate an excellent series of samples from Sanikiluaq (1994, 1995, 1998, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011). As such, we propose, once again, that NCP consider switching our eastern Arctic temporal beluga monitoring location to Sanikiluaq. This will, however, entail additional retrospective analysis and costs to NCP.

Results

As part of an ongoing whale sampling and stock identity program, supported by the Nunavut Wildlife Management Board (NWMB), FJMC, NIF and DFO, samples were collected by hunters during their subsistence hunts using standardized whale kits. Blubber, kidney, liver, ovaries and uterus, muscle and the lower jaw, as well as morphometric data were collected for each animal. All samples were shipped frozen to the Freshwater Institute and stored at - 20°C until analysis.

We now have a very unique long term data set for HOCs in western Arctic beluga; fourteen time points spanning twenty one years. As shown in Table 1, no real trends are evident. Of particular interest is the fact that HCHs are not showing the declines observed atmospherically and in the Arctic Ocean (Li et al., 2004) since the ban in the usage of the technical mixture by China in 1983 and followed by India in 1990. As was postulated for mercury, the lack of response of HCH in western Arctic beluga to the declining levels in the Arctic atmosphere and Ocean could be, at least in part, attributed to recent changes in ice cover, which may, for example, alter the foraging of the beluga whales or their prey (Stern and Macdonald, 2005; Gaden et al. 2009, 2010; Loseto et al. 2006, 2008a,b, 2009; Kuzyk et al. 2010). First results from IPY CFL and ArcticNet Phase II field programs designed to try and determine the effects that climate change will have on the ocean-sea ice-atmosphere coupling of hexachlorocyclohexane (HCH) and transport within the western Arctic have been published (Pucko et al. 2010a,b, Pucko et al. 2011, 2012).

Aging of the 2007- 2010 Hendrickson Island beluga have now been completed. The aging of the 2011 animals should be completed before the end of the current calendar year.

Expected Project Completion Data

This study, in conjunction with the trace metal work, is expected to be on going

NCP Performance Indicators

Performance Indicator	Number	Detail / Description
Number of northerners engaged in your project		All samples included in this study were collected as part of community monitoring programs.
meetings/ workshops held in the North	2	1) March 07, 2012. Beluga results meeting in Tuktoyaktuk 2) April 12-15, 2011. ArcticNet IRIS meeting in Inuvik
citable publications	12	1) Gaden, A.; Ferguson, S.; Harwood, L.; Melling, H.; Alikamik, A.; Stern, G.A.; 2012 Western Canadian Arctic ringed seal organochlorine contaminant trends in relation to sea ice break-up. Environ. Sci, Technol. 46, 4427–4433. 2) Gaden, A.; Ferguson, S. H.; Harwood, L.; Melling, H.; Stern, G. A. Mercury Trends in Ringed Seals *(Phoca hispida)* from the Western Canadian Arctic since 1973 : Associations with Length of Ice-Free Season. Environ. Sci Technol. 2009, 43, 3646-3651. 3) Gaden, A. and Stern, G.A., Temporal Trends in Beluga, Narwhal and Walrus Mercury Levels: Links to Climate Change. In A Little Less Arctic: Top Predators in the World's Largest Northern Inland Sea, Hudson Bay, edited by S.H. Ferguson, L. L. Loseto, and M. L. Mallory (Springer, 2010), pp. 197. 4) Kuzyk, Z.A.; Macdonald, R.W.; Johannessen, S.C.; Stern, G.A. 2010. Biogeochemical controls on PCB deposition in Hudson Bay. Sci. Technol. 44, 3280–3285. 5) Loseto, L. L.; Stern, G. A.; Deibel, D.; Connelly, T. L.; Prokopowicz, A.; Fortier, L.; Ferguson, S. H. 2008a. Linking mercury exposure to habitat and feeding behaviour in Beaufort Sea beluga whales. J. Marine Systems, Special Issue: Sea ice and life in a river-influenced arctic shelf ecosystem, 74, 1012. 6) Loseto, L. L.; Stern, G. A.; Ferguson, S.H. 2008 Size and biomagnification: How habitat selection explains beluga mercury levels. Environ. Sci. Technol. 11, 3982-3988. 7) Loseto, L.L.; Stern, G.A.; Deibel, D.; Connelly, T.; Gemmill, B.; Prokopowicz, A.; Fortier, L.; Ferguson, S.H. 2009. Summer diet of beluga whales inferred by fatty acid analysis of the eastern Beaufort Sea food web. J. Experimental Marine Biology and Ecology, 374, 12-18. 8) Pućko, M.; Stern, G.A.; Macdonald, R.W.; Barber, D.G. 2010. 2α- and γ hexachlorocyclohexane (HCH) measurements in the brine fraction of sea ice in the Canadian High Arctic using a sump-hole technique. Environ. Sci. Technol. 44, 9258-9264. 9) Pućko, M.; Stern, G.A.; Barber, D.G.; Macdonald, R.W.; Rosenberg, B. 2010. International Polar Year (IPY) Circumpolar Flaw Lead (CFL) System Study: the importance of brine processes for α- and γ-hexachlorocyclohexane (HCH) accumulation/ rejection in the sea ice. Atmosphere-Ocean, 48 (4) 2010, 0–00 doi:10.3137/OC318.2010. 10) Pućko, M.; Stern, G.A.; Macdonald, R.W.; Rosenberg. B.; Barber, D.G. 2011a. The influence of the atmosphere-snow-ice-ocean interactions on the levels of hexachlorocyclohexanes (HCHs) in the Arctic cryosphere. J. Geophysical Research – Oceans. 116, C02035, doi:10.1029/2010JC006614. 11) Pućko, M.; Stern, G.A.; Macdonald, R.W.; Barber, D.G.; Rosenberg. B.; Walkusz, W. When will α-HCH disappear from the Arctic Ocean? Submitted to Journal of Marine Systems, March, 2012 12) Chaulk, A.; Stern, G.A.; Armstrong, D.; Barber, D.G.; Wang, F. 2011. Mercury distribution and transport across the ocean-sea ice-atmosphere interface in the western Arctic Ocean. Environ. Sci. Technol., 45, 1866–1872

Table 1. Mean (stdev) of major HOC groups and compounds in blubber from western Arctic beluga (ng g^{-1}, wet wt).

Loc	Year	Sex	n	Age	%lipid	ΣCBz	ΣHCH	ΣCHL	ΣDDT	ΣPCB	ΣCHB	Diel-drin	Oxy-chlor
HL	1989	M	12	29.0 (15.0)	90.5 (3.7)	421.5 (185.9)	269.3 (111.3)	1857.6 (667.8)	2930.8 (1125.8)	3800.0 (1587.7)	4548.0 (1462.6)	297.5 (112.1)	487.7 (143.6)
HI	1994	M	10	33.4 (10.8)	93.3 (2.8)	669.6 (168.7)	215.8 (55.5)	1601.4 (495.5)	4283.8 (2591.7)	3949.1 (1819.5)	11207.4 (6735.6)	324.2 (118.4)	477.0 (109.9)
HI	1995	M	15	32.1 (10.4)	81.3 (3.3)	783.2 (380.4)	211.9 (40.6)	2076.2 (1025.8)	3907.7 (1753.7)	4176.6 (1473.3)	6701.0 (3207.3)	287.9 (141.7)	519.1 (348.2)
HI	1996	M	10	27.5 (6.8)	92.4 (4.6)	666.3 (117.5)	243.0 (23.3)	1803.1 (274.0)	4415.3 (2030.9)	4246.8 (1146.9)	10519.3 (4708.5)	397.7 (133.4)	498.3 (45.0)
HI	2001	M	18	32.3 (9.7)	82.2 (3.5)	518.7 (169.4)	205.5 (44.0)	1932.4 (808.5)	3445.1 (1633.7)	3986.7 (1737.5)	6266.4 (3634.6)	296.9 (103.9)	499.0 (225.6)
HI	2002	M	9	30.4 (8.1)	90.9 (2.2)	421.1 (109.1)	234.3 (34.8)	1408.9 (351.3)	2480.3 (1361.5)	2745.7 (1033.7)	7024.5 (3324.2)	376.0 (113.4)	439.9 (126.1)
HI	2003	M	9	27.2 (9.3)	91.3 (3.9)	518.3 (113.2)	243.1 (50.1)	1556.5 (361.5)	2736.0 (2134.3)	3084.4 (1462.9)	6188.5 (2600.1)	338.4 (100.7)	519.7 (119.3)
HI	2004	M	10	25.3 (6.0)	85.1 (6.8)	888.0 (189.0)	329.2 (50.8)	2932.8 (535.7)	3747.0 (1928.3)	4894.1 (948.8)	7554.1 (2360.1)	500.7 (99.4)	744.8 (192.5)
HI	2005	M	10	26.8 (9.6)	92.4 (3.4)	623.5 (196.3)	269.3 (68.2)	2568.5 (1715.6)	4545.8 (3595.3)	3633.1 (1906.5)	5680.1 (3776.0)	447.0 (186.8)	991.7 (684.7)
HI	2006	M	14	23.6 (7.2)	90.8 (6.2)	567.6 (197.7)	229.8 (33.6)	1498.8 (416.7)	2017.0 (851.8)	3100.2 (1081.7)	3673.6 (1614.5)	289.0 (80.4)	518.23 (162.2)
HI	2007	M	10	25.0 (19.2)	86.0 (9.9)	650.1 (251.8)	254.7 (31.9)	2236.1 (853.1)	3805.4 (2124.4)	3744.1 (1391.8)	7226.1 (3276.8)	359.3 (114.0)	698.4 (281.2)
HI	2008	M	10	35.6 (12.0)	80.1 (5.9)	392.4 (90.5)	121.5 (23.5)	1412.5 (582.7)	1348.7 (698.8)	3006.6 (1247.6)	4585.5 (2707.9)	209.2 (68.6)	290.5 (99.5)
HI	2009	M	10	33.7 (11.8)	94.0 (3.7)	434.8 (131.1)	191.2 (88.6)	1336.7 (380.6)	4309.7 (2317.5)	3697.7 1475.1)	7268.0 (4382.7)	347.7 (99.6)	432.0 (133.4)
HI	2010	M	10	25.5 (8.0)	92.1 (3.5)	497.7 (93.8)	222.4 (48.0)	1074.5 (260.1)	2619.5 (866.3)	2397.5 (438.4)	6081.2 (2470.8)	384.0 (97.2)	522.3 (104.3)
HI	2011	M	10	nd	92.4 (3.7)	590.2 (110.6)	2663.8 (66.2)	1768.6 (801.6)	3084.2 (2244.8)	3690.2 (2109.7)	4394.7 (2114.6)	484.7 (175.6)	517.7 (216.7)

HL = Husky Lakes; HI = Hendrickson Island; nd = not yet determined; ΣDDT = Sum of *p,p´*-DDT, *p,p´*-DDE, *p p´*-DDD, *o,p´*-DDT, *o,p´*-DDE and *o,p´*-DDD; SHCH = α- β- and γ-HCH isomers; ΣCHL = all chlordane related compounds, including heptachlor; ΣCBz = Sum of 1245TCB, 1234TCB, P5CBz, HCBz; ΣPCB = Sum of CB1, 3, 4/10, 7, 6, 8/5, 19, 18, 17, 24/27, 16/32, 26, 25, 31, 28, 33, 22, 45, 46, 52, 49, 47, 48, 44, 42, 41/71, 64, 40, 74, 70/76, 66, 95, 56/60, 91, 84/89, 101, 99, 83, 97, 87, 85, 136, 110, 82, 151, 144/135, 149, 118, 134, 114,131, 146, 153, 132, 105, 141, 130/176, 179, 137, 138, 158, 178/129, 175, 187, 183, 128, 185, 174, 177, 171, 156, 201/157, 172/197, 180, 193, 191, 200, 170, 190, 198, 199, 196/203, 189, 208, 195, 207, 194, 205, 206, 209

Table 2a. Mean (stdev) of major HOC groups and compounds in blubber from male Pangnirtung beluga (ng g^{-1}, wet wt).

Loc	Year	Sex	n	Age	%lipid	ΣCBz	ΣHCH	ΣCHL	ΣDDT	ΣPCB	ΣCHB	Diel-drin	Oxy-chlor
PG	1982	M	9	8.7 (5.8)	90.5 (2.4)	438.7 (79.0)	251.6 (57.5)	1614.2 (363.9)	5132.1 (2466.9)	4140.9 (1303.9)	9451.6 (2318.6)	604.7 (106.1)	271.7 (59.0)
PG	1986	M	16	5.8 (1.6)	90.9 (3.5)	376.8 (99.1)	259.4 (72.7)	1405.6 (318.2)	3233.8 (1051.4)	2569.8 (638.6)	7536.3 (1852.3)	449.4 (101.8)	290.5 (128.1)
PG	1991	M	3	8.7 (6.6)	94.7 (3.5)	549.2 (105.1)	348.6 (245.6)	2084.2 (836.1)	5387.5 (2074.2)	3368.0 (620.2)	15169.9 (9407.1)	1132.9 (937.1)	736.5 (280.9)
PG	1992	M	15	10.8 (5.6)	91.0 (2.2)	399.2 (203.6)	211.0 (77.7)	2067.0 (469.3)	5386.6 (1666.3)	3972.6 (986.4)	9801.8 (2522.5)	450.6 (170.6)	411.3 (124.0)
PG	1995	M	5	14.1 (8.6)	92.3 (3.3)	810.3 (550.0)	322.6 (205.5)	2628.9 (844.1)	4562.9 (3745.8)	4229.5 (1497.0)	16793.6 (8807.8)	1110.5 (565.3)	914.1 (338.6)
PG	1996	M	6	17.0 (5.5)	88.8 (2.9)	566.2 (188.2)	219.6 (57.6)	1685.3 (582.0)	6138.1 (798.6)	4783.1 (992.9)	12641.6 (3041.4)	666.2 (170.3)	194.9 (47.8)
PG	1997	M	9	12.1 (4.1)	91.2 (2.4)	789.2 (149.5)	233.6 (45.4)	1551.2 (772.2)	5290.5 (1879.9)	4015.6 (719.7)	9414.4 (3271.7)	1551.2 (772.2)	291.8 (180.8)
PG	2002	M	6	17.4 (3.8)	89.8 (2.4)	572.9 (220.1)	174.6 (66.6)	956.6 (439.1)	4072.3 (1203.9)	3772.9 (791.3)	6271.6 (1948.6)	359.8 (113.2)	145.4 (83.18)
PG	2005	M	7	nd	93.7 (2.0)	128.3 (83.9)	77.7 (25.7)	1145.3 (767.1)	2334.6 (1730.1)	1780.7 (1109.6)	3835.5 (1929.6)	295.9 (198.2)	357.5 (253.2)
PG	2006	M	3	nd	88.5 (1.9)	333.3 (159.5)	112.0 (33.4)	1422.3 (592.5)	1709.5 (849.5)	2368.7 (861.1)	4870.2 (1610.1)	420.6 (166.2)	431.7 (180.9)
PG	2007	M	1	nd	94.6	683.2	210.1	3129.2	4325.7	3772.4	15113.3	908.3	922.5
PG	2008	M	4	nd	74.1 (5.8)	154.7 (104.7)	55.3 (36.4)	1253.2 (749.9)	1265.9 (883.1)	2691.8 (1698.2)	6604.3 (5532.6)	224.7 (146.2)	253.5 (172.9)
PG	2009	M	1	nd	94.6	136.8	162.1	1247.2	1257.8	1570.0	4899.3	630.7	211.0

na = not yet determined; SDDT = Sum of *p,p′*-DDT, *p,p′*-DDE, p *p′*-DDD, *o,p′*-DDT, *o,p′*-DDE and *o,p′*-DDD; ΣHCH = α- β- and γ-HCH isomers; ΣCHL = all chlordane related compounds, including heptachlor; ΣCBz = Sum of 1245TCB, 1234TCB, P5CBz, HCBz; ΣPCB = Sum of CB1, 3, 4/10, 7, 6, 8/5, 19, 18, 17, 24/27, 16/32, 26, 25, 31, 28, 33, 22, 45, 46, 52, 49, 47, 48, 44, 42, 41/71, 64, 40, 74, 70/76, 66, 95, 56/60, 91, 84/89, 101, 99, 83, 97, 87, 85, 136, 110, 82, 151, 144/135, 149, 118, 134, 114,131, 146, 153, 132, 105, 141, 130/176, 179, 137, 138, 158, 178/129, 175, 187, 183, 128, 185, 174, 177, 171, 156, 201/ 157, 172/197, 180, 193, 191, 200, 170, 190, 198, 199, 196/203, 189, 208, 195, 207, 194, 205, 206, 209; nd = not yet determined

Table 2b. Mean (stdev) of major HOC groups and compounds in blubber from female Pangnirtung beluga (ng g-1, wet wt).

Loc	Year	Sex	n	Age	%lipid	ΣCBz	ΣHCH	ΣCHL	ΣDDT	ΣPCB	ΣCHB	Diel-drin	Oxy-chlor
PG	1986	F	4	3.5	92.9 (0.6)	404.8 (127.8)	292.7 (72.0)	1454.3 (572.6)	3238.7 (1522.3)	2783.0 (818.7)	8230.1 (1353.6)	514.0 (232.3)	335.3 (164.6)
PG	1991	F	7	4.2	94.5 (3.5)	1375.0 (1065.5)	420.4 (189.6)	2956.4 (1401.6)	7611.0 (5961.2)	4271.4 (2107.6)	20274.1 (8170.6)	1454.4 (762.1)	1034.3 (531.7)
PG	1992	F	8	13.1	91.6 (2.8)	246.8 (173.4)	173.5 (58.9)	1252.1 (493.0)	2482.1 (913.8)	2391.9 (847.5)	5784.8 (2409.6)	281.0 (102.6)	238.2 (111.4)
PG	1995	F	5	7.8	89.8 (7.9)	801.8 (415.2)	325.1 (93.0)	2473.3 (793.7)	3157.3 (889.3)	3265.3 (745.9)	15755.3 (9116.7)	1149.9 (413.7)	961.4 (391.4)
PG	1996	F	10	14.1	87.5 (7.2)	251.0 (209.4)	113.5 (65.0)	904.7 (655.6)	2521.2 (1589.1)	2047.8 (1433.1)	5324.7 (3786.7)	298.0 (231.0)	101.7 (56.6)
PG	2005	F	2	nd	92.1 (1.4)	150.0 (9.6)	78.6 (1.0)	919.7 (24.5)	1954.0 (208.6)	1882.5 (24.4)	3527.7 (309.0)	293.9 (44.2)	282.8 (21.0)
PG	2006	F	1	nd	82.4	334.5	150.7	886.4	747.2	1348.3	2553.9	340.8	226.2
PG	2007	F	3	nd	97.9 (3.2)	73.5 (45.4)	70.3 (43.4)	665.2 (424.4)	736.5 (545.3)	985.1 (484.2)	3369.9 (1558.6)	158.3 (96.9)	135.9 (110.6)
PG	2009	F	2	nd	94.1 (1.6)	139.5 (9.8)	88.0 (5.2)	719.5 (121.8)	1046.4 (44.1)	1389.2 (285.7)	3699.5 (798.9)	380.9 (28.3)	158.7 (47.6)
PG	2010	F	3	nd	88.6 (2.4)	323.4 (230.2)	127.2 (64.3)	614.5 (440.3)	1303.8 (991.5)	1022.1 (766.6)	11012.4 (8588.6)	839.7 (609.2)	315.7 (248.4)

na = not yet determined; SDDT = Sum of *p,p′*-DDT, *p,p′*-DDE, *p p′*-DDD, *o,p′*-DDT, *o,p′*-DDE and *o,p′*-DDD; SHCH = α- β- and γ-HCH isomers; ΣCHL = all chlordane related compounds, including heptachlor; ΣCBz = Sum of 1245TCB, 1234TCB, P5CBz, HCBz; ΣPCB = Sum of CB1, 3, 4/10, 7, 6, 8/5, 19, 18, 17, 24/27, 16/32, 26, 25, 31, 28, 33, 22, 45, 46, 52, 49, 47, 48, 44, 42, 41/71, 64, 40, 74, 70/76, 66, 95, 56/60, 91, 84/89, 101, 99, 83, 97, 87, 85, 136, 110, 82, 151, 144/135, 149, 118, 134, 114,131, 146, 153, 132, 105, 141, 130/176, 179, 137, 138, 158, 178/129, 175, 187, 183, 128, 185, 174, 177, 171, 156, 201/ 157, 172/197, 180, 193, 191, 200, 170, 190, 198, 199, 196/203, 189, 208, 195, 207, 194, 205, 206, 209; nd = not yet determined.

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Mercury in Beluga, Narwhal and Walrus from the Canadian Arctic: Status In 2012

Présence de mercure chez le béluga, le narval et le morse de l'Arctique canadien : situation en 2012

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Abstract

Additional samples of liver, kidney, muktuk and muscle of beluga whales were collected in 2011/2012 and analyzed for mercury and selenium. These new data were added to the growing database on concentrations of these elements in arctic marine mammals. All the new samples reported here were from beluga and none from narwhal or walrus. Mercury content varies among organs within an animal and among animals from a given site and time of collection. The growing data on mercury and selenium in these animals offer opportunities to test for differences among organs within individual animals at specific times and locations, among regions for particular organs and species and among years at locations where collections have been made repetitively. Tests for changes that relate to time or location or other variables become increasingly rigorous as new collections supply additional data. Of the organs analyzed in this study, liver typically has the highest concentrations of mercury,

Résumé

En 2011 2012, nous avons recueilli des échantillons supplémentaires de foie, de reins, de muktuk et de muscle de béluga et analysé leurs concentrations de mercure et de sélénium. Ces nouvelles données ont été versées dans une base de données sans cesse grandissante sur les concentrations de ces éléments chez les mammifères marins arctiques. Tous les nouveaux échantillons mentionnés dans le présent résumé ont été prélevés sur des bélugas, et non sur des narvals ou des morses. Les concentrations de mercure varient d'un organe à l'autre chez un même animal et d'un animal à l'autre, selon le lieu et le moment de la collecte. L'ensemble de données de plus en plus vaste sur le mercure et le sélénium chez ces animaux offre la possibilité de vérifier les variations de concentrations entre les organes d'individus à des moments et à des emplacements spécifiques, d'une région à l'autre en ce qui concerne les organes et les espèces et d'une année à l'autre lorsque des échantillons sont prélevés à répétition à certains

followed by kidney, muscle and muktuk. Mercury levels in any of the organs analyzed varied considerably from animal to animal with standard deviations often half or even more of the mean value, making it statistically difficult to detect differences among samples. Estimation of temporal change is complicated by the fact that mercury accumulates with age so that older animals usually have higher levels than younger ones from the same location. The role of age was further complicated for beluga when it was learned that these whales form one growth layer group in their teeth per year, not two as had been assumed previously (Stewart et al, 2006). Ages reported from before this information was developed have been doubled and recent age data are reported on the basis of one layer per year. Since the basis of comparison of mercury levels among different groups of beluga requires adjustment for differing ages, age data are critical. Usually the chemical analyses are completed prior to the age determinations and so there is a lag in the interpretations. Mercury and selenium in liver are related statistically and this is hypothesized to be the result of the formation of HgSe in biological tissues, possibly as a means to detoxify mercury.

endroits. Les essais portant sur les changements liés au moment ou à l'emplacement des collectes ou à d'autres variables deviennent de plus en plus rigoureux à mesure que de nouveaux ensembles de données s'ajoutent à la base. Parmi les organes analysés dans le cadre de cette étude, le foie est celui qui, en général, présente les plus fortes concentrations de mercure, suivi des reins, des muscles et du muktuk. Les concentrations de mercure dans les organes analysés variaient considérablement d'un individu à l'autre, les écarts types équivalant souvent à la moitié ou même plus de la valeur moyenne. Il est donc statistiquement difficile de déceler des différences parmi les échantillons. L'estimation du changement temporel se complique du fait que le mercure s'accumule avec l'âge, ce qui fait que les animaux plus âgés présentent habituellement des concentrations plus élevées que les jeunes d'un même emplacement. Le rôle de l'âge s'est davantage compliqué chez le béluga lorsque nous avons appris que ces baleines forment un groupe de couches de croissance par an dans les dents, et non pas deux comme nous l'avions cru jusqu'ici (Stewart et al., 2006). Les âges qui avaient été indiqués jusqu'alors ont été doublés, alors que les données récentes sont indiquées en fonction d'un seul groupe de couches de croissance par année. Étant donné que la base de comparaison des concentrations de mercure chez les différents groupes de bélugas demande un rajustement du fait des différences d'âge, les données sur l'âge sont essentielles. De façon générale, les analyses chimiques se font avant la détermination de l'âge, ce qui entraîne un délai dans l'interprétation. Les concentrations de mercure et de sélénium dans le foie sont liées statistiquement, et nous sommes d'avis qu'il s'agit du résultat de la formation de HgSe dans les tissus biologiques, possiblement comme moyen de détoxifier le mercure.

Key Messages

- New data were obtained on levels of mercury and selenium in four organs of beluga from Hendrickson Island (n=18), Arviat (n=15) and Sanikiluaq (n=13). Ages for these whales are not available yet.

Messages clés

- De nouvelles données ont été obtenues sur les concentrations de mercure et de sélénium dans quatre organes de bélugas de l'île Hendrickson (n = 18), d'Arviat (n = 15) et de Sanikiluaq (n = 13). Toutefois, l'âge de ces animaux n'est pas encore disponible.

- The average level of mercury in liver of the eighteen beluga from Hendrickson Island in 2011 was 25.7 $\mu g \cdot g^{-1}$ (wet weight), well above the average value of 16.3 $\mu g \cdot g^{-1}$ obtained in 2010 but consistent with earlier average values from 2004 to 2009. The levels were scattered widely as indicated by the standard deviation of 24.0 $\mu g \cdot g^{-1}$, almost as great as the average. The lowest value for liver in 2011 was 3.12 $\mu g \cdot g^{-1}$ and the highest was 70.5 $\mu g \cdot g^{-1}$. All but one of the whales sampled from this location in 2011 were males.

- The fifteen beluga sampled from Arviat in 2011 averaged 14.5 $\mu g \cdot g^{-1}$ mercury in liver, similar to the average value obtained in 2010 (15.9 $\mu g \cdot g^{-1}$). Again the values were spread widely from 0.77 to 38.5 $\mu g \cdot g^{-1}$ for a standard deviation of 11.4 $\mu g \cdot g^{-1}$. The lowest value of 0.77 $\mu g \cdot g^{-1}$ is unusual and might be expected from a very young animal; we do not have ages but it was not from a particularly small animal (male, 383.5 cm long). The samples were biased toward males (10 males, 3 females, 2 not determined) but not so extremely as those from Hendrickson Island.

- The average level of mercury in livers from the thirteen beluga from Sanikiluaq in 2011 was 16.2 $\mu g \cdot g^{-1}$, within the range of average values from this location in previous samples. The range of individual values in 2011 was from 2.14 $\mu g \cdot g^{-1}$ to 60.8 $\mu g \cdot g^{-1}$. Unlike Hendrickson Island and Arviat, the whales from Sanikiluaq were predominately females (7 female, 4 male and 2 not determined). The average length of this sample of beluga was the shortest we have recorded from this location to date (334 cm) as compared with a range of previous average lengths from 341 cm to 392 cm).

- Average levels of mercury in liver (means from 14.5 to 25.7 $\mu g \cdot g^{-1}$) of beluga from all three locations in 2011 remained well above 0.5 $\mu g \cdot g^{-1}$ (the guideline used to regulate the sale of commercial fish in Canada). Considering the individual livers, all forty-six exceeded the fish guideline. The same was true for levels of mercury in kidney samples although mean levels were much lower than

- En 2011, la concentration moyenne de mercure dans le foie des 18 bélugas de l'île Hendrickson était de 25,7 $\mu g \cdot g^{-1}$(poids humide), soit bien au dessus de la valeur moyenne de 16,3 $\mu g \cdot g^{-1}$ obtenue en 2010. Cette concentration est cependant conforme aux valeurs moyennes obtenues de 2004 à 2009. Les concentrations étaient très variables, comme l'indique l'écart type de 24,0 $\mu g \cdot g^{-1}$ équivalant presque à la moyenne. La plus faible concentration dans le foie en 2011 était de 3,12 $\mu g \cdot g^{-1}$ et la plus élevée, de 70,5 $\mu g \cdot g^{-1}$. À cet emplacement, tous les bélugas échantillonnés en 2011 sauf un étaient des mâles.

- En 2011, les 15 bélugas dont nous avons prélevé des échantillons à Arviat présentaient une concentration moyenne de 14,5 $\mu g \cdot g^{-1}$ de mercure dans le foie, soit une concentration semblable à la moyenne obtenue en 2010 (15,9 $\mu g \cdot g^{-1}$). Encore une fois, les valeurs sont largement réparties, variant de 0,77 à 38,5 $\mu g \cdot g^{-1}$, avec un écart type de 11,4 $\mu g \cdot g^{-1}$. La plus faible concentration de 0,77 $\mu g \cdot g^{-1}$ est inhabituelle et pourrait avoir été mesurée chez un très jeune individu. Nous n'avons pas l'âge des animaux, mais cette concentration a été mesurée chez un individu qui n'était pas particulièrement petit (mâle, 383,5 cm de longueur). Les échantillons ont principalement été prélevés sur des mâles (10 mâles, 3 femelles et 2 individus au sexe non déterminé), mais pas presque exclusivement comme à l'île Hendrickson.

- La concentration moyenne de mercure mesurée dans le foie des 13 bélugas de Sanikiluaq en 2011 était de 16,2 $\mu g \cdot g^{1}$ et se situait à l'intérieur de l'intervalle des valeurs moyennes des échantillons précédents pour cet emplacement. En 2011, la plage de valeurs individuelles allait de 2,14 $\mu g \cdot g^{-1}$ à 60,8 $\mu g \cdot g^{-1}$. Contrairement aux prélèvements effectués à l'île Hendrickson et à Arviat, les individus de Sanikiluaq étaient principalement des femelles (7 femelles, 4 mâles et 2 individus au sexe non déterminé). La longueur moyenne des bélugas de cet échantillonnage était la plus courte que those in liver. Levels in muscle were lower yet with all locations having average values around 1 $\mu g \cdot g^{-1}$. One whale from Sanikiluaq (the smallest one sampled) actually had very low muscle mercury at 0.28 $\mu g \cdot g^{-1}$, below the guideline. Levels in muktuk were the lowest with all three locations having mean levels near the guideline of 0.5 $\mu g \cdot g^{-1}$ (Hendrickson Island 0.54 $\mu g \cdot g^{-1}$, Arviat 0.39 $\mu g \cdot g^{-1}$, Sanikiluaq 0.50 $\mu g \cdot g^{-1}$).

- Mercury and selenium in samples of liver and kidney from Hendrickson Island were strongly correlated statistically. However, there was no statistical relationship between mercury and selenium in liver or muktuk in the whales from this location. Muktuk contained more selenium per weight of mercury than the other organs.

- In 2011, levels of mercury in liver of whales from Hendrickson Island were again higher than those from either Hudson Bay community. With the exception of 2010, the levels found in beluga from the Mackenzie Delta have generally been higher than in those from eastern sites

- The question of temporal change in levels of mercury is of interest one of the primary purposes of this study. It is complicated by a relationship between mercury in organs and the ages of the whales. We still lack age data for a number of collections and for all samples in 2011. As more age data become available, more rigorous statistical examinations will be made for temporal trends by transforming data to reduce correlations between means and standard deviations and by adjusting mercury levels for whales of different ages.

nous avons enregistrée à cet emplacement à ce jour (334 cm). La plage de longueurs moyennes variait auparavant de 341 à 392 cm.

- Les concentrations moyennes de mercure dans le foie (moyennes variant de 14,5 à 25,7 $\mu g \cdot g^{-1}$) des bélugas aux trois emplacements pour l'année 2011 sont demeurées bien au dessus de 0,5 $\mu g \cdot g^{-1}$ (la ligne directrice pour la vente commerciale du poisson au Canada). De façon individuelle, chacun des 46 foies dépassait cette ligne directrice. Il en était ainsi pour les concentrations de mercure dans les échantillons de reins, même si les concentrations moyennes étaient beaucoup plus faibles que dans le foie. Les concentrations dans les muscles étaient moins élevées; à tous les emplacements, la moyenne était d'environ 1 $\mu g \cdot g^{-1}$. Un béluga de Sanikiluaq (le plus petit échantillonné) présentait en fait une concentration très faible de mercure, soit 0,28 $\mu g \cdot g^{-1}$, dans le muscle échantillonné, ce qui est inférieur à la ligne directrice. Les concentrations dans le muktuk étaient les plus basses; aux trois emplacements, elles se situaient près de la ligne directrice de 0,5 $\mu g \cdot g^{-1}$ (0,54 $\mu g \cdot g^{-1}$ à l'île Hendrickson, 0,39 $\mu g \cdot g^{-1}$ à Arviat et 0,50 $\mu g \cdot g^{-1}$ à Sanikiluaq).

- Les concentrations de mercure et de sélénium dans les échantillons de foie et de rein provenant de l'île Hendrickson étaient fortement corrélées statistiquement. Cependant, il n'y avait pas de relation statistique entre le mercure et le sélénium dans le foie ou le muktuk des bélugas de cet emplacement. Le muktuk contenait plus de sélénium par poids de mercure que les autres organes.

- En 2011, les concentrations de mercure dans le foie des bélugas de l'île Hendrickson étaient encore une fois plus élevées que celles des collectivités de la baie d'Hudson. À l'exception de 2010, les concentrations mesurées dans les bélugas du delta du Mackenzie ont généralement été plus élevées que celles des sites plus à l'est.

- La question du changement temporel des concentrations de mercure est intéressante, et elle constitue un des principaux objectifs de la présente étude. Elle se complique du fait de la relation entre le mercure dans les organes et l'âge des bélugas. Il nous manque encore des données à propos de l'âge pour un certain nombre de collectes et pour tous les échantillons de 2011. À mesure que ces données deviendront disponibles, nous procéderons à des examens statistiques plus rigoureux à propos des tendances temporelles en transformant les données afin de réduire les corrélations entre les moyennes et les écarts types et en ajustant les concentrations de mercure pour les individus d'âges différents.

Objectives

To provide incremental information on levels of mercury and selenium in organs of beluga, narwhal and walrus from selected locations in the Canadian Arctic, to maintain a database of this information and to assess long-term trends of mercury in these animals.

Introduction

The levels of mercury in organs of northern marine mammals have generally exceeded the guideline level of 0.5 $\mu g \cdot g^{-1}$ used to regulate the sale of commercial fish for human consumption in Canada. With regard to subsistence fisheries, there is no regulation governing the concentrations of mercury in fish or other traditional foods including marine mammals. Indeed, given the nature of subsistence harvests, any such guideline would be difficult or impossible to enforce. There is a published recommendation that fish consumed in a subsistence fishery not exceed 0.2 $\mu g \cdot g^{-1}$ (Health and Welfare Canada, 1979) although this recommendation has no binding, legal status.

There are three main hypotheses about the source of the mercury to the animals. The first is that the mercury is present naturally in northern habitats and the animals there simply reflect the geology and oceanography of their feeding ranges. The second is that processes associated with climate change have altered the availability of mercury present naturally in the habitat. The third is that mercury from outside the habitat has been imported with movements of air (or water or ice) and that some of that mercury has found its way into northern animals. The extent to which these or other arguments apply is not yet clear. Studies of sediment cores suggest that more mercury has been reaching recent lake sediments than was the case when deeper, older layers of sediment were laid down (Hermanson, 1993; Lockhart et al., 1998) but this observation does not establish whether the excess mercury is natural mercury being mobilized from soils in the drainage basins or whether it is imported into the basin presumably with moving air masses. Studies of mercury in beluga teeth suggest that most of the mercury in contemporary beluga from the Beaufort Sea has been derived from recent anthropogenic activity (Outridge et al., 2002). However, parallel studies of mercury in teeth of walrus from Igloolik found that recent levels were not elevated over archeological samples suggesting little anthropogenic mercury in those animals (Outridge et al., 2002). Since pervious studies by Outridge et al. (2000) has shown that mercury levels in teeth are correlated with those in liver, kidney, muscle and muktuk, it seems likely that the trends reported in teeth occurred similarly in other organs.

The samples we describe here were all collected since the 1970s; Mercury has increased in air over the North Atlantic (Slemr and Langer, 1992) and mercury has been measured in air and in snow in the Arctic (Lu et al., 2001). While there is little doubt that industrial mercury is deposited in the Arctic, the ultimate fate of that mercury remains in question. Processes within the snow suggest that much of the mercury deposited to Arctic snow may be volatilized back into the air without ever reaching arctic animals. A question of great interest is whether mercury resulting from human activities is sufficient to cause changes in the levels of mercury in arctic animals. Stern and Macdonald (2005) postulated that the apparent increases of mercury in western Arctic beluga since the early 1990's may be attributed to recent changes in ice cover and distribution in the western Arctic Ocean. Gaden et al. (2009) found that levels of mercury in muscle of ringed seals collected from Holman between 1973 and 2007 showed no temporal trend but were related in a curvilinear way to the length of the ice-free season. Gaden and Stern (2010) have found that mercury levels in female beluga from Arviat decreased between the early 1980s and 2008. They used isotopic ratios of $\delta^{15}N$ and $\delta^{13}C$ to show that beluga feeding had changed over the interval. They suggested that this was likely due to the capture of prey from more offshore areas in response to the longer ice-free season over the interval. Loseto et al. (2008) have begun to look at biological variables that reflect feeding habits of Beaufort Sea beluga to help explain the levels of mercury found in them.

A previous study of mercury in northern animals pooled data from different locations in the eastern and western Arctic and reported a trend to higher levels in both regions (Wagemann et al., 1996). With growing recognition that arctic populations of marine mammals are composed of multiple stocks that are hunted separately in different communities, the need is for trend data on a stock-specific basis. Locations were considered separately by Lockhart et al., (2005), however, those and other earlier assessments will have to be repeated using the amended ages of beluga.

Whales may range long distances from the communities where they are hunted, but the hunting itself is usually relatively close to the communities. Here, mammals are described only by the communities where the samples were obtained. Hence two or more communities may hunt the same stock if those communities are relatively near each other.

The raw data from this investigation are archived in the Freshwater Institute and currently comprise records of mercury and often selenium in organs of 1206 arctic beluga, 285 walrus, 413 narwhal and 1052 ringed seals. Biologists obtain samples from hunter kills and those samples provide the tissue for most of these analyses. The archive grows through the collection and analyses of new samples and sometimes also through the analyses of archived samples from past collections not analyzed previously. Over time, the accumulated data offer increasingly rigorous opportunities to test for changes that may relate to environmental variables. Beluga ages in the archived data have been revised in keeping with the new information on growth layer formation in beluga (Stewart et al., 2006).

Activities In 2011/2012

This report covers data available by May, 2012 describing mercury and selenium in organs of beluga collected in 2011. The collection of samples is done independently of this project and is not described here. Similarly beluga ages are determined by other projects and these are added as they become available. The analytical methods have been described in previous reports and have been continued unchanged. Liver tissue of most animals was analyzed and kidney, muscle and muktuk were also analyzed when available. The new data are listed in Table 1. The project is concerned principally with mercury but many of the same samples were analyzed for selenium as well because of its probable relationship to the toxicology of mercury.

New Data Added for Collections in 2011

The new information available on mercury and selenium in organs of beluga collected in 2011 is summarized in Table 1. Ages for these whales are not available yet.

Mercury and selenium in beluga from Hendrickson Island, 2011

Eighteen beluga were obtained from Hendrickson Island in 2011; similar to 2010, all were males except one. The unadjusted mean level of mercury in the livers of these animals was 25.7 ± 24 $\mu g \cdot g^{-1}$ (wet weight, Table 1). This average level is substantially above that found in 2010 (16.3 7 $\mu g \cdot g^{-1}$) and is similar to averages reported since the early 2000s. The range of mercury levels found is typically broad and that remained the case in 2011 with the minimum level in liver being 3.12 $\mu g \cdot g^{-1}$ and the maximum 70.5 $\mu g \cdot g^{-1}$; the standard deviation of the mean was 24.0 $\mu g \cdot g^{-1}$, almost as large as the mean. The high variability of mercury in these and other samples makes it statistically difficult to detect changes over time. As in previous sets of samples, liver had the highest levels of mercury (25.7 $\mu g \cdot g^{-1}$) followed by kidney (3.92 $\mu g \cdot g^{-1}$), muscle (1.21 $\mu g \cdot g^{-1}$), and muktuk (0.54 $\mu g \cdot g^{-1}$) (Table 1). Mercury levels among the four organs were positively correlated with the strongest statistical association between muscle and muktuk (Table 2).

Data on whale lengths were collected and the individual lengths varied from 365 to 434 cm with a mean length of 402 cm. Lacking age data, lengths were found to correlate with mercury in liver ($r=+0.63$, $p=0.0047$). Selenium levels in liver were also correlated with length although less strongly ($r=+0.59$, $p=0.010$). For kidney, neither levels of mercury nor selenium were related to length ($p>0.05$ for both elements). Levels of mercury in muscle were correlated with length ($r=+0.62$, $p=0.0061$) but those of selenium were not. Mercury in muktuk was related to length ($r=+0.60$, $p=0.0088$) but selenium was not.

Table 1. New data for mercury and selenium in organs of beluga added to the database by May, 2012. (Ages for these whales are not available yet.)

Species	Location	Year	Organ	Mean Age (yr) and number of samples	Mean Length (cm) and number of samples	Mean Total mercury ($\mu g \cdot g^{-1}$) and number of samples	Std. Dev. Total Hg	Mean selenium ($\mu g \cdot g^{-1}$) and number of samples
Beluga	Hendrickson	2011	Liver		402.3 (18)	25.7 (18)	24.0	13.2 (18)
Beluga	Hendrickson	2011	Kidney		402.3 (18)	3.92 (18)	2.69	3.65 (18)
Beluga	Hendrickson	2011	Muscle		402.3 (18)	1.21 (18)	0.54	0.36 (18)
Beluga	Hendrickson	2011	Muktuk		402.3 (18)	0.54 (18)	0.25	3.40 (18)
Beluga	Arviat	2011	Liver		405.2 (13)	14.5 (15)	11.4	8.46 (15)
Beluga	Arviat	2011	Kidney		405.2 (13)	11.9 (12)	11.7	3.14 (12)
Beluga	Arviat	2011	Muscle		405.2 (13)	0.94 (15)	0.33	0.32 (15)
Beluga	Arviat	2011	Muktuk		405.2 (13)	0.39 (15)	0.13	2.79 (15)
Beluga	Sanikiluaq	2011	Liver		333.5 (13)	16.2 (13)	16.7	11.7 (13)
Beluga	Sanikiluaq	2011	Kidney		333.5 (13)	7.38 (13)	10.9	3.49 (13)
Beluga	Sanikiluaq	2011	Muscle		333.5 (13)	0.97 (13)	0.78	0.44 (13)
Beluga	Sanikiluaq	2010	Muktuk		333.5 (13)	0.50 (13)	0.35	2.54 (13)

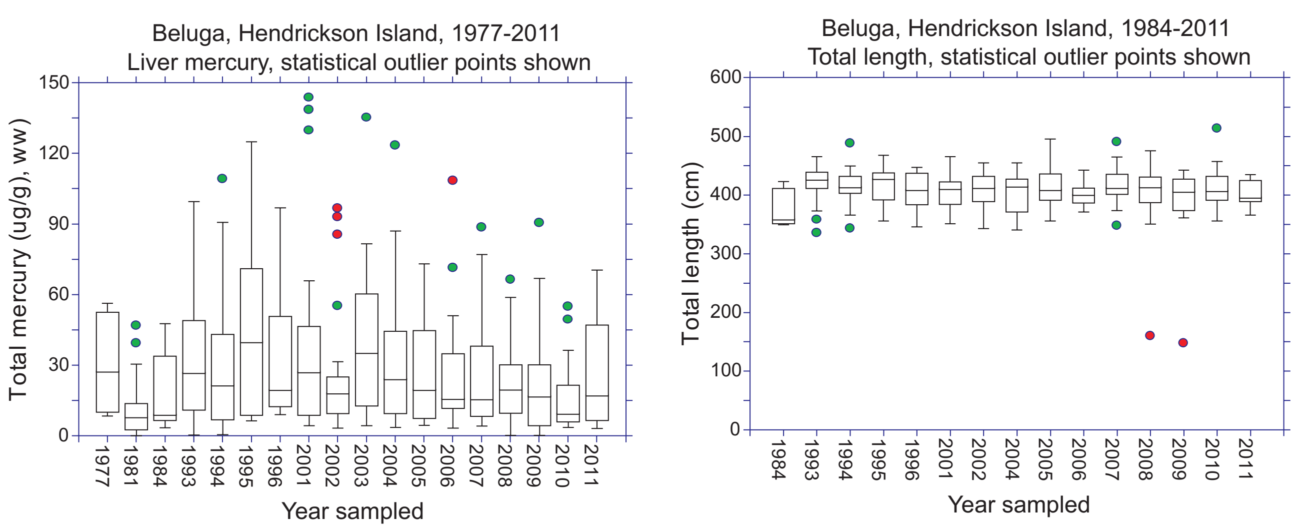
Table 2. Correlation matrix between unadjusted mercury concentrations (µg·g^{-1} wet weight) in organs of eighteen beluga whales from Hendrickson Island in 2011

		Liver	Kidney	Muscle	Muktuk
Liver	r		0.697	0.796	0.820
	p		0.001294	0.000076	0.000031
	n		18	18	18
Kidney	r			0.528	0.636
	p			0.024456	0.004562
	n			18	18
Muscle	r				0.922
	p				0.000000
	n				18

Mean statistics are influenced strongly by unusually high or low values and levels of mercury frequently vary widely because of statistically extreme points. For example, levels of mercury in liver of beluga from Hendrickson Island were examined as the dependent variable by the Robust Regression technique of NCSS software using length as the independent variable and the results indicated five extreme values for mercury in liver, all of them well above the expected values for the lengths of the individuals identified. If the mean level of mercury in liver is recalculated with those five high-mercury individuals excluded, then the mean value for the remaining 13 whales falls to only 12.2 µg·g^{-1}. Clearly the mean was influenced strongly by those unusual values. The median is less strongly influenced by statistical outlier points that fall at either end of the range and for that reason medians and percentile ranges have been used to illustrate the variation in mercury levels over the years. Figure 1 shows the median levels of mercury in liver over the period from 1977 to 2011 (left panel). Since ages are not available and since total length is frequently related to mercury levels, the right panel in Figure 1 also shows the total length of the beluga in years for which length measurements were reported from 1984 to 2011.

Figure 1. Box plots of median mercury levels (µg·g^{-1} wet weight) in liver of beluga whales from the Mackenzie Delta from 1977 to 2010 (left panel). The horizontal line in each box

Figure 1.



represents the median value while the box itself represents the range from the 25th to the 75th percentile or the interquartile range (IQR). The vertical line extending from each box represents the upper and lower "adjacent values"; the upper adjacent value is the largest observation that is less than or equal to the 75th percentile plus 1.5 times the IQR and the lower adjacent value is the smallest observation that is greater than or equal to the 25th percentile minus 1.5 times the IQR. Values outside the upper or lower adjacent values are called outside values and can be mild or severe. Green dots represent mild statistical outside values and red dots severe ouside values; mild outside values are not unusual but severe outside values are.

Right panel, median lengths (cm) of beluga in years for which length measurements are available. The only severe outside values for length were two foetal animals, one obtained in 2008 and the other 2009. These two individuals had mercury levels below 1 $\mu g \cdot g^{-1}$ in liver but failed to meet the definition of outside values for mercury.

Inspection of the median and percentile range values for mercury in liver and for total length offer no obvious indication of a sustained consistent trend in either measurement over the periods for which these measurements are available. When ages of these whales become available, the relationship between age and mercury will be examined as has been done in previous years. The relationship between mercury and either age or length is probably a reflection of a more fundamental relationship between mercury and the feeding history of the whales.

Similar plots for median levels of mercury in kidney, muscle and muktuk are shown in Figure 2 with vertical scales different for each organ due to the differing levels found there. Again there is no obvious single consistent trend in levels over the time intervals for which measurements are available. Median values for mercury often appear somewhat higher during the 1990s than after about 2005 but more rigourous statistical treatments will be required to determine whether this is so.

Figure 2.

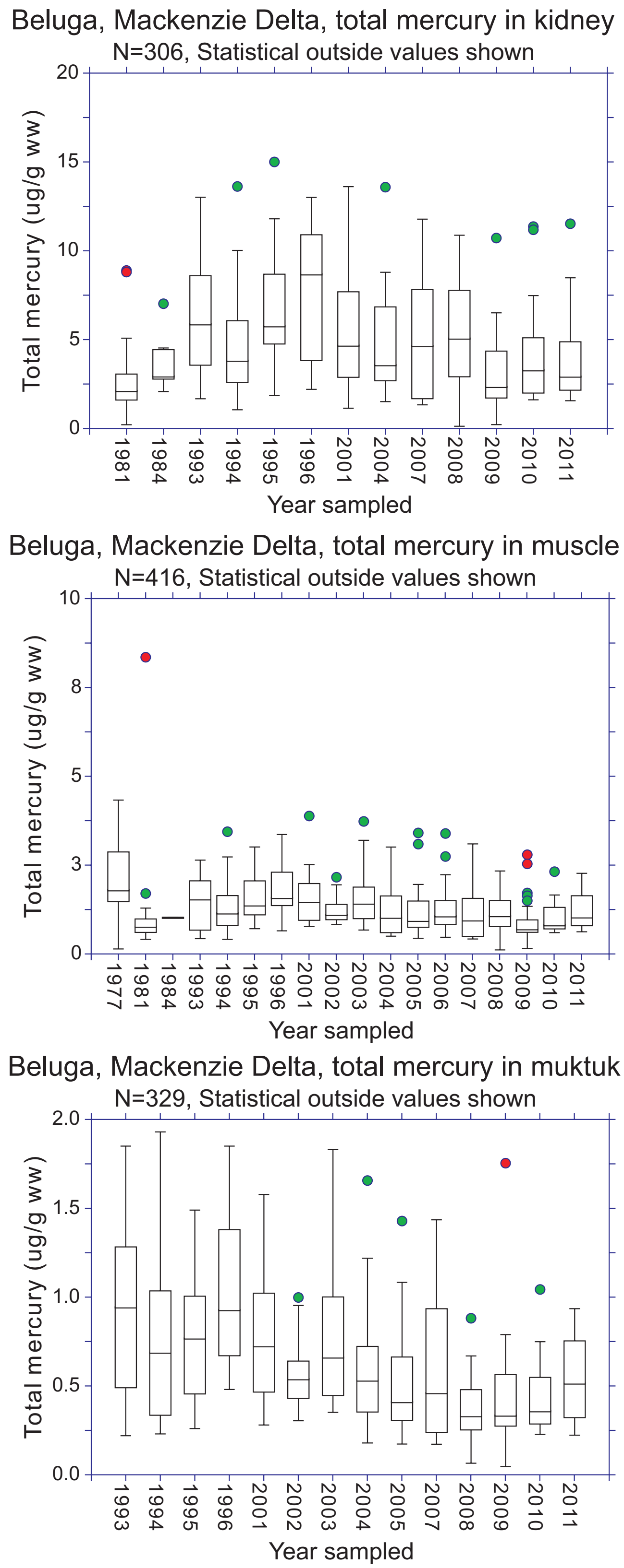


Figure 2. Box plots of median mercury levels (µg·g-1 wet weight) in kidney (left), muscle (centre) and muktuk (right) of beluga whales from the Mackenzie Delta over the intervals for which measurements are available. Note that the vertical scale on each panel differs and that they all differ from the vertical scale shown for mercury in liver (Figure 1). Box properties as in Table 1.

The relationships between mercury and selenium differ in liver and kidney from those in muscle and muktuk. Liver and kidney had very strong statistical linkages between mercury and selenium but muscle and muktuk did not (Figure 3). The basis for these differences is unknown. Levels of mercury and selenium in liver were strongly correlated (r=+0.95, p=0.000000) each other (Figure 3, lower panels). Kidney had lower levels of both elements than liver but had but had equally strong relationship between these elements (r=+0.94, p=0.000000. Levels of both mercury and selenium in muscle were lower yet and concentrations of the two elements were not correlated significantly (r=0.36, not significant, Figure 3, upper left). Muktuk differed from the other organs in that it had the lowest levels of mercury but levels of selenium about the same as those in kidney (Table 1, Figure 3, upper right). Mercury and selenium in muktuk were not related to each other statistically (r=-0.32, not significant). Clearly consumption of muktuk from these whales would provide a much higher intake of selenium than of mercury.

Figure 3. Relationships between concentrations of mercury and selenium (µg·g-1 wet weight) in muscle (upper left), muktuk (upper right), liver (lower left) and kidney (lower right) of beluga whales from Hendrickson Island, 2011. Note differences in scales of both axes.

Figure 3.

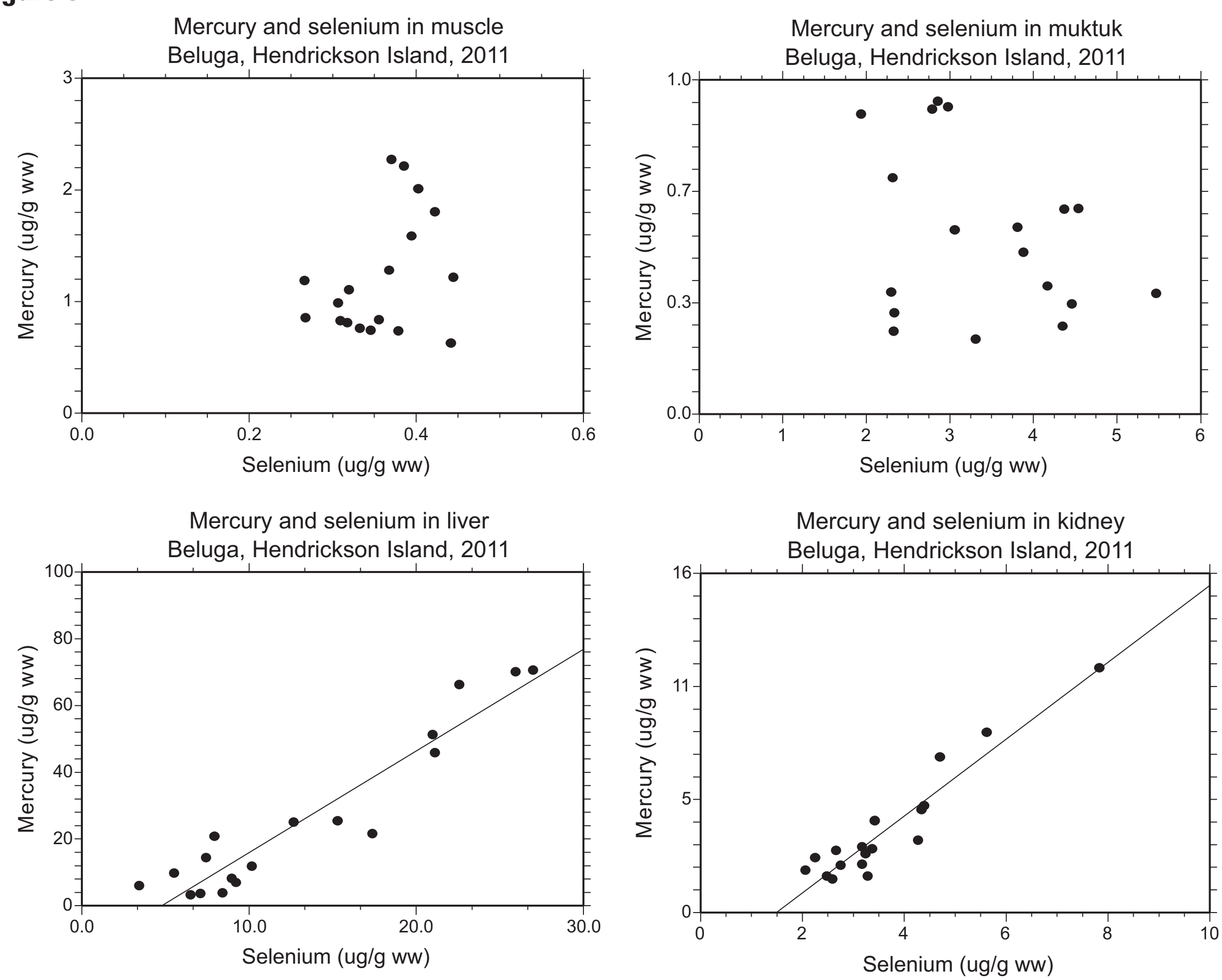


Table 3. Correlation matrix between unadjusted mercury concentrations ($\mu g \cdot g^{-1}$ wet weight) in organs of beluga whales from Arviat in 2011

		Liver	Kidney	Muscle	Muktuk
Liver	r		0.193	0.692	0.594
	p		n.s.	0.0043	0.0195
	n		12	15	15
Kidney	r			0.385	0.453
	p			n.s.	n.s.
	n			12	12
Muscle	r				0.915
	p				0.000002
	n				15

n.s., not significant at probability of 0.05

Mercury and selenium in beluga from Arviat, 2011

Fifteen beluga were obtained from Arviat in 2011, but lengths were obtained for only 12 of them. There were 10 males, 3 females and 2 of unknown gender. Ages are not available yet and so the mercury and selenium measurements were tested for statistical relationships to length. The mean length was 405 cm, the largest mean value we have recorded from Arviat and almost the same as the mean length for the beluga from Hendrickson Island (402 cm, Table 1). Mercury in liver averaged 14.5 $\mu g \cdot g^{-1}$, as compared with kidney at 11.9 $\mu g \cdot g^{-1}$, muscle, 0.94 $\mu g \cdot g^{-1}$ and muktuk at 0.39 $\mu g \cdot g^{-1}$ (Table 1). The statistical correlations between pairs of organs are shown in Table 3. Mercury levels in liver were correlated with those in muscle and muktuk but not with those in kidney. Levels in kidney were not correlated with those in any of the other organs. The strongest statistical relationship was between levels in muscle and those in muktuk, similar to the same observation in whales from Hendrickson Island.

There were no significant correlations between whale length and the levels of either mercury or selenium in any of the four organs sampled. The median levels of mercury in liver are shown in Figure 4 (left panel) for the eight collections we have from Arviat and they are somewhat higher in the most recent samples than in the earliest ones. Median lengths are also higher in recent samples (Figure 4, right panel) suggesting that

Figure 4.

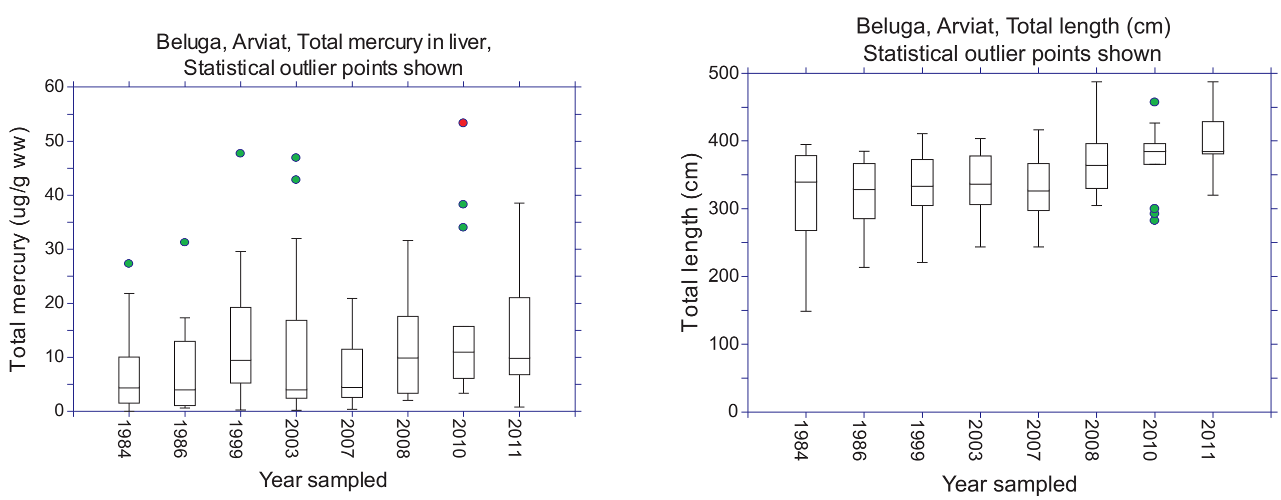


Figure 5.

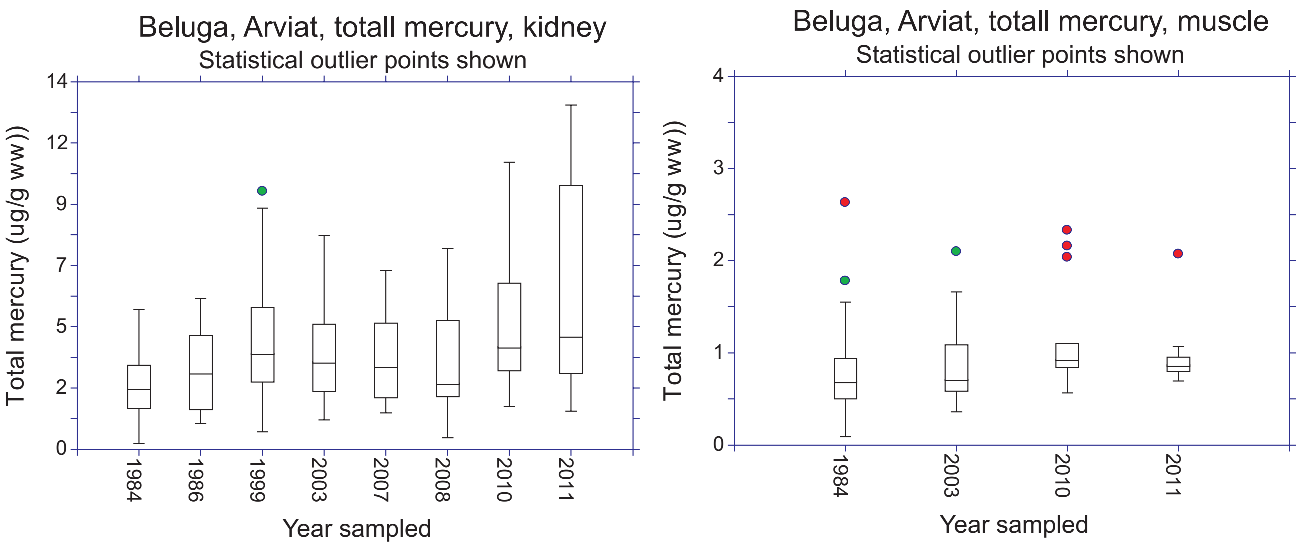


Figure 6.

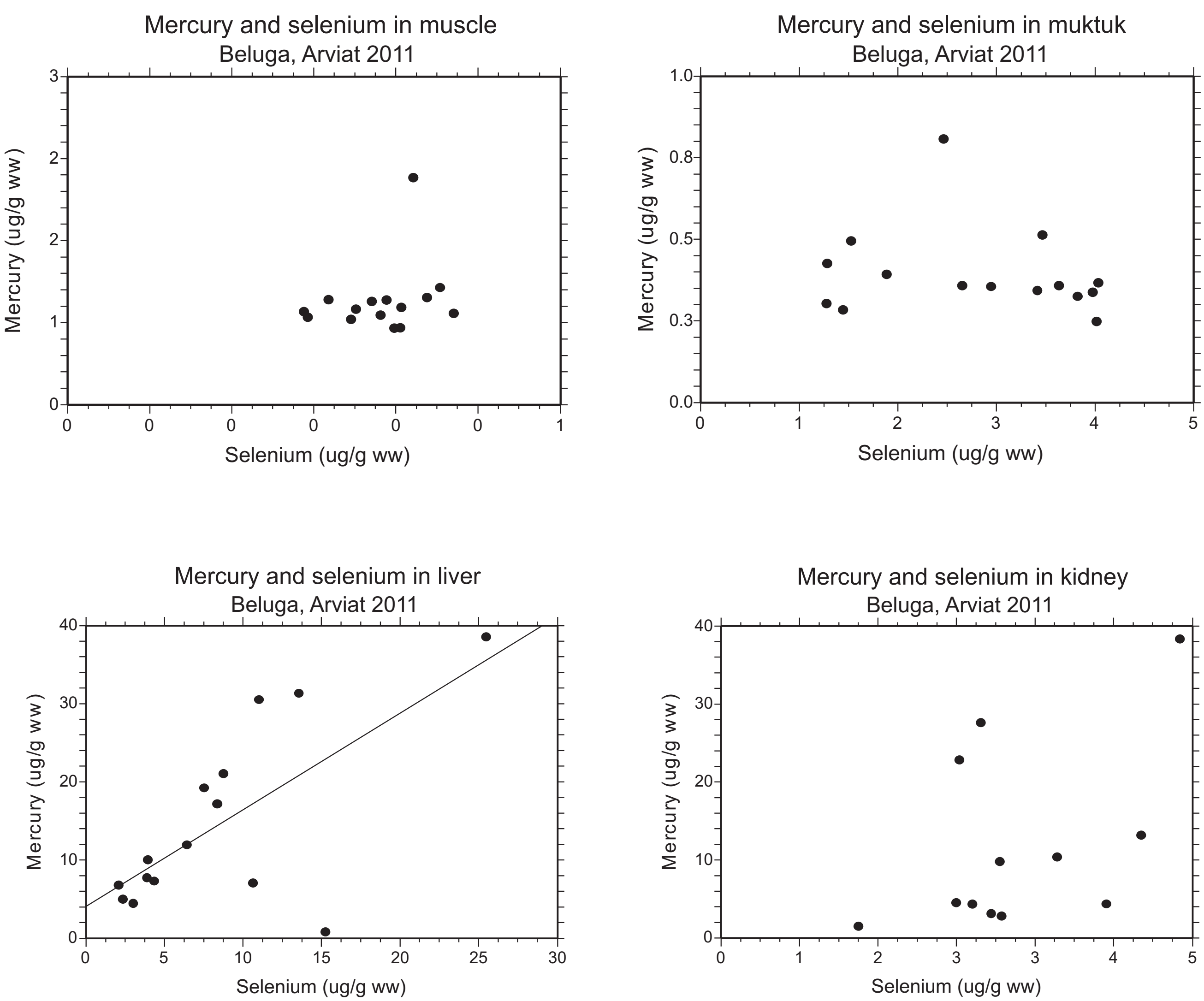


Table 4. Correlation matrix between unadjusted mercury concentrations (µg·g^{-1} wet weight) in organs of beluga whales from Sanikiluaq in 2011

		Liver	Kidney	Muscle	Muktuk
Liver	r		0.917	0.850	0.859
	p		0.00001	0.00024	0.00017
	n		13	13	13
Kidney	r			0.947	0.933
	p			0.000001	0.000003
	n			13	13
Muscle	r				0.980
	p				0.000000
	n				13

the increase in mercury may be an artifact of sampling longer whales. However, since no significant statistical correlation was found between whale length and mercury in any of the organs, the high medians for mercury in liver in the most recent samples are probably not simple artifacts related to differences in lengths.

Figure 4. Box plots of median mercury levels (µg·g^{-1} wet weight) in liver of beluga whales from Arviat for eight sets of samples taken from 1984 to 2011 (left panel). Right panel, median lengths (cm) of beluga in the same years. Box descriptions as in Figure 1.

The same relationships of the mercury levels in 2011 to those in earlier samples are shown in Figure 5 for kidney and muscle. .Prior to 2011, we obtained no samples of muktuk from Arviat beluga. As with liver, median values of mercury in kidney and muscle are higher than those in early samples. More appropriate statistical methods will be required to test this rigourly.

Figure 5. Box plots of median mercury levels (µg·g^{-1} wet weight) in kidney (left) and muscle (right) of beluga whales from Arviat over the intervals for which measurements in these organs are available. Note that the vertical scale on each panel differs and that they all differ from the vertical scale shown for mercury in liver (Figure 4). Box descriptions as in Figure 1.

Mercury and selenium were correlated with each other in liver (r=+0.68, p=0.0055) but not in kidney, muscle or muktuk (Figure 6).

Figure 6. Relationships between concentrations of mercury and selenium (µg·g^{-1} wet weight) in liver (upper left), kidney (upper right), muscle (lower left) and kidney (lower right) of beluga whales from Arviat, 2011. Note differences in scales of both axes.

Mercury and selenium in beluga from Sanikiluaq, 2011

We obtained the same four organ samples from thirteen beluga taken at Sanikiluaq in 2011. These whales on average were considerably shorter than those from Arviat but they contained comparable levels of mercury in liver. The mean length of the whales from Sanikiluaq was only 334 cm (± 34.2 cm) as compared with 405 cm (±50.2 cm) at Arviat. The mean concentration of mercury in liver was 16.2 µg·g^{-1}, similar to the mean 14.5 µg·g^{-1} at Arviat (Table 1). The relationships of mercury levels in pairs of organs are listed in Table 4. Mercury concentrations were strongly correlated between all pairs of organs (Table 4) with the comparison between muscle and muktuk again the strongest.

Length was again examined for any statistical relationship to concentrations of mercury or selenium in the four organs but no significant relationships were found.

Figure 7.

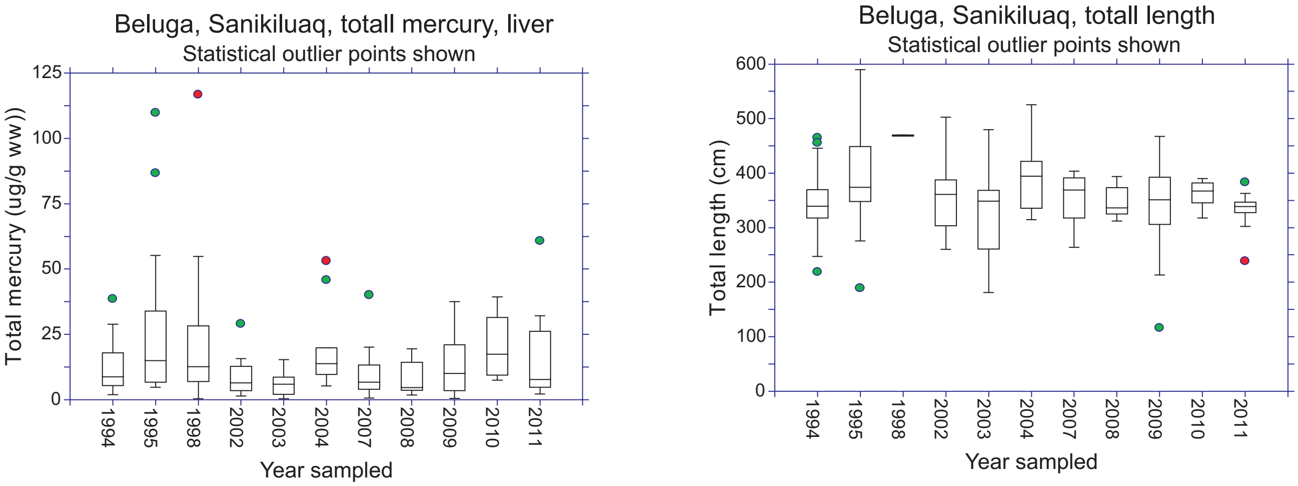
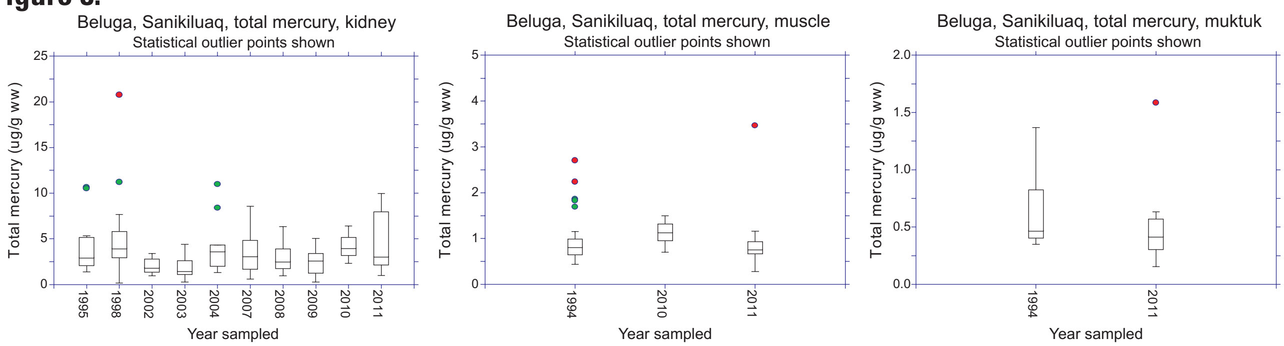


Figure 8.



Median levels of mercury in liver are compared in Figure 7 (left panel) showing data for 172 whales over eleven sampling years since 1994. There is no obvious single trend over the period but rather an oscillation between higher and lower medians. Ages were not available but median lengths are shown in the right panel of Figure 7. (Length was available for one whale only in 1998.)

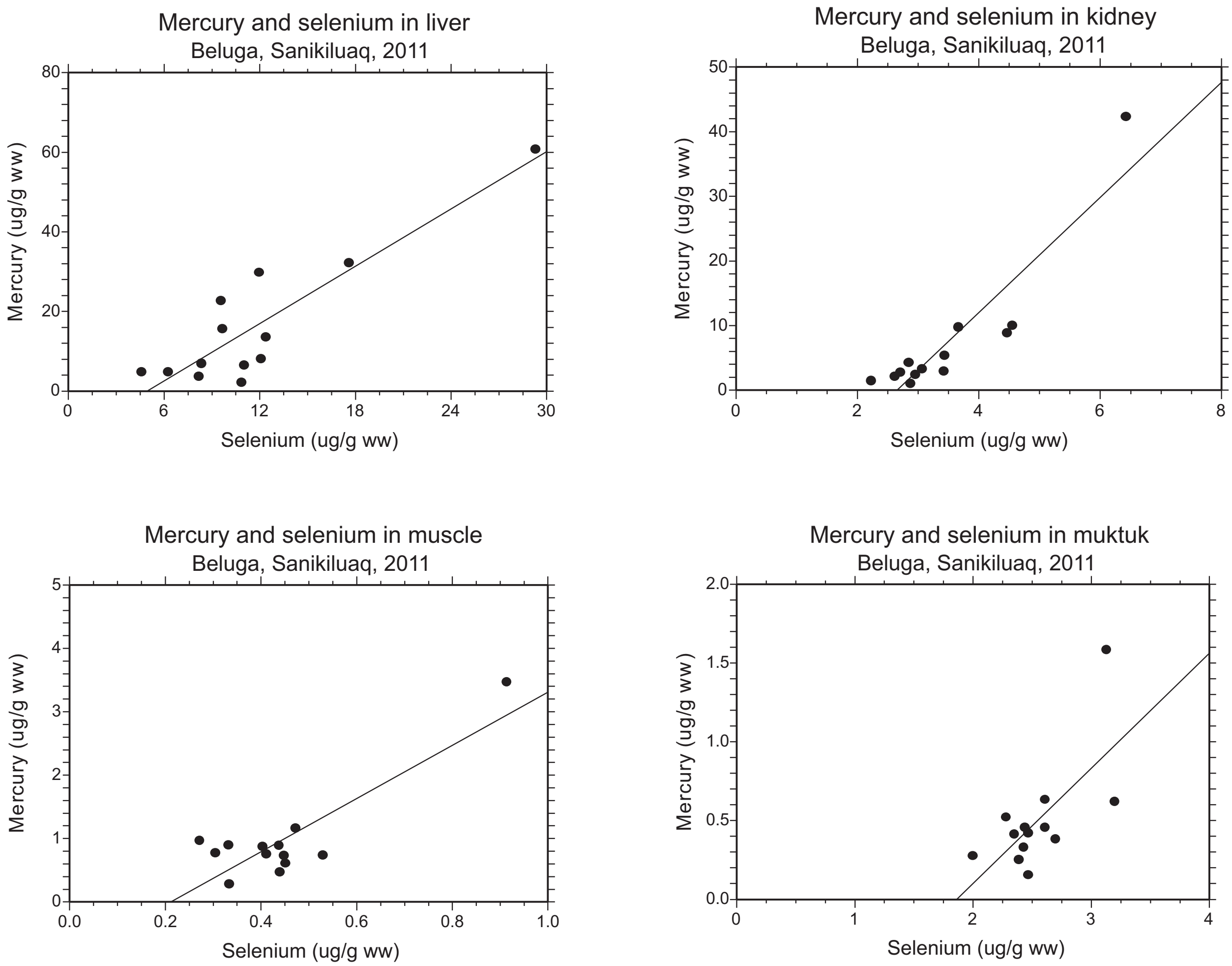
Figure 7. Box plots of median mercury levels (µg·g^{-1} wet weight) in liver of beluga whales from Sanikiluaq for eleven sets of samples taken from 1994 to 2011 (left panel). Right panel, median lengths (cm) of beluga in the same years. Box descriptions as in Figure 1.

Comparisons among years for levels of mercury in the remaining organs are shown in Figure 8. We have ten sampling periods for which mercury was determined in kidney but only three for muscle and two for muktuk. Consistent temporal trends are not obvious in the median values but more detailed statistical analysis will be required before offering further comment on them.

Figure 8. Box plots of median mercury levels (µg·g^{-1} wet weight) in kidney (left), muscle (centre) and muktuk (right) of beluga whales from Sanikiluaq over the intervals for which measurements in these organs are available. Note that the vertical scale on each panel differs and that they all differ from the vertical scale shown for mercury in liver (Figure 7). Box descriptions as in Figure 1.

Levels of mercury and selenium were correlated in all four organs reported here although the relationships were driven largely by one animal with unusually high levels of both mercury and

Figure 9.



selenium in all four organs (Figure 9). That unusual point is readily visible in all four panels of Figure 9. The levels of selenium in muktuk again exceeded the levels of mercury.

Figure 9. Relationships between concentrations of mercury and selenium ($\mu g \cdot g^{-1}$ wet weight) in liver (upper left), kidney (upper right), muscle (lower left) and kidney (lower right) of beluga whales from Sanikiluaq, 2011. Note differences in scales of both axes.

Expected Project Completion Date

Mercury at the levels in the beluga reported here remains a concern with regard to human dietary intakes. The levels also pose legitimate questions regarding the sources of the mercury, the toxicological effects on the animals themselves, the relationships between mercury and selenium, and temporal and spatial patterns of mercury contamination. Probably some form of this research will have to be continued for as long as beluga and other marine mammals in the Arctic are hunted for human consumption.

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Temporal Trends of Contaminants in Arctic Seabird Eggs

Tendances temporelles des contaminants dans les œufs d'oiseaux de mer de l'Arctique

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Abstract

Contaminants are monitored in arctic seabird eggs as an index of contamination of arctic marine ecosystems. Eggs of three species of seabird (thick-billed murre, northern fulmar, black-legged kittiwake) have been collected from Prince Leopold Island in the Canadian High Arctic since 1975. For comparative purposes, we have also been monitoring thick-billed murre eggs from Coats Island in northern Hudson Bay since 1993. In order to examine inter-year variation in the temporal trend data series, annual egg collections have been made since 2005 for two species of seabirds (thick-billed murre, northern fulmar) from Prince Leopold Island. Concentrations of most of the legacy organochlorines (e.g. PCBs, DDE) as well as dioxins (PCDDs) and furans (PCDFs) have decreased in those two species at Prince Leopold Island since 1975 whereas levels of total mercury have increased. Levels of polybrominated diphenyl ethers (PBDEs), a group of brominated flame retardants, increased from 1975 to 2003 followed by a decreasing trend.

Résumé

Les contaminants dans les œufs d'oiseaux de mer de l'Arctique font l'objet d'une surveillance, car ils constituent un indice de la contamination des écosystèmes marins de l'Arctique. Les œufs de trois espèces d'oiseaux de mer (Guillemot de Brünnich, Fulmar boréal et Mouette tridactyle) ont été recueillis sur l'île Prince Leopold, dans l'Extrême Arctique canadien, depuis 1975. À des fins de comparaison, nous surveillons aussi les œufs de Guillemot de Brünnich sur l'île Coats, dans le nord de la baie d'Hudson, depuis 1993. Dans le but d'étudier la variation interannuelle des séries de données sur les tendances temporelles, nous avons effectué, depuis 2005, des collectes annuelles d'œufs de deux espèces d'oiseaux de mer (Guillemot de Brünnich et Fulmar boréal) sur l'île Prince Leopold. Les concentrations de la plupart des organochlorés légués du passé (p. ex. les BPC, le DDE) ainsi que celles des dioxines (les PCDD) et des furanes (les PCDF) détectées dans les deux espèces de l'île Prince Leopold ont diminué depuis 1975, alors que les concentrations de mercure total ont augmenté. Les concentrations

des polybromodiphényléthers (PBDE), un groupe de produits ignifuges bromés, ont augmenté de 1975 à 2003. Cette augmentation a été suivie d'une tendance à la baisse.

Key Messages

- Concentrations of legacy organochlorines (e.g. PCBs, DDT, chlordanes, chlorobenzenes) as well as dioxins and furans have decreased since 1975 in eggs of two arctic seabird species, the thick-billed murre and northern fulmar, at Prince Leopold Island.
- Total mercury (Hg) concentrations have increased significantly since 1975 in eggs of those same two arctic seabird species at Prince Leopold Island.
- Levels of polybrominated diphenyl ethers (PBDEs), a group of brominated flame retardants, increased from 1975 to 2003 and now appear to be decreasing in both species.

Messages clés

- Les concentrations d'organochlorés légués du passé (p. ex. les BPC, le DDT, les chlordanes, les chlorobenzènes) ainsi que les concentrations de dioxines et de furanes ont diminué depuis 1975 dans les œufs de deux espèces d'oiseaux de mer de l'Arctique, le Guillemot de Brünnich et le Fulmar boréal, sur l'île Prince Leopold.
- Les concentrations de mercure total (Hg) ont augmenté de façon significative depuis 1975 dans les œufs de ces deux oiseaux de mer de l'Arctique, sur l'île Prince Leopold.
- Les concentrations des polybromodiphényléthers (PBDE), un groupe de produits ignifuges bromés, ont augmenté de 1975 à 2003 et semblent maintenant être en train de diminuer chez les deux espèces.

Objectives

- To monitor contaminants in seabird eggs as an index of contamination of arctic marine ecosystems.
- In order to continue the temporal trend data series for contaminants and increase the power of the datasets, eggs are collected annually (since 2005) from each of two species of seabirds (northern fulmar, thick-billed murre) from Prince Leopold Island. For comparative purposes, we also make annual collections of thick-billed murre eggs from Coats Island in northern Hudson Bay (our Low Arctic monitoring colony since 1993) in parallel with the High Arctic collections.

Introduction

Eggs of thick-billed murres *(Uria lomvia)*, northern fulmars *(Fulmarus glacialis)* and black-legged kittiwakes *(Rissa tridactyla)* from Prince Leopold Island in the Canadian High Arctic have been monitored for contaminants since 1975 (Braune 2007) to provide an index of contamination of the arctic marine ecosystem and possible implications for seabird health. Early sampling of arctic seabird eggs for contaminant analyses was opportunistic but, with NCP funding, collections have been standardized to every five years since 1988. Since 1975, most of the legacy persistent organic pollutants or POPs (e.g. PCBs, DDT) have been declining whereas total mercury (Hg) has been increasing (Braune 2007), as have the perfluorinated carboxylic acids (PFCAs) (Braune 2011) and, up until 2003, the polybrominated diphenyl ethers (PBDEs). However, after 2003, ΣPBDE concentrations appear to be decreasing (Braune 2008).

In order to examine the inter-year variation in contaminants data, and to improve the statistical power of the temporal trend data series for Canadian Arctic seabirds, we have been collecting eggs from each of two species of seabirds (northern fulmar, thick-billed murre) from Prince Leopold Island in Lancaster Sound, Nunavut, annually since 2005. For comparative purposes, we have also been making annual collections of thick-billed murre eggs from Coats Island in northern Hudson Bay (our Low Arctic monitoring colony since 1993) in parallel with the High Arctic collections. Eggs are analyzed for the normal suite of legacy POPs and total Hg, and the murre and fulmar eggs from Prince Leopold Island are analyzed for PBDEs, hexabromocyclododecane (HBCD), polychlorinated dibenzo-p-dioxins (PCDDs), dibenzofurans (PCDFs), coplanar PCBs, and perfluorinated compounds (PFCs), as well.

Activities in 2011-2012

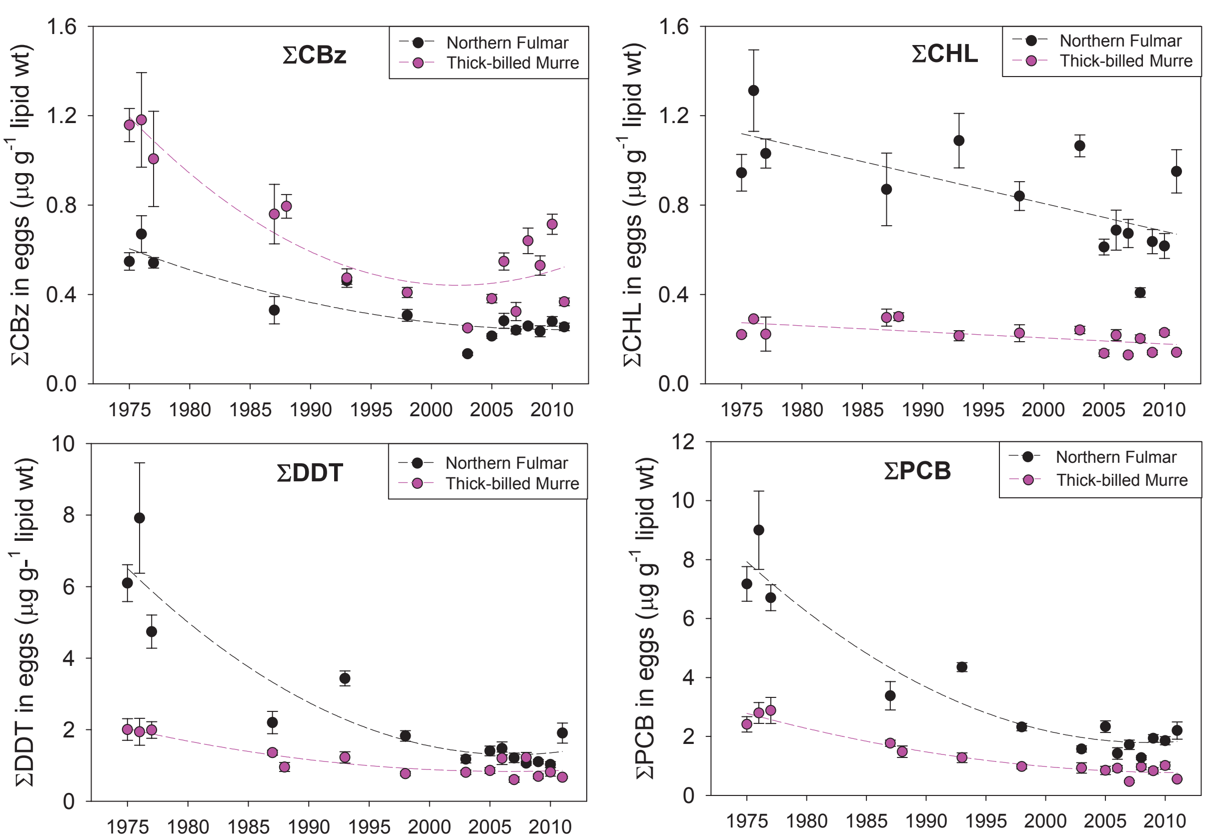
Sample collection/analysis: Eggs (n=15) were collected on the basis of one egg per nest from each of two species of seabirds (northern fulmar, thick-billed murre) from Prince Leopold Island (74°02'N, 90°05'W) in Lancaster Sound as well as from thick-billed murres on Coats Island (62°30'N, 83°00'W) in northern Hudson Bay. Eggs were analyzed for the normal suite of legacy POPs (e.g. PCBs, DDT, chlordanes, chlorobenzenes, etc.), PBDEs, HBCD, and PFCs in pools of 3 eggs each (15 eggs per collection = 5 pools of 3 eggs each). Murre and fulmar eggs from Prince Leopold Island were also analyzed for PCDDs, PCDFs and coplanar PCBs in pools of 5 eggs each (15 eggs per collection = 3 pools of 5 eggs each) to conform with previous analyses. All eggs were individually analyzed for total Hg and stable isotopes of nitrogen ($^{15}N/^{14}N$) and carbon ($^{13}C/^{12}C$).

Analytical methods: Analyses of the legacy POPs, PBDEs, HBCD, PFCs and total Hg are carried out at the National Wildlife Research Centre (NWRC) laboratories at Carleton University in Ottawa, Ontario. The legacy POPs are analyzed by gas chromatography using a mass selective detector (GC/MSD) according to NWRC Method No. MET-CHEM-OC-06B. Analyses of the standard 14 PBDE congeners and total-α-HBCD are carried out using GC-low resolution MS run in negative ion chemical ionization (NCI) mode also according to NWRC Method No. MET-CHEM-OC-06B. PFCs are analyzed using HPLC/MS/MS in negative electrospray mode (ESI-) according to NWRC Method No. MET-WTD-ORG-RES-PFC-02. PFCs analyzed include 10 PFCAs (including PFOA), 4 PFSAs (including PFOS), 3 FTUCAs, PFOSA and 3 FtOHs. Total mercury (Hg) is analyzed using an Advanced Mercury Analyzer (AMA-254) equipped with an ASS-254 autosampler for solid samples according to NWRC Method No. MET-CHEM-AA-03I. The method employs direct combustion of the sample in an oxygen-rich atmosphere. PCDDs, PCDFs and coplanar PCBs are analyzed by the Research and Productivity Council (RPC) in Fredericton, NB, which identify and quantify the compounds by high resolution gas chromatography coupled to a High Resolution Mass Spectrometer (HRGC/HRMS) using internal and external standards. The method is based on EPA Method 1613B in which specific congeners are targeted. Comparability with previous results generated by NWRC is assessed by analysis of two commercial Certified Reference Materials. Quality assurance/quality control (QA/QC) is monitored by NWRC Laboratory Services which is an accredited laboratory through the Canadian Association for Laboratory Accreditation (CALA). Both the NWRC and RPC laboratories have participated in the NCP's QA/QC Program. Stable isotope (C, N) analyses are carried out through the Environment Canada lab at PNWRC in Saskatoon with isotopic measurements made at the Department of Soil Science, University of Saskatchewan, Saskatoon. All samples are archived in the National Wildlife Specimen Bank housed at the NWRC in Ottawa.

Capacity Building: The contaminants monitoring program at Prince Leopold Island in the Canadian High Arctic is part of a long-term, integrated seabird monitoring program which has been investigating seabird population trends and relationships with climate change and contaminants for over 30 years. In 2011, Joanna Panipak of Clyde River was hired to help organize field logistics for several field camps including Prince Leopold Island and help with community correspondence. As well, Josiah Nakoolak from Coral Harbour was hired to help with the field work at Coats Island, as has been the case for more than 20 years at that site. Building on earlier successful collaborations between NWRC and the Arctic College program in Iqaluit, Nasivvik funds were again used in 2011 to send Guy Savard (NWRC technician) and Jennifer Provencher (graduate student) to Iqaluit to work with Arctic College students, teaching them the proper protocols for dissection of birds in the context of marine bird research including contaminants work.

Communications: Presentations on the work that Environment Canada is doing on arctic birds are given regularly in Resolute Bay, the closest community to Prince Leopold Island, including a presentation to the Resolute Bay HTA in late March 2011. A meeting with the Resolute Bay HTA planned for March 2012 was postponed do to unfavourable weather conditions. Presentations on marine bird research at Coats Island, East Bay and other areas in the region are given at the school and elsewhere in Coral Harbour about every two years. Presentations were made to the Coral Harbour HTO in April 2011 and in Cape Dorset in March 2012. The residue data along with a plain language summary of the findings from this project is submitted to the Niqiit Avatittinni Committee (Nunavut) for their review and recommendation as to the most appropriate communications strategy back to the northern communities. Annual reports of the results to date are made to the NCP and results will continue to be published in a peer-reviewed scientific journals. As well, the *Coastlines* newsletter, which contains plain-language summaries of our work, was resurrected in

Figure 1. Mean annual concentrations (± SE) of organochlorines in eggs of northern fulmars and thick-billed murres from Prince Leopold Island, 1975-2011. ΣCBz = Sum Chlorobenzenes (tetra-, penta- & hexachlorobenzene); ΣCHL = Sum Chlordanes (oxychlordane, cis- & trans-nonachlor, cis- & trans-chlordane, heptachlor epoxide); ΣDDT = Sum p,p'-DDE, p,p'-DDD and p,p'-DDT; ΣPCB = Sum of 69 congeners.



 B. Braune

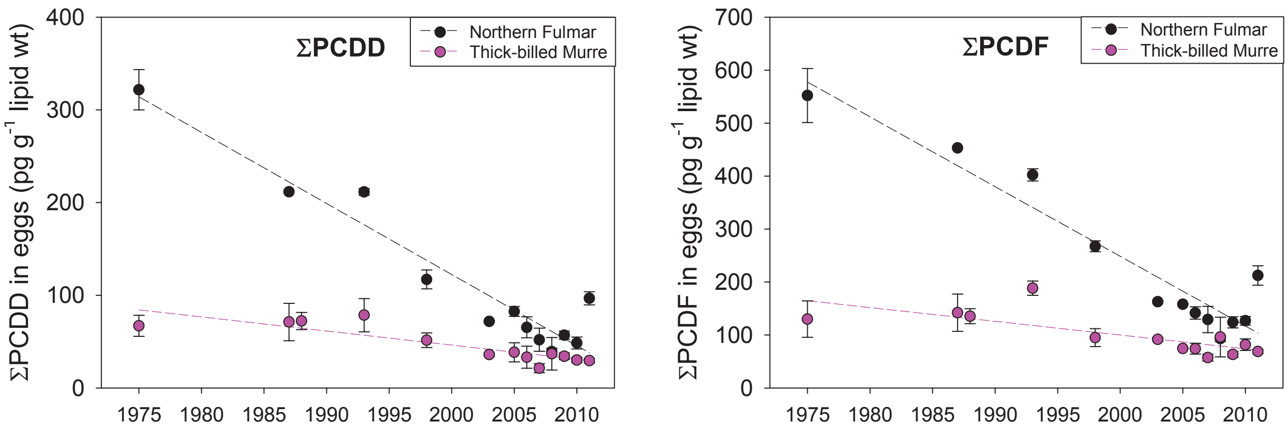
2011-2012 and was sent to HTOs, NGOs as well as appropriate government environmental contacts in Nunavut.

Traditional Knowledge: It is difficult to incorporate new traditional knowledge annually into an ongoing contaminants monitoring program focussed on established seabird colonies which have been studied for many years. However, in 2009, extensive, community-based interviews relating to observations of bird population trends were conducted in Cape Dorset, Kimmirut, Igloolik, and Coral Harbour. This information was compiled as part of a Ph.D. thesis and will be published shortly. In 2010, we initiated interviews on local knowledge of other seabirds, including Arctic terns, which some communities tell us are in decline. To date, results suggest that Inuit have observed declines in populations of shorebirds and terns, and increases in goose populations, but no trends or obvious differences in other marine bird abundance or distribution. These data provide potentially useful information for how to assess whether environmental stressors (e.g. contaminants, climate change) may be affecting northern migratory bird populations.

Results

Concentration data for seabird eggs collected in 2011 are summarized in Table 1. Concentrations of most legacy organochlorines have decreased significantly in eggs of northern fulmars (e.g. ΣCBz: n=66, r=-0.78, p<0.00001; ΣCHL: n=66, r=-0.55, p<0.00001; ΣDDT: n=66, r=-0.89, p<0.00001; ΣPCB: n=66, r=-0.90, p<0.00001) and thick-billed murres (e.g. ΣCBz: n=65, r=-0.61, p<0.00001; ΣCHL: n=65, r=-0.48, p<0.0001; ΣDDT: n=65, r=-0.70, p<0.00001; ΣPCB: n=65, r=-0.82, p<0.00001) at Prince Leopold Island since 1975 (Figure 1). Although the declines seem to be levelling off, there is still some inter-annual fluctuation occurring, particularly in certain cases; e.g. ΣCBz in murres, ΣCHL in fulmars (see Figure 1). Concentrations of ΣPCDD (fulmars: n=34, r=-0.86, p<0.00001; murres: n=36, r=-0.67, p<0.00001) and ΣPCDF (fulmars: n=34, r=-0.86, p<0.00001; murres: n=36, r=-0.67, p<0.00002) have also decreased significantly since 1975 (Figure 2). ΣPBDE increased in both species from 1975 to 2003 and then started to decline, albeit with inter-annual fluctuations (Figure 3). Total Hg concentrations have increased significantly in eggs of the fulmars (n=66, r=0.55, p<0.00001) and murres (n=65, r=0.62, p<0.00001) at Prince Leopold Island between 1975 and 2011 (Figure 4). However, there appears to be considerable inter-annual fluctuation in concentrations since 2005 with a possible decline reflected in the murre eggs in the last few years (see Figure 4).

Figure 2. Mean annual concentrations (± SE) of total polychlorinated dibenzo-p-dioxins (ΣPCDD) and total dibenzofurans (ΣPCDF) in eggs of northern fulmars and thick-billed murres from Prince Leopold Island, 1975-2011.



Discussion and Conclusions

With the implementation of global and regional conventions which regulate or ban the use of certain persistent organic pollutants (POPs), most legacy POPs in biota have declined in the circumpolar Arctic over the past few decades (Rigét et al. 2010). Accordingly, most of the legacy POPs have decreased in eggs of thick-billed murres and northern fulmars monitored at Prince Leopold Island since 1975 (Braune 2007; Figure 1). PCDDs and PCDFs have also declined (Figure 2). Concentrations of the legacy organochlorines as well as PCDDs and PCDFs in eggs of the ivory gull *(Pagophila eburnea)* collected from Seymour Island in the Canadian High Arctic also either decreased or showed little change between 1976 and 2004 (Braune et al. 2007).

Figure 3. Mean annual concentrations (± SE) of total PBDEs (ΣPBDE) in eggs of northern fulmars and thick-billed murres from Prince Leopold Island, 1975-2011. ΣPBDE = Sum BDE 17, 28, 49, 47, 66, 100, 99, 85, 153, 138, 183.

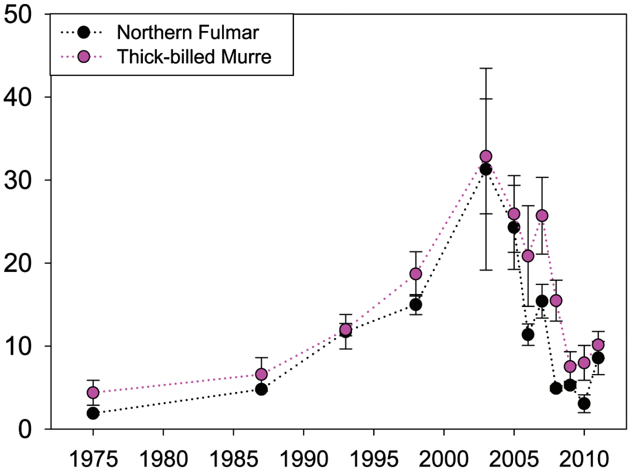
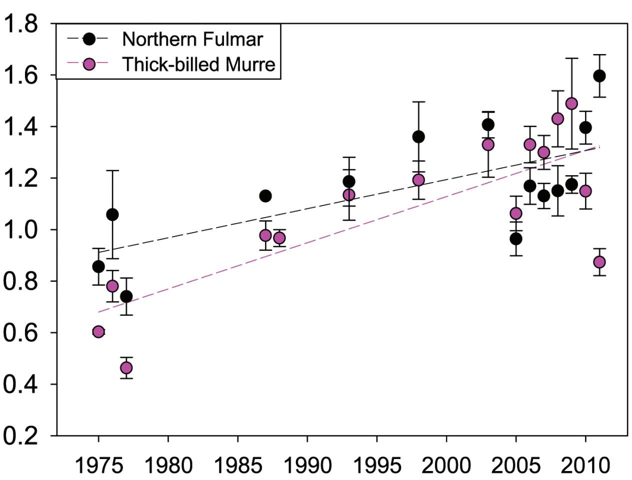


Figure 4. Mean annual concentrations (± SE) of total Hg in eggs of northern fulmars and thick-billed murres from Prince Leopold Island, 1975-2011.



Polybrominated diphenyl ethers (PBDEs) were first detected in Canadian Arctic seabird livers and eggs by Braune and Simon (2004). Subsequent retrospective analyses and continued monitoring have shown that concentrations of ΣPBDEs in eggs of thick-billed murres and northern fulmars from Prince Leopold Island steadily increased from 1975 to 2003 after which, levels started to decrease (Figure 3). An increase in ΣPBDE concentrations between 1976 and 2004 is also reflected in eggs of the ivory gull collected from Seymour Island in the Canadian Arctic (Braune et al. 2007). BDE-47 was the predominant congener in thick-billed murres and northern fulmars (Braune, unpublished data), as well as in the ivory gull eggs (Braune et al. 2007) in all years analyzed. BDE-47 was a major component of the commercial Penta-BDE product used in polyurethane foam for which North America accounted for most of the global demand (Hale et al. 2003). The declining concentrations observed in the fulmar and murre eggs after 2003 may reflect the phasing out of Penta-mix BDE usage in North America after 2005 (de Wit et al. 2010).

Total Hg concentrations have been increasing in seabird eggs from Prince Leopold Island since 1975 (Braune 2007). Concentrations of total Hg in eggs of the ivory gull collected from Seymour Island also increased between 1976 and 2004, although the increase was not statistically significant (Braune et al. 2006). This pattern of increasing Hg trends in Canadian Arctic seabirds supports the west-to-east circumpolar gradient in the occurrence of recently increasing Hg trends which is based on a higher proportion of marine time-series in the Canadian and Greenland region of the Arctic showing significant Hg increases than in the North Atlantic Arctic (Rigét et al. 2011). The reasons for this are complex but likely involve anthropogenic

Table 1. Mean concentrations (± standard error) of organochlorines[1] (μg g^{-1} wet weight), ΣPBDE[2] (ng g^{-1} wet weight), PFOS and ΣPFCA[3] (ng g^{-1} wet weight) and total Hg (μg g^{-1} dry weight) in egg of northern fulmars and thick-billed murres collected from Prince Leopold Island, and thick-billed murres collected from Coats Island in 2011.

	Prince Leopold Island		Coats Island
	Fulmars	Murres	Murres
N[4]	5	5	5
% Lipid	9.6 ± 0.1	11.0 ± 0.4	11.0 ± 0.5
ΣCBz	0.024 ± 0.002	0.040 ± 0.002	0.035 ±0.003
ΣCHL	0.091 ± 0.009	0.015 ± 0.001	0.017 ± 0.002
ΣDDT	0.18 ± 0.027	0.073 ± 0.003	0.10 ± 0.008
ΣPCB	0.21 ± 0.029	0.060 ± 0.003	0.081 ± 0.006
ΣPBDE	0.82 ± 0.19	1.09 ± 0.14	1.66 ± 0.15
PFOS	19.8 ± 1.67	23.8 ± 1.29	NA
ΣPFCA	23.6 ± 2.69	16.5 ± 0.45	NA
Hg	1.60 ± 0.082	0.87 ± 0.053	0.76 ± 0.033

[1] ΣCBz = Sum Chlorobenzenes (tetra-, penta- & hexachlorobenzene); ΣCHL = Sum Chlordanes (oxychlordane, cis- & trans-nonachlor, cis- & trans-chlordane, heptachlor epoxide); ΣDDT = Sum p,p'-DDE, *p,p'*-DDD and *p,p'*-DDT; ΣPCB = Sum of 69 congeners.

[2] ΣPBDE = Sum BDE 17, 28, 49, 47, 66, 100, 99, 85, 153, 138, 183.

[3] ΣPFCA = Sum C6 to C15.

[4] N = number of 3-egg pools

and natural emissions coupled with environmental and biological (e.g. food-web) processes which may also be affected by climate change.

Expected Project Completion Date

This is an ongoing monitoring program and a core NCP biomonitoring project

Acknowledgements

Thanks to D. Nettleship, A. Gaston, M. Mallory, G. Grant and all of the field crews for their collection of the seabird eggs over the years. Thanks also to the northern communities who have supported research activities on marine birds and, in particular, Josiah Nakoolak from Coral Harbour for his continued help at Coats Island over the years. Sample preparation and chemical analyses were carried out by the Laboratory Services personnel at the National Wildlife Research Centre in Ottawa. Stable-nitrogen isotope analyses were coordinated by K. Hobson of Environment Canada in Saskatoon. Funding over the years has been provided by Environment Canada and the Northern Contaminants Program of Aboriginal Affairs and Northern Development Canada (formerly Indian and Northern Affairs Canada). Logistical support out of Resolute Bay is provided by the Polar Continental Shelf Program, Natural Resources Canada.

NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	2	• Joanna Panipak of Clyde River helped with field logistics at Prince Leopold Island • Josiah Nakoolak of Coral Harbour worked at Coats Island
number of project-related meetings/ workshops held in the North (April 1, 2011 – March 31, 2012)	3	• April 2011 - meeting with Coral Harbour • March 2012 – meeting with Cape Dorset • March 2012 - meeting at Resolute planned but postponed due to bad weather
number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	2 directly 1 + 15-20	• Joanna Panipak of Clyde River helped organize field work • one southern coop student assisted with sample processing in the lab • Jennifer Provencher (graduate student) helped train 15-20 Arctic College students to dissect birds in the context of marine bird research including contaminants work
number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	2011: 9 2012: 2	2011 • 2 publications in peer-reviewed journals • one chapter in AMAP Assessment • one chapter in conference proceedings • NCP Synopsis Report • 4 conference presentations 2012 • 2 publications accepted for publication in peer-reviewed journals

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

Tendances temporelles et variations spatiales des polluants organiques persistants et des métaux chez l'omble chevalier anadrome de l'Arctique canadien

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Abstract

Our study is a core biomonitoring project investigating contaminant 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. In 2011, twenty sea-run char were collected from Ekaluktutiak and from Mittimatalik and shipped whole to Saskatoon. Mercury analyses have been completed for 2011 caught sea-run char while persistent organochlorine analyses are ongoing. Mercury concentrations continue to be low in char from both locations and well below commercial sale guidelines; there is a weak trend for mercury concentrations to be increasing at Cambridge Bay but not Pond Inlet. Persistent organic contaminant concentrations were low with no trend evident over the 2004-2010 record.

Résumé

Notre projet de biosurveillance de base examine les tendances des contaminants chez l'ombre chevalier anadrome à Ekaluktutiak (Cambridge Bay), site d'importantes pêches commerciales, et à Mittimatalik (Pond Inlet). Nous étudions l'ombre chevalier anadrome à cause de son importance pour les pêches dans la plupart des collectivités côtières. En 2011, 20 individus anadromes ont été recueillis à Ekaluktutiak et à Mittimatalik et envoyés entiers à Saskatoon. Les analyses des concentrations de mercure présentes chez les ombres chevaliers anadromes prélevés en 2011 sont terminées, tandis que les analyses des contaminants organochlorés persistants sont en cours. Les concentrations de mercure continuent d'être faibles aux deux emplacements et demeurent bien en deçà des lignes directrices pour la vente commerciale. Il y a une faible tendance à la hausse des concentrations de mercure à Cambridge Bay,

When Cambridge Bay data were compared with measurements made in the late 1980s, most contaminants occurred in substantially higher concentrations than in recent times; the exception is PCBs which have shown no change. It is possible that a smaller number of congeners were examined in the late 1980s than current times which could account for the lack of a trend. At Pond Inlet, only HCH showed evidence of a decline since the late 1980s; at that time, concentrations were substantially lower at Pond Inlet than Cambridge Bay except for PCB where concentrations were similarly low.

mais non à Pond Inlet. Les concentrations de contaminants organiques persistants étaient faibles, et aucune tendance n'était évidente pour les données de 2004 à 2010. Lorsque les données pour Cambridge Bay ont été comparées aux mesures prises à la fin des années 1980, la plupart des contaminants étaient présents en concentrations considérablement plus élevées à cette époque, à l'exception de celles des BPC qui n'ont pas changé. Il est cependant possible qu'un plus petit nombre de congénères aient été examinés à la fin des années 1980, ce qui expliquerait qu'il n'y ait pas de tendance. À Pond Inlet, seul l'hexachlorure de benzène (HCH) a montré des signes de déclin depuis la fin des années 1980; à ce moment, les concentrations étaient beaucoup plus faibles à Pond Inlet qu'à Cambridge Bay, à l'exception des concentrations de BPC, qui étaient faibles aux deux endroits.

Key Messages

- Mercury concentrations were very low in sea-run char caught in 2011, i.e., well below the 0.5 µg/g guideline for the commercial sale of fish.
- There was a trend of mercury increase at Cambridge Bay (1991-2011) but not at Pond Inlet (2005-2010) where the monitoring period is shorter.
- Concentrations of legacy contaminants (PCBs, DDT, CBz, HCH, chlordane and toxaphene) were low.
- Most legacy organic contaminants occurred in substantially lower concentrations over 2004-2011 than 1987 for char from Cambridge Bay; exceptions were PCB and toxaphene. It is possible that more congeners of PCB and toxaphene were measured over 2004-2010 than in 1987. At Pond Inlet, only HCH concentrations were lower in 1987 than 2005-2010. No trends were evident in PBDE concentrations over 2004 (or 2005) to 2010 for the two communities.

Messages clés

- Les concentrations de mercure présentes chez les individus anadromes prélevés en 2011 sont très faibles et sont bien inférieures à la ligne directrice de 0,5 µg/g pour les poissons destinés à la vente commerciale.
- Une tendance à la hausse a été constatée pour les concentrations de mercure à Cambridge Bay (1991 2011), mais non à Pond Inlet (2005 2010), où la période de surveillance était plus courte.
- Les concentrations d'anciens contaminants (BPC, DDT, CBz, HCH, chlordane et toxaphène) étaient faibles.
- À Cambridge Bay, la concentration de la plupart des contaminants organiques anciens était beaucoup plus faible au cours de la période de 2004 à 2011 qu'en 1987, à l'exception des BPC et du toxaphène. Il est possible qu'un plus grand nombre de congénères de BPC et de toxaphène aient été mesurés en 2004 2010 qu'en 1987. À Pond Inlet, seules les concentrations d'HCH étaient plus faibles en 1987 qu'en 2005

- Fish appear healthy.

2010. Aucune tendance n'est évidente en ce qui concerne les concentrations d'éther diphénylique polybromé (PBDE) au cours de la période de 2004 (ou de 2005) à 2010 pour les deux collectivités.

- Les poissons semblaient en santé.

Objectives

1. Determine levels of persistent organic pollutants (POPs) and metals (including mercury) as well as "new" POPs in sea-run char which are harvested by Arctic communities.

2. Investigate the role of factors such as fish age, trophic feeding, climate, and location in affecting contaminant body burdens and trends.

3. Contribute to AMAP's and CACAR's assessment of long-term trends in metals and POPs in the Arctic and subarctic and the factors affecting such trends.

4. Provide and explain data to Arctic environmental contaminant committees, health committees, and local communities in a timely manner so that appropriate advice can be given on consuming sea-run char, a food source which is particularly low in contaminant concentration.

Introduction

Arctic char (*Salvelinus alpinus*), a member of the Salmonidae family, is widespread throughout much of the Arctic (Scott and Crossman 1998). Char have a wide variety of life history forms; some live in fresh waters all their lives while others migrate to the sea in late spring, spending a few weeks feeding on benthos and forage fish before returning inland for the fall (Ganter et al. 2010 a, b; Swanson and Kidd 2010, Swanson et al. 2010). Char form an important component of the diet of northern coastal communities and in some locations such as Cambridge Bay, fish are sufficiently abundant to support a commercial fishery. Sea-run char tend to have lower concentrations of mercury and persistent organic contaminants than char that do not migrate to sea and much lower concentrations than marine mammals (Johansen et al. 2004; Muir et al. 2008b; Gantner et al. 2010a, b; Swanson and Kidd 2010). Differences have been related to the slower growth rates of landlocked char compared to sea-run populations (Evans et al. 2005a; Muir et al. 2005, 2008a, 2010; Swanson and Kidd 2010). For mercury, which requires methylation in order to bioaccumulate and biomagnify, concentrations are more likely to be high in fish inhabiting small lakes which warm in the summer compared to the cold and deep waters of the ocean where methylation rates are lower (Evans et al. 2005b). A recently completed M. Sc. Thesis by van der Velden (2012) gives greater weight to the importance of lower mercury levels in the diet of sea-run than resident char than the growth diltuion hypothesis.

The Northern Contaminants Program (NCP) includes char in its monitoring in order to provide communities with essential information on contaminant levels in their traditional foods. NCP also is designed to track the decline of legacy persistent organic contaminants such as PCBs and DDT which over the past several decades were carried by the air and ocean currents to the Arctic where they are taken up by animals such as char (Fisk et al. 2003). With the reduced usage of these chemicals globally (Hung et al. 2010), it is expected that their concentrations will decline in the environment. Such declines may be slower in the Arctic since these chemicals continue to migrate north under the grasshopper effect which may be further facilitated by warming trends even though the contaminant reservoirs in the south are diminishing. Furthermore, the cold and low productivity in the arctic environment hinders rapid degradation of these chemicals and their burial in newly formed sediments.

In addition to concerns with legacy persistent organic contaminants, researchers are concerned about the environmental fate of the newer classes of compounds that are now being manufactured. These new classes, which have a shorter history of presence in the north, include compounds such as brominated flame retardants and perfluorinated chemicals (Butt et al. 2007, 2010; Muir et al. 2008b; Tittlemier and Chan 2006). Mercury, a naturally-occurring metal, also is of concern because at high concentrations, it can be toxic. Furthermore, increasing amounts of mercury have been carried to northern Canada since the mid 1880s with the onset of the industrial revolution and increased combustion (Muir et al. 2009; Kirk et al. 2011). The more recent record is subject to some debate as mercury emission controls have been implemented in many countries, reducing their emission rates, but other countries, particularly those in Asia, are building more coal-fired power plants and potentially releasing more mercury despite their modern technology (Pacyna et al. 2006; Durnford et al. 2010; Weiss-Penzias et al. 2007). Global warming also is expected to affect mercury pathways (ACIA 2005).

Our sea-run char monitoring program began in 2004 when persistent organic contaminants and metals, including mercury, were assessed in six communities annually until 2010, when the program was scaled back to three communities (Nain, Cambridge Bay, and Pond Inlet) and then 2011 when only Cambridge Bay and Pond Inlet contributed to the monitoring program. These communities were selected because of existing contaminant data from earlier studies, as well as for their location, the importance of the commercial fisheries (Ekaluktutiak) and our excellent community interactions. The early monitoring provided necessary data on spatial variations in mercury and persistent organic contaminant concentrations in sea-run char. It confirmed that concentrations were uniformly low (Evans and Muir 2008, 2009, 2010) and differed from lake trout (*Salvelinus namaycush*) and landlocked (or resident) char which showed highly elevated mercury and persistent organic contaminant concentrations in some lake populations (Evans et al. 2005 a, b; Lockhart et al. 2005; Ryan et al. 2005).

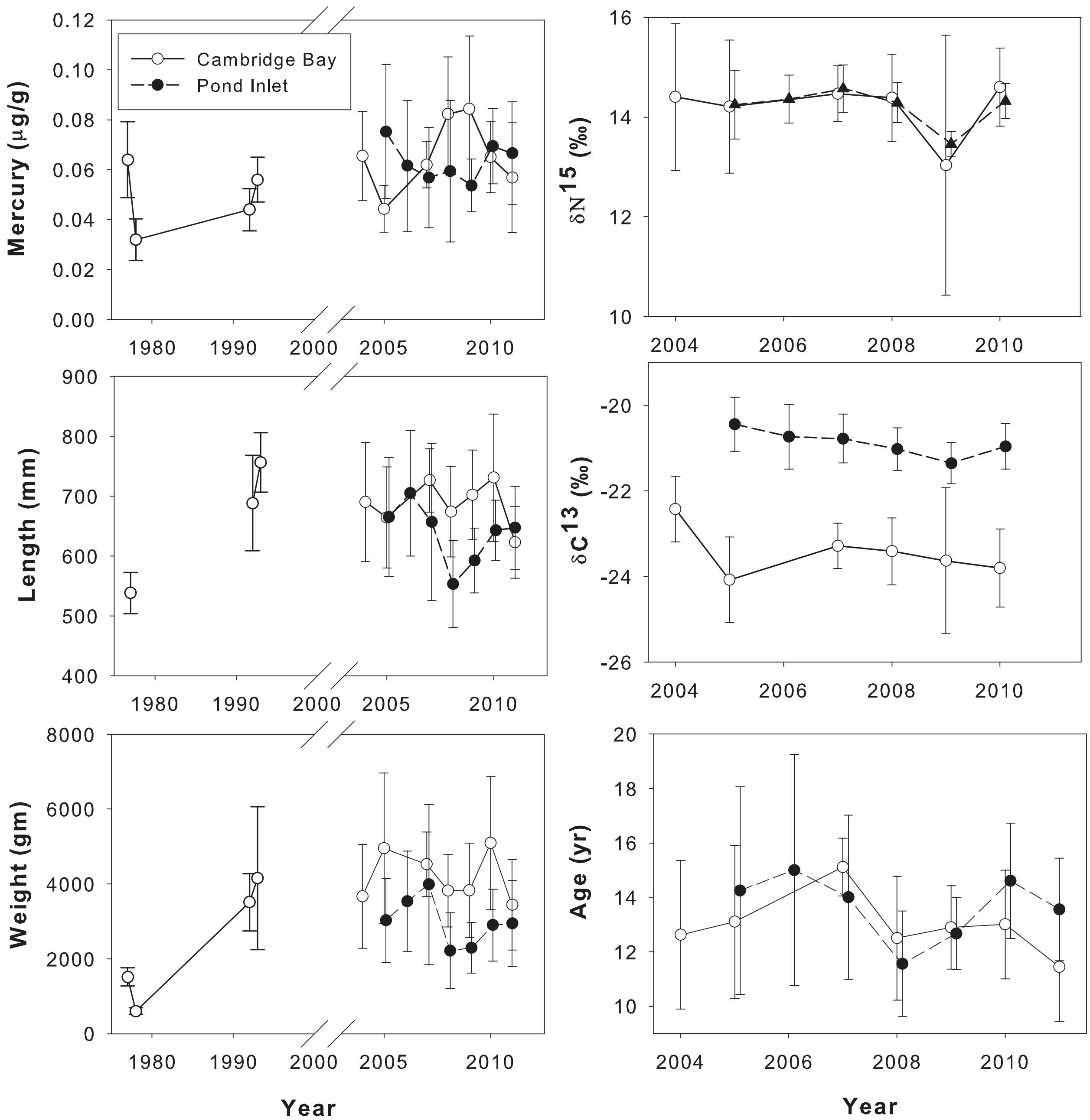
Activities in 2011-2012

In late winter 2011, Cambridge Bay, Pond Inlet and Nain were contacted again about the proposed collections; the study was discussed and a copy of the plain language summary and the consultation forms were sent. A copy of the full proposal and the 2010-2011 report were also requested and sent. This was followed by telephone conversations and E-mails to arrange for the 2011 collections. Twenty sea-run char were shipped whole and frozen from each community to Saskatoon where sample processing began.

Length, weight, age, and gender were determined on all fish from each location along with liver, gonad, and stomach weight; notations were made of the presence of parasites and/or disease where appropriate. A fillet sample, as well as, the liver, stomach, and gonad were retained from each fish. Carbon and nitrogen isotope and percent moisture analyses are performed on all fish. Ten of the twenty fish from each location were selected for metals, legacy organic contaminants and PDBE and PFA analyses, with the sample archive consisting of various tissue samples from all twenty fish per location. Archived samples are maintained at -40oC in a walk-in freezer at the National Hydrology Research Centre which has a monitoring system overseen by commissionaires 24-hours a day, 365 days a year. Fish age and mercury concentration data have been provided by the analytical laboratories. Stable isotope, metal and organochlorine contaminant analyses are ongoing.

Results of our research to date have been reported in Evans and Muir (2011), as well as, at the September 2011 NCP workshop in Victoria. We have also contributed to CACAR and CARA expert work groups. As well, a M.Sc. Thesis (supported primarily by Arctic Net) investigating mercury concentrations in sea-run and resident char along a latitude gradient

Figure 1. Time trends in length, mercury concentration and carbon and nitrogen isotope ratios for sea run char from Cambridge Bay and Pond Inlet.

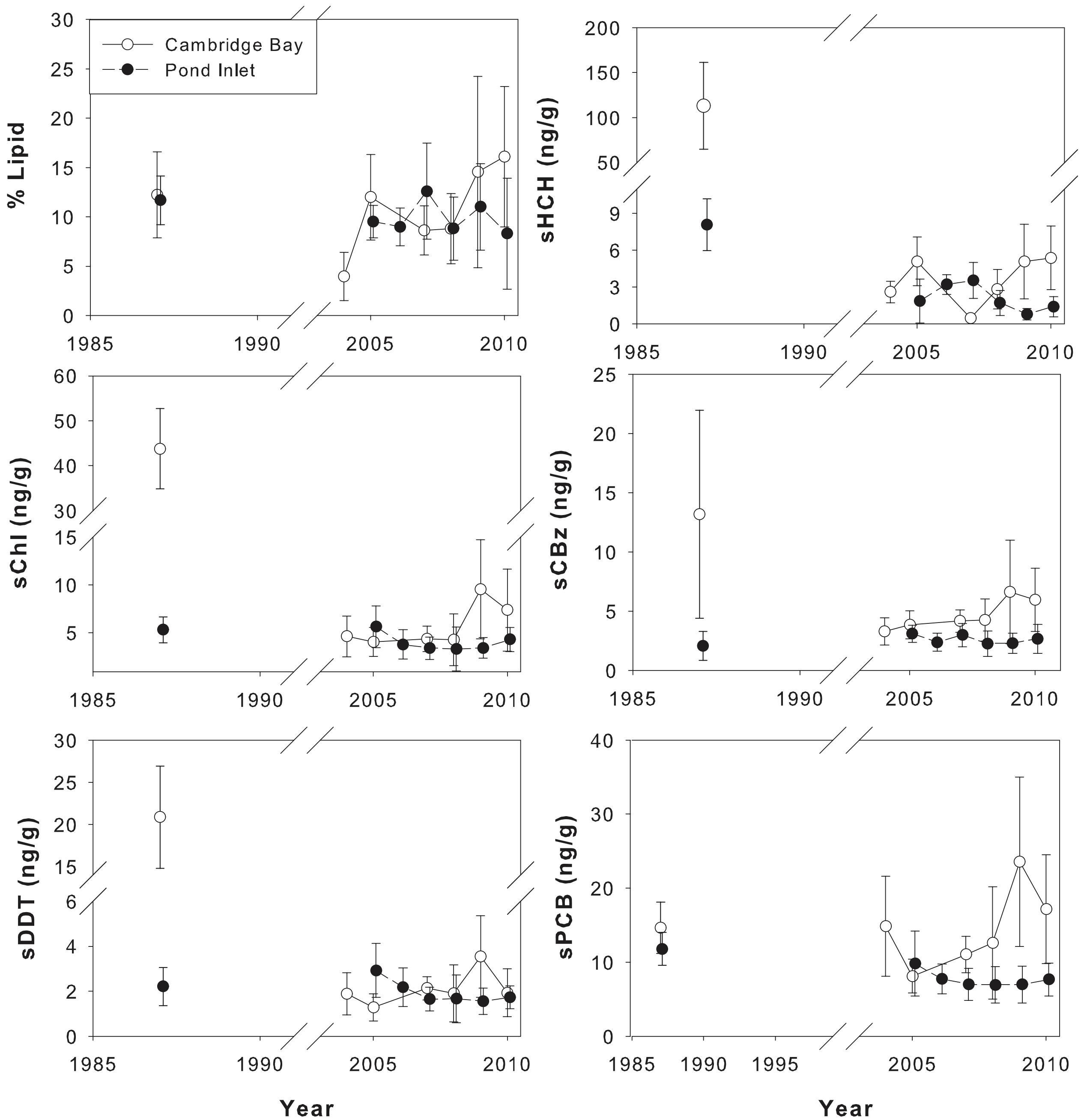


(including Nain, Iqaluit, Pangnirtung and Pond Inlet) was recently and successfully defended by Shannon van der Velden; papers are expected to be submitted shortly.

Results

Temporal variations in mercury levels
Cambridge Bay is the site of a long-term commercial fishery with their earliest mercury measurements made in 1977, 1978, 1992 and 1993 (Lockhart et al. 2005) Fish caught in 1977 and 1978 were small (length was not determined in 1978) and were not suitable to include in time trend analyses. It is noteworthy that mercury concentrations were not correspondingly lower in these fish (than more recent times) which could suggest that mercury concentrations were higher in size-adjusted char in the late 1970s than later times. With the exception

Figure 2. Time trends in lipids (%) and persistent organic contaminants in sea-run char at Cambridge Bay and Pond Inlet



of 2006, mercury concentrations were measured annually from 2004-2011 under NCP. Mercury concentrations showed a trend of increase over 2005-2009 but were lower in 2011 and 2011. When all available data (excluding 1977 and 1978) were considered, there was a significant trend of mercury increase with variations in mercury concentration also explained by fish length ($R^2 = 0.45$; F= 10.04, p =0.0001).

Pond Inlet has been monitored annually since 2005. Fish harvested from Pond Inlet were, on average, smaller than at Cambridge Bay. Mercury concentrations in Pond Inlet char decreased from 2005-2008, roughly following the decreased length of the fish analyzed, and then increased in 2010. Variations in mercury concentration were explained only by length. Pond Inlet char appeared to rely on more littoral carbon than Cambridge Bay char, while nitrogen isotope ratios were similar.

Temporal variations in legacy POPs and PBDEs

Persistent organic contaminants (Fig. 2) were determined in sea-run char at Cambridge Bay and Pond Inlet in 1987 (Muir et al. 1990, unpublished data); these early data must be examined with some caution as analytical methods have changed and were based on whole body rather than fillet measurements. Lipid concentrations in Cambridge Bay char were relatively high in 1987, lower in 2004 and then showed a general trend of increase over 2006-2010 (Fig. 2). HCH, chlordane, CBz, and DDT (but not PCB) concentrations were substantially higher in 1987 than in 2004-2010. There was no obvious trend in contaminant concentrations over 2004-2010 although concentrations tended to be higher in 2009 and 2010 corresponding to higher lipid levels.

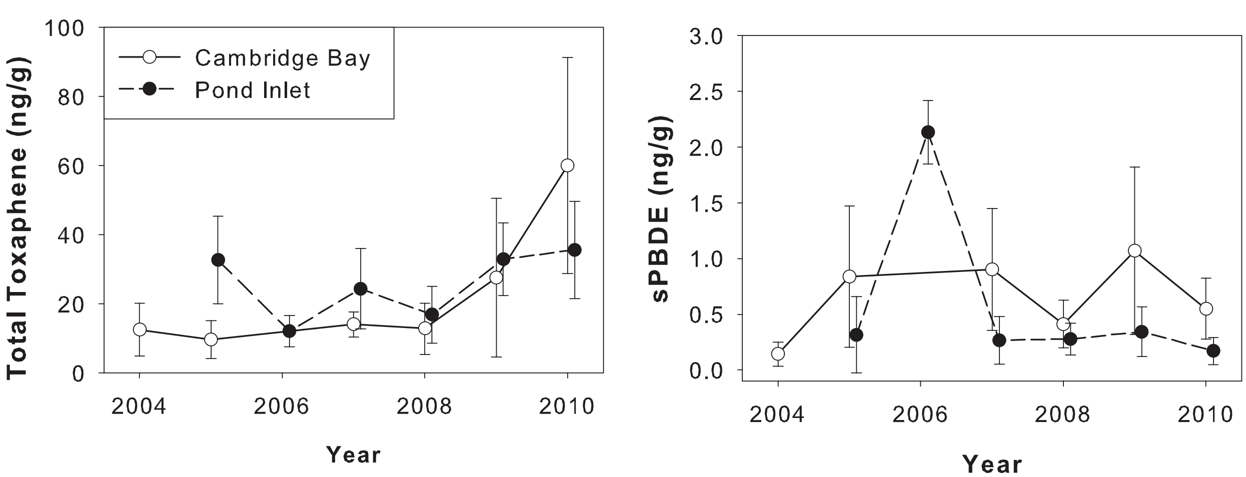
Lipid concentrations in Pond Inlet char were less variable than at Cambridge Bay and had no trends evident. Although HCH concentrations were slightly lower over 2005-2010 than previous measurements, CBz, DDT, PCB and chlordane all occurred in generally similar concentrations over the two study periods. Concentrations were slightly lower over 2008-2010, however statistical analyses need to be conducted to determine whether represent an actual temporal decline or instead variation due to differences in fish length and lipid content.

Toxaphene was the most abundant of the persistent organic contaminant measured (Fig. 3). There was an apparent trend of increasing concentrations with time at Cambridge Bay. Concentration in 1987 (not graphed) was 42 ng/g (Muir et al. 1990), which is higher than 2004-2009 concentrations but lower than 2010 concentrations. Toxaphene concentrations in Pond Inlet char showed a slight trend of increase over 2006-2010, although statistical analyses are required to assess the variables affecting this trend. PBDE concentrations were low in char from both communities with no time trend evident over the short time period in which these fish were analyzed (Fig. 3).

Discussion and Conclusions

Mercury and persistent organic contaminant concentrations are low in sea-run char. There appears to be a trend of increasing mercury concentrations in char at Cambridge Bay over 1992-2011 but not Pond Inlet over 2004-2011. Such an increase could be driven by a warming trend which may be enhancing productivity and mercury methylation, while increased mercury emissions from Asia could also play

Figure 3. Temporal variability in toxaphene and PBDEs (ng/g wet weight) in sea-run char from Cambridge Bay and Pond Inlet.



a role (Stern et al. 2005; Outridge et al. 2007; Muir et al. 2009; Carrie et al. 2010; Riget et al. 2011). Stable carbon and nitrogen isotope ratios exhibited no obvious trend suggesting that trophic feeding of sea run char in the Cambridge Bay area has not changed in recent years although feeding regime in earlier time periods is unknown. However, it is possible that mercury concentrations in their food supply have changed.

Most legacy organic contaminant concentrations (i.e., HCH, chlordane, CBZ, and DDT) were lower over 2004-2010 at Cambridge Bay than in 1987. This decrease could in part be due to declining usage and long-range transport to the north (Hung et al. 2010). Similar declines are also being observed in Great Slave Lake fish (Evans and Muir 2012). PCB and toxaphene show no evidence of decline. This observation, combined with the low concentrations of these chemicals, is somewhat unexpected. It is possible that a smaller suite of congeners were analyzed in 1987 than later years; differences may also be due to the fact that whole body was analyzed in 1987 versus fillet under NCP but this should affect all legacy organic contaminant comparisons. Only HCH appears lower at Pond Inlet over 2005-2010 than in 1987.

Overall, the data base for assessing time trends in contaminants in sea run char is short which limits the sensitivity to detect change (Riget et al. 2010). As the data base grows with more years of sampling, sensitivity will improve. Data such as fish age and stable isotopes will also provide information on char growth rates, trophic feeding and their response to the warming trend which has been observed in this region of the Arctic.

NCP Perfomance Indicator

Performance Indicator	Number	Detail / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	3	We rely on the Hunters and Trappers Association or an equivalent to arrange for the harvest of fish allowing for more than one fisherperson to be involved. We deal directly with a representative of the Hunters and Trappers office in each community and they then delegate who shall collect the fish. In the case of this study, we do not know directly which individuals are performing the collection.
number of project-related meetings/workshops held in the North (April 1, 2011 – March 31, 2012)	0	
number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	1	One M.Sc. Student
number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	1 2011: 61	(Riget et al. 2011). Contributions to CACAR and AMAP reports.

Expected Completion Date

This is core trend monitoring project with monitoring expected to continue with the NCP program.

Acknowledgements

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Temporal Trends of Persistent Organic Pollutants and Mercury in Landlocked Char in High Arctic Lakes

Tendances temporelles des polluants organiques persistants et du mercure chez l'omble chevalier dulcicole de l'Extrême-Arctique

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Abstract

This long term study is examining trends over time of mercury and other trace elements, as well as legacy and new persistent organic pollutants (POPs) in landlocked Arctic char collected annually from three lakes near the community of Resolute Bay on Cornwallis Island (Amituk, Char and Resolute) and in Lake Hazen in Quttinirpaaq National Park on Ellesmere Island. In 2011, arctic char samples were successfully collected from all four lakes. To assess trends over time, results were combined with previous results from the same lakes. With the addition of results from 2011 we found no statistically significant trends of mercury in char in the four study lakes although concentrations

Résumé

La présente étude à long terme traite des tendances temporelles du mercure et d'autres éléments en trace, ainsi que des polluants organiques persistants (POP), anciens et nouveaux, chez l'omble chevalier dulcicole (confiné aux eaux intérieures). Nous avons recueilli des échantillons tous les ans dans les lacs Amituk, Char et Resolute, près de la collectivité de Resolute Bay, sur l'île Cornwallis, et dans le lac Hazen, dans le parc national Quttinirpaaq, sur l'île d'Ellesmere. En 2011, on est parvenu à recueillir des échantillons d'omble chevalier dans les quatre lacs. Afin d'évaluer les tendances temporelles, les résultats ont été combinés aux résultats antérieurs obtenus

have declined slightly since 2005. Legacy POPs such as hexachlorocyclohexanes, PCBs and DDT are declining in char in all lakes. However newer contaminants such as brominated flame retardants have increased in some lakes. Local sources could be important for toxaphene as well as PFOS in Resolute Lake.

pour les mêmes lacs. Après l'ajout des résultats de 2011, nous n'avons établi aucune tendance statistique significative en ce qui a trait à la concentration de mercure chez les populations d'omble chevalier des quatre lacs étudiés. Les concentrations ont cependant légèrement diminué depuis 2005. Les concentrations des POP anciens, tels que l'hexachlorure de benzène, les BPC et le DDT, sont en déclin chez l'ombre chevalier dans tous les lacs. Cependant, des contaminants plus récents, comme les produits ignifuges bromés, ont augmentés dans certains lacs. Des sources locales pourraient être importantes pour ce qui est des concentrations de toxaphène et de PFOS dans le lac Resolute.

Key Messages

- Concentrations of mercury concentrations in landlocked char from the four study lakes have declined slightly since 2005 but the overall trend is not statistically significant.
- Legacy POPs such as hexachlorocyclo-hexanes, PCBs and DDT are declining in char in all lakes while some newer flame retardant chemicals are increasing.

Messages clés

- Dans les quatre lacs étudiés, les concentrations de mercure chez l'ombre chevalier ont légèrement diminué depuis 2005, mais la tendance globale n'est pas statistiquement significative.
- Les concentrations de POP anciens, tels que l'hexachlorure de benzène, les BPC et le DDT, sont en déclin chez l'ombre chevalier dans tous les lacs. Cependant, les concentrations de nouveaux produits ignifuges sont à la hausse.

Objectives

1. Determine long term temporal trends of persistent organic pollutants (POPs) and metals in landlocked Arctic char from lakes in the Canadian high arctic islands by analysis of annual or biannual sample collections.
2. Investigate factors influencing contaminant levels in landlocked char such as the influence of sampling time, water temperature, diet and climate warming.
3. Determine levels of current POPs and metals as well as "new" potential POPs in fish from lakes of importance to the community of Resolute Bay (Qausuittuq) and provide this information on a timely basis.

Introduction

Landlocked char are important sentinel species in Arctic lakes. They are long lived and slow growing, especially compared to anadromous or searun char, which achieve faster rates of growth by feeding in the marine environment (Power et al. 2008). As the only top predators in most high latitude Arctic lakes, landlocked char (Köck et al. 2004; Power et al. 2008) are good indicators of changes in inputs of methyl mercury, the toxic and bioaccumulative form of mercury. The same considerations apply to persistent organic pollutants (POPs) which are known to have similar biomagnification potential as methyl mercury. Char thus provide information on the range of chemical contaminants and time trends of these chemicals in Arctic freshwater systems which complements studies on mammals and birds from the same regions. However, there is much lake to lake and individual variation in contaminant levels which needs to be better understood.

There is a lot more information now available on contaminants in landlocked char populations and their food webs as a result of studies by Gantner et al (2009; 2010a; 2010b), Swanson and Kidd (2010), Swanson et al. (2010), Chételat et al. (2008; 2010) and van der Velden (2012). These studies show that catchment-to-lake area ratio influences mercury in char as do methyl mercury concentrations in chironomids and benthic algae.

This study reports on results of continued annual sampling and contaminant analysis of char at Resolute, Char and Amituk lakes on Cornwallis Island as well as from Lake Hazen in Quttinirpaaq National Park on Ellesmere Island. Annual sampling has been used in order to try to achieve the goal of detection of a 5% change over a 10-15 year period with a power of 80% and confidence level of 95% (INAC 2005). Landlocked char annual collections have been successfully carried out in Resolute Lake since 1997 (Köck et al. 2004; Muir et al. 2005), however, in Char and Amituk, fishing is more difficult due to low numbers (Char) and weather dependent access by helicopter (Amituk). Char collection in Lake Hazen is also a challenge mainly due the high cost of flights into the Parks Canada Hazen camp on the northwestern shore of the lake. While collections of char from Char, Amituk and Hazen have not been as consistent as in Resolute Lake, all lakes have 10 or more years of sample collections. Collection numbers have typically ranged from 7 to 25 adult fish (>200 g) per lake except in Char Lake where the range has been 3 to 10 fish annually. Further details on past results from these study lakes are given in previous synopsis reports (Muir et al. 2008; 2009; 2010; 2011a).

Activities in 2011-12

Sample collection: Samples were successfully collected in July 2011 from Amituk, Char, Hazen and Resolute Lakes. In 2011, we were again challenged at Char Lake, with only 4 fish collected despite several long net sets. At Hazen the collections were carried out by Parks Canada staff at Quttinirpaaq National Park at the end of June 2011, char were filleted on site, and then samples and fish heads transported on ice to Polar Continental Shelf Project (PCSP) labs in Resolute. In a related NCP project (Kidd et al. 2011), graduate student Gretchen Lescord collected landlocked char, lake water and food web samples from 6 lakes in the Resolute area including zooplankton and juvenile char from Amituk, Char and Resolute lakes. Fish were dissected in PCSP labs at Resolute. Samples (skin- on fillets) were frozen in Resolute and then shipped to the Environment Canada labs, Burlington, Ontario, and stored at -20°C until analysis. Char otoliths were removed and archived for future age determinations.

Chemical analysis: Analytical methods were unchanged from previous reports (Muir et al. 2008; Muir et al. 2009). All analyses were performed by the National Laboratory for Environmental Testing (NLET) at Canada Centre for Inland Waters in Burlington. Mercury and 31 other elements were analysed in Arctic char muscle (skinless). Organohalogen compounds were determined in homogenized char (muscle plus skin) samples. PCBs and organochlorine pesticides (OCPs) were analysed in final cleaned up extracts were by gas chromatography with electron-capture detection (GC-ECD). All organohalogen analyses were conducted in the NLET "ultraclean" room (carbon and HEPA filtered air; positively pressured) to minimize background contamination. Toxaphene, endosulfan isomers and endosulfan sulfate, PBDEs and hexabromocyclododecane (HBCD) and bis(tribromophenoxyethane (BTBPE) were analysed by low resolution GC-negative ion mass spectrometry (GC-NIMS). Toxaphene was determined as "total" toxaphene using a technical toxaphene standard and also by quantification of individual chlorobornanes (see Muir et al. (2004) for further details on methods). Perfluorinated chemicals (PFCs) in char muscle were analysed as described in Reiner et al. (2012).

Stable isotope analyses: Muscle from all fish analysed for mercury and POPs were analysed for stable isotopes of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) at University of Waterloo Environmental Isotope Lab in muscle samples using isotope ratio mass spectrometry.

Quality assurance (QA): Certified reference materials (CRMs) for heavy metals included DOLT-2, DORM-2 and TORT-2 (National Research Council of Canada) and 1588b cod liver and 1946 lake trout from NIST (National Institute of Standards and Technology) for PCBs, OCPs, and PBDEs. CRMs and reagent blanks were also run with each sample batch of 10 samples. Blanks were generally <1% of measured values for individual OCPs and <5% for individual PCBs. Blanks for BDE 47 and BDE 99 ranged from 5-10% of values in samples while for BDE 209 blanks were up to 50% of sample values. All results for PBDEs were blank subtracted while no correction was used for PCB/OCPs. NLET organics and metals labs are participants in the NCP Quality Assurance Program. The NLET labs are accredited by the Standards Council of Canada through Canadian Environmental Analytical Laboratory program to the standard CAN-P-4D (ISO/IEC 17025). During 2010-11 the Muir laboratory participated in an interlab comparison of PFCs in reference materials from the National Institute for Standards and Technology (NIST) which is now published (Reiner et al. 2012).

Statistical analyses: Geometric mean concentrations and upper/lower 95% confidence intervals were calculated with log transformed data and back transformed for graphical presentation. Results for POPs were lipid adjusted by dividing by fraction lipid. Non-detect concentrations were replaced with a random number between 10% and 50% of the instrumental detection limit. Based on previous data analyses (Muir et al. 2011a) results for all elements and POPs were log10 transformed in order to reduce coefficients of skewness and kurtosis to <2.

Results

Mercury: We have previously reported that mercury levels were increasing slowly in Arctic char from Amituk, Char and Resolute lakes (Muir et al. 2008; 2009). However, when the 2010 and 2011 results were included and trends were analysed with the PIA software (Bignert 2007) using length adjusted log transformed means for each sampling year, no statistically significant trends were found in all 4 lakes (Table 1). Results for Resolute Lake, with 15 sampling years, have achieved the goal of detecting a 5% change (with a power of 80% at α=5 %). Thus any future change is likely to be quickly detected. In fact, the overall trend in Resolute Lake is for declining mercury (-2.4% per year) and there has been a general decline of mercury in Lake Hazen and Amituk Lake as well since 2005. But these trends are not statistically significant over this limited number of years.

Legacy POPs: Trends for legacy POPs based on samples collected up 2010 to were analysed using PIA software. Results for analysis of the 2011 samples are pending. α-HCH is changing the most rapidly of all POPs in all four lakes with an annual decline of 9.7 to 18% (Table 2). β-HCH actually increased in char from Amituk and Hazen Lakes. ΣDDT, and ΣPCBs declined significantly in all lakes. Toxaphene declined in all lakes except in Resolute Lake where it showed an overall increasing trend due to recent higher concentrations. Since this increase only occurred at Resolute Lake it may be related to a local source within the watershed which is an area that includes Resolute airport and a former military base.

New POPs: Trends for ΣPBDEs (sum of 14 BDEs; major congeners 47, 99, and100) in landlocked char vary widely among lakes. ΣPBDE concentrations increased overall in all lakes compared to the 1990s but are now declining in Amituk and Resolute lakes (Figure 1; Table 2). No decline of ΣPBDEs has been observed in char from Char Lake while in Lake Hazen concentrations have been increasing steadily since 2001.

Table 1. PIA analysis of time series for mercury concentrations in landlocked char muscle.

Lake		# years	Overall trend [1]	Power to detect a log-linear trend of 5% with this number of years	lowest detectable change[2]
Amituk	1989 – 2011	11	-0.61% (NS)	23%	12%
Char	1993 – 2011	10	0.51% (NS)	50 %	7.2%
Hazen	1990 – 2011	11	0.48% (NS)	14%	16 %
Resolute	1993 – 2011	15	-2.4% (NS)	80%	5%

[1] Trends based on length adjusted geometric means analysed using PIA (Bignert 2007)

Table 2. Percent annual decline (negative) and increase in selected POPs [1] in arctic char from the four study lakes using the PIA program (Bignert 2007).

	Time period	Sampling Years	Toxa-phene	ΣPCB	ΣDDT	α-HCH	β-HCH	ΣPBDEs[2]
Amituk	1989-2009	10	-9.8*	-8.3*	-8.9*	-18.0*	6.7*	60
	2003-2009	6	–	–	–	–	–	-23
Char	1993-2010	10	-4.1	-8.4*	-9.6*	-16.0*	1.6	2.1
Hazen	1990-2010	10	-7.9	-7.0	-14.0*	-11.0*	7.3	23*
	2001-2010	8	–	–	–	–	–	98*
Resolute	1997-2010	13	15*	-3.9	-2.8	-9.7*	-1.5	21*
	2005-2010	6	–	–	–	–	–	-19

[1] * indicated statistically significant trend (P <0.05)

[2] Results for PBDEs generally from the 1990s to mid-00s; dates shown in the time period column

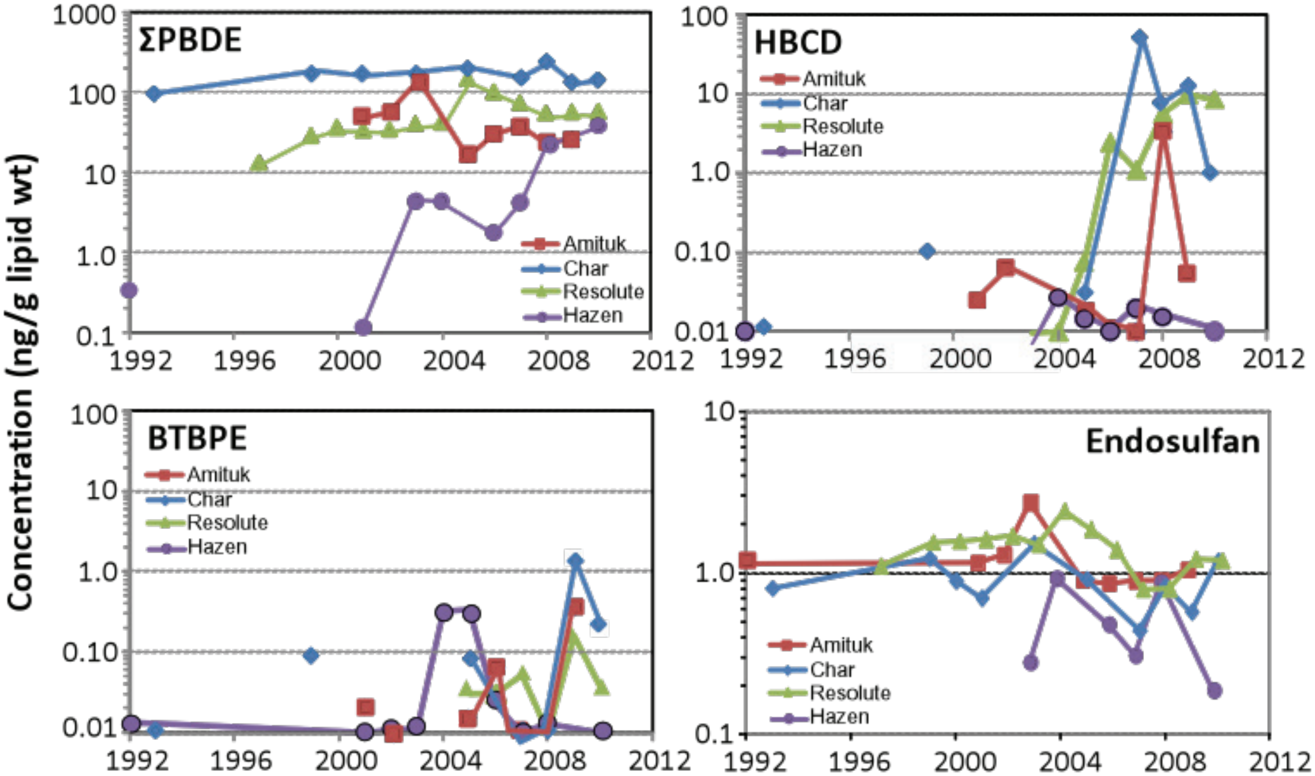
[3] Results for toxaphene in Resolute Lake char are for 2003-2010 only

HBCD and BTBPE, which are both replacements for PBDE flame retardants were also detected in char muscle (Figure 1). Concentrations of HBCD were near detection limits in all lakes until 2006 when levels increased particularly in Resolute and Char Lake. BTBPE concentrations remain near detection limits except in Char Lake where concentrations reached 1 ng/g lipid wt in 2009 (Figure 1).

Concentrations of α-endosulfan increased during the 1990s until 2003- 2004, in landlocked char particularly in Amituk and Resolute Lakes (Figure 1). No significant increase or decline of α-endosulfan was seen in Lake Hazen char. β-endosulfan was generally not detected (<0.01 ng/g) while endosulfan sulphate (ES) was present at similar concentrations as the α-isomer. However, temporal trends of ES could not be estimated because it was not determined in samples taken prior to 2007.

Time trends of PFCs in landlocked char were previous discussed in detail in our 2011 report. With new results from 2011, PFOS continues to remain higher in char from Char Lake, while it remains unchanged in Amituk and Hazen. ΣPFCAs (sum of perfluoro alkyl acids with 9 to 12 carbons) showed little change in concentration 2007-2011 in Lakes Hazen, Char and Amituk.

Figure 1. Trends in concentrations of HBCD, BTBPE, ΣPBDEs (sum of 14 congeners) and α-endosulfan in landlocked char from Resolute, Amituk, Char, and Hazen lakes (early 90s-2010). Symbols represent geometric mean concentrations. Error bars are omitted for clarity.



Discussion and Conclusions

Analysis of trends of mercury in landlocked char from the four lakes with results from 2011 included, indicates no overall statistically significant trends although declining concentrations have been observed in the past 5 to 6 years. Annual sampling, and relatively low within year variation, has succeeded in achieving 80% statistical power at Resolute Lake and may soon achieve this in Char Lake if fishing success there continues. The results contrast with lake trout and burbot from Great Slave Lake (Evans and Muir 2011a), with burbot in the Mackenzie River (Carrie et al. 2010), and in fish from small lakes in the Mackenzie River basin (Evans and Muir 2011b) where increasing mercury in fish has been reported. Recently Riget et al (2010) found that length adjusted mercury concentrations in landlocked char from a lake in southwestern Greenland increased significantly over the period 1994 to 2008 (6 sampling years). This trend was tentatively linked to increasing mean monthly air temperature during May to August although correlations were not statistically significant due to small number of sampling times. These results for Greenland can be investigated with the much larger datasets available for the four lakes in this study

The increase of toxaphene in char in Resolute Lake is surprising but given that this increase is only occurring in the lake which is downstream from the Resolute airport, it suggests release of some previously deposited local contamination, as observed for PFOS (Muir et al. 2011a). The increase in PBDEs in char is in general agreement with observations for ringed seals in the Canadian arctic (Ikonomou et al. 2002; Ikonomou and Addison 2008) and for arctic air (Su et al. 2007) as well as in ringed seals (Muir et al. 2011b). Overall, landlocked char appear to be excellent bioindicators of mercury, legacy POPs and new bioaccumulative contaminants.

NCP Performance Indicator

Performance Indicator	Number	Detail / Description
number of northerners engaged in your project	2	This project hired Debbie and Brandy Iqaluk to help sample fish.
Number of meetings/workshops held in the north	1	Team members met with HTC Manager, Nancy Amarualik while in Resolute (July 2011).
Number of students involved in the project	2	Graduate students Gretchen Lescord and Ben Barst helped with fish collections in Resolute, Char and Amituk Lakes during 2011.
Number of citable publications	None	Contributed data to the CACAR mercury and POPs assessments.

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

Tendances spatiales et à long terme des polluants organiques persistants et des métaux présents chez le touladi et la lotte dans les Territoires du Nord-Ouest

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Abstract

Our study is investigating temporal trends in persistent organochlorine contaminants and mercury in Great Slave Lake. Two areas are being investigated, i.e., the West Basin which is profoundly affected by the Slave River inflow and the East Arm where direct atmospheric inputs are believed to be the more important contaminant source. Within each region, a pelagic (lake trout) and more sedentary (burbot) predator are being investigated. Lake trout were caught at Hay River (West Basin) and Lutsel K'e (East Arm) and burbot were caught at Fort Resolution (West Basin) with NCP funds. With other funds we continued our burbot sampling at Lutsel K'e and northern pike (mercury only) at Fort Resolution. HCH, chlordane, DDT and toxaphene concentrations have declined in lake trout (fillet) and burbot

Résumé

Notre étude porte sur les tendances temporelles des concentrations de contaminants organochlorés persistants et de mercure dans le Grand lac des Esclaves. Deux zones sont visées par l'étude : le bassin ouest, sur lequel l'arrivée d'eaux de la rivière des Esclaves influe profondément; et le bras est, pour lequel on croit que les apports atmosphériques directs sont la plus importante source de contaminants. Un prédateur pélagique (touladi) et un prédateur plus sédentaire (lotte) sont étudiés dans chaque région. Des touladis ont été capturés à Hay River (bassin ouest) et à Lutsel K'e (bras est) et des lottes, à Fort Resolution (bassin ouest), grâce à des fonds provenant du PLCN. D'autres fonds ont permis de poursuivre l'échantillonnage de la lotte à Lutsel K'e et du grand brochet (pour le mercure seulement)

(liver) since the early 1990s with the rate possibly faster for burbot than lake trout; differences could be due to the tissues analyzed or the ecology of the fish. CBz and PCBs, and PBDEs show no evidence of a decline in lake trout but declines were evident in burbot. Mercury concentrations continue to evidence of a long-term trend of increase in burbot and lake trout although this trend has weakened in recent years. Under related studies we continued to work on assessments of mercury concentrations in fish in lakes in the Deh Cho area, provided advice on mercury issues and reservoirs and contributed to capacity building studies at Fort Resolution and Lutsel K'e.

Key Messages

- Among the legacy persistent organic contaminants, HCH, chlordane, DDT and toxaphene are showing strong trend of declines in lake trout (fillet) and burbot (liver) in fish caught from the West Basin and East Arm of Great Slave Lake. There is no evidence that CBz and PCB concentrations are declining.

- While trend of mercury increase persist for lake trout in both study locations and West Basin burbot, the trend is weaker with a decline in mercury concentrations in these fish in recent years. There is no mercury trend of increase for East Arm burbot and West Basin pike possibly in part due to weaker long-term records.

- While mean annual air temperature has shown a trend of increase over 1970-2010, the correlation between air temperature and mercury concentration for West Basin lake trout (for which we have the longest temporal record) was weak suggesting that additional factors need to be investigated in

à Fort Resolution. Les concentrations de HCH, de chlordane, de DDT et de toxaphène ont diminué chez le touladi (filet) et la lotte (foie) depuis le début des années 1990, plus rapidement probablement chez la lotte que chez le touladi, les différences pouvant être attribuables aux tissus analysés ou à l'écologie des poissons. Les données sur les concentrations de CBZ, de BPC et de PBDE ne montrent aucune baisse chez le touladi, mais révèlent une nette baisse chez la lotte. Les concentrations de mercure continuent d'indiquer une tendance à la hausse à long terme chez la lotte et le touladi, mais la tendance a faibli au cours des dernières années. Dans le cadre d'études connexes, nous avons continué à évaluer les concentrations de mercure chez les poissons dans les lacs de la région Deh Cho, fourni des conseils sur les problèmes liés au mercure et les réservoirs de mercure et contribué à des études sur le renforcement de la capacité effectuées à Fort Resolution et à Lutsel K'e.

Messages clés

- Chez des spécimens de touladi (filet) et de lotte (foie) ayant été capturés dans le bassin ouest et le bras est du Grand lac des Esclaves, on constate une forte tendance à la baisse de certains contaminants organiques persistants légués du passé notamment, le HCH, le chlordane, le DDT et le toxaphène. Rien n'indique que les concentrations de CBZ et de BPC soient en train de diminuer.

- Bien qu'une tendance à la hausse du mercure persiste chez le touladi aux deux endroits et chez la lotte dans le bassin ouest, la tendance est plus faible, en raison d'une diminution des concentrations de mercure chez ces poissons au cours des dernières années. Il n'y a pas de tendance à la hausse pour ce qui est de la concentration de mercure chez la lotte dans le bras est et chez le brochet dans le bassin ouest, probablement, en partie, à cause de la faiblesse des données à long terme.

- Même si les températures de l'air moyennes annuelles présentaient une tendance à la hausse dans la période 19702010, la assessing the factors affecting the mercury increase in lake trout (and by inference other species).

corrélation entre la température de l'air et la concentration de mercure chez le touladi (poisson pour lequel nous possédons la plus longue série chronologique de données) dans le bassin ouest était faible, ce qui laisse supposer que des facteurs supplémentaires pouvant influer sur l'augmentation de la concentration de mercure chez le touladi (et peut être chez d'autres espèces) doivent être étudiés.

Objectives

1. Determine temporal trends in persistent organic contaminants, mercury, and other metals in lake trout at two locations (West Basin near Hay River, East Arm at Lutsel K'e) and burbot in the West Basin (offshore of Fort Resolution) through annual sampling, extending the 1993-2010 data sets to 2011 and beyond.

2. Investigate factors affecting temporal variability in contaminants in lake trout and burbot including length, age, trophic feeding, and lipid levels.

3. Participate in and contribute information to AMAP and CACAR expert work groups for trend monitoring for POPs and mercury.

4. Communicate results to the communities and the commercial fisheries in a timely manner, including through the Northwest Territories Regional Contaminants Committee.

Introduction

Great Slave Lake, located in the Northwest Territories, is part of the Northern Contaminant Program's (NCP) long-term biomonitoring program which includes lake trout and burbot. Under NCP, the earliest measurements of contaminants (persistent organic pollutants) in these fish occurred in 1993; lake trout and burbot (in addition to whitefish and lower components of the food web) were investigated in two regions of the lake (Evans 1994, 1995). In the mid 1990s, additional studies were conducted on contaminant deposition rates in the West Basin of the lake with concerns focussed on downstream influences from Alberta (Evans et al. 1996); this was followed by studies of metals in fish centring on concerns with the decommissioned Pine Point mine near Fort Resolution (Evans et al. 1998 a, b). Mercury determinations in fish also were made on a periodic basis as part of the Department of Fisheries and Oceans' Fish Inspection Services; these data have been summarized in Lockhart et al. (2005). Since 1999, lake trout and burbot have been monitored for contaminant trends annually with two exceptions: monitoring was not conducted in 2003 and burbot sampling at Lutsel K'e was discontinued in 2004 as part of the core NCP biomonitoring program. With eleven years of high quality biomonitoring data (1999-2010), less rigorous NCP data going back to 1993, and periodic fish inspection data (mercury only) going back to the 1970s, temporal trends are now beginning to be detected.

Fish are being monitored for contaminant trends in the West Basin which is relatively shallow, warm and productive and profoundly affected by the Slave River inflow; fish are also being monitored in the East Arm which is deeper, colder, and less productive (Rawson 1955; Fee et al. 1985). The East Arm is profoundly affected by atmospheric deposition whereas the West Basin is profoundly affected by Slave River inflow, the major source of water to the lake. While the original rationale for studying two locations was based on concerns of the influence of the Slave River on contaminant loading and biomagnification in Great Slave Lake, it also is allowing us to investigate how the limnological features of the two regions affect contaminant pathways. There was little evidence that the Slave River was profoundly affected by industrial activity several hundreds of kilometres to the south. Persistent organic contaminant concentrations are likely to be higher in biota in the low productivity waters of the East Arm than the higher productivity waters of the West Basin (Larsson et al. 1998; Berglund et al. 2001; Houde et al. 2008) while mercury levels are likely to be higher in the West Basin than the East Arm fish because of temperature, watershed, and productivity effects (Bodaly et al. 1993; Evans et al 2005b). Differences in fish growth and feeding characteristics between the two basins will also be influential in affecting contaminant levels in fish.

Lake trout (*Salvelinus namaycush*) is an omnivorous, cold-water stenotherm with a thermal optimum of ca. 10oC and largely confined to cold, deep and well-oxygenated waters during summer; burbot also is a predatory fish with a thermal optimum of 15.6o-18.3oC (Rawson 1951; Scott and Crossman 1998). Burbot liver, which is prized, is lipid-rich and hence high in persistent organic contaminants (Kidd et al. 1995; Evans et al. 2005a; Ryan et al. 2005).

Activities in 2011-2012

Capacity Building and Traditional Knowledge

In 2011-2012 we received Cumulative Impacts Monitoring Program (CIMP) funds which were based on the monitoring of the Great Slave Lake ecosystem. This funding allowed us to provide training opportunities to community members at Fort Resolution: Lutsel K'e had its own funding and we provided support to their limnological monitoring studies when asked primarily by providing guidance in temperature, pH and conductivity measurements. We were less involved in the Hay River CIMP study which was in collaboration with Fisheries and Oceans. At Fort Resolution we worked primarily with Elizabeth Giroux who tabulated the results of a traditional knowledge survey on changes noted in water quality, weather, and fish populations. She also entered several years of data from the water intake plant on temperature, turbidity, color, pH, iron and manganese concentrations and prepared Excel graphs. These experiences are providing her with training in data entry and manipulation and an opportunity to investigate some long-term trends in water quality in the Resolution Bay area. She currently is working with weather, domestic fish data and sport fishery records for the Little Buffalo River.

Communications

Various communications and reports were provided on this study in 2011-2012. Contributions were made to the mercury and persistent organic contaminant chapters of the CACAR report on spatial and temporal trends in contaminants in lake trout and burbot in Great Slave Lake. A scientific paper reporting mercury trends in lake trout, burbot and our sediment core studies (Evans and Muir 2010 a, b) was submitted to a scientific journal and is now in revision. Presentations were given in Yellowknife on our CIMP monitoring program (GeoScience meeting) and on metals and PAHs in sediments in the Mackenzie River Basin including the Mackenzie River, its tributaries, the delta and Great Slave Lake (Fisheries and Oceans Workshop). A presentation on our findings was given at the Northern Contaminant Program Results Workshop in September; the annual report was submitted. We also provided advice on a mercury monitoring program with the proposed expansion of the Bluefish Hydroelectric facility and additional input on mercury concentrations in lake trout in Nonacho Lake. We continued to contribute input to mercury assessments and advisories.

Great Slave Lake and related – collections and biological measurements

In 2011-2012, 20 lake trout were collected from the Lutsel K'e area (East Basin) and northwest of Hay River (West Basin). In addition, 20 burbot were collected in the Fort Resolution area (near the Slave River inflow, West Basin). Collections were done by community members or by a commercial fisherman (Hay River). Fish were frozen and shipped whole to Environment Canada (Saskatoon) for processing. Total length, fork length (lake trout only), round weight, liver weight, gonad weight, and gender were determined for all fish; features such as the presence of parasites, discolored liver, skinniness, and crude measures of stomach contents were noted. Aging structures (otoliths) were removed from all fish and age later determined for all fish. Approximately 100 gm of dorsal fillet, the liver and stomach were removed from all fish for analyses and/or archiving. A subsample of fillet was freeze-dried, percent moisture determined, and analyzed for carbon and nitrogen stable isotopes for all 20 fish from each location. Ten fish from each location were selected for persistent organic contaminant and metal analyses. With the exception of persistent organic contaminants, all analyses have been completed.

With George Low, Dehcho AAROM Coordinator, Dehcho First Nations, we worked on the continued periodic assessment of mercury concentrations in Deh Cho Lakes. Mercury concentrations were assessed in fish from Big Island, Ekali, Fish, Sanquez, Trout and Willow Lakes. Mercury and metals concentrations were assessed in fish from Tahlina Lake and in partnership with Ka'a'gee Tu First Nation who wished to obtain current baseline information before Paramount oil/gas activities intensified. CIMP funds were used to collect burbot from Lutsel K'e and northern pike from Fort Resolution.

Results

Persistent organic contaminants trend monitoring

Several legacy persistent organic contaminants are declining in concentration in lake trout fillet and burbot liver at the two study locations, i.e., HCH, DDT, chlordane and toxaphene (Fig. 1). The declines were not steady and in some years, concentrations returned to earlier high values, e.g., chlordane and DDT for Lutsel K'e trout caught in 2001 and burbot caught in 2002. Toxaphene also appears to be declining markedly with concentrations over the late 2000s substantially lower than in late 1990s and early 2000s. Trends of decline were significant (p=0.05) except for East Arm lake trout for chlordane and East Arm burbot for DDT. Concentrations were higher in burbot liver than lake trout fillet, most likely due to the substantially higher lipid content of burbot liver than lake trout fillet. In general, concentrations were lower in West Basin than East Arm fish as expected.

Other legacy persistent organic contaminants are not showing clear evidence of decline (Fig. 2). For example, CBZ concentrations in lake trout apparently declined at both locations from 1993 to the late 1990s and but are now showing some evidence of increasing concentrations particularly over 2005-2009; however spikes were observed in the early and mid 2000s. CBz concentrations in burbot liver have been variable and overall no trend is evident in either location. Similarly, no trend was evident in PCB concentrations.

PBDE concentrations in lake trout increased from 2004 to 2005 and then declined but are now showing a weak trend of increase. The converse is observed for burbot liver. Trends may become apparent with the analyses of older archived samples.

Mercury trend monitoring

While mercury concentrations have been showing a general trend of increase in lake trout and burbot in Great Slave Lake (Evans and Muir 2010a), this has weakened in recent years, particularly for West Basin fish (Fig. 3) although trends remain significant (p =0.05). Mercury concentrations also declined for East Arm fish in recent but remain the trend of increase remains significant for lake trout. Mercury concentrations in northern pike from the West Basin showed no evidence of a trend although the temporal record is weaker than that for lake trout and burbot. While mean annual air temperatures at Yellowknife have shown a long-term trend of increase since the 1970s (Fig. 4), the correlation between mean mercury concentration in lake trout (West Basin) and mean annual air temperature for the same year was poor indicating that other variables must be considered in interpreting time trends in fish mercury concentrations. Mean mercury concentrations in pike, lake trout and walleye remain below 0.5 µg/g, the commercial sale guideline.

Figure 1. Time trends in HCH, chlordane, DDT, and toxaphene concentrations (wet weight) in lake trout (fillet) and burbot (liver) collected from the West Basin and East Arm. Data are shown as means ± 1 standard deviation.

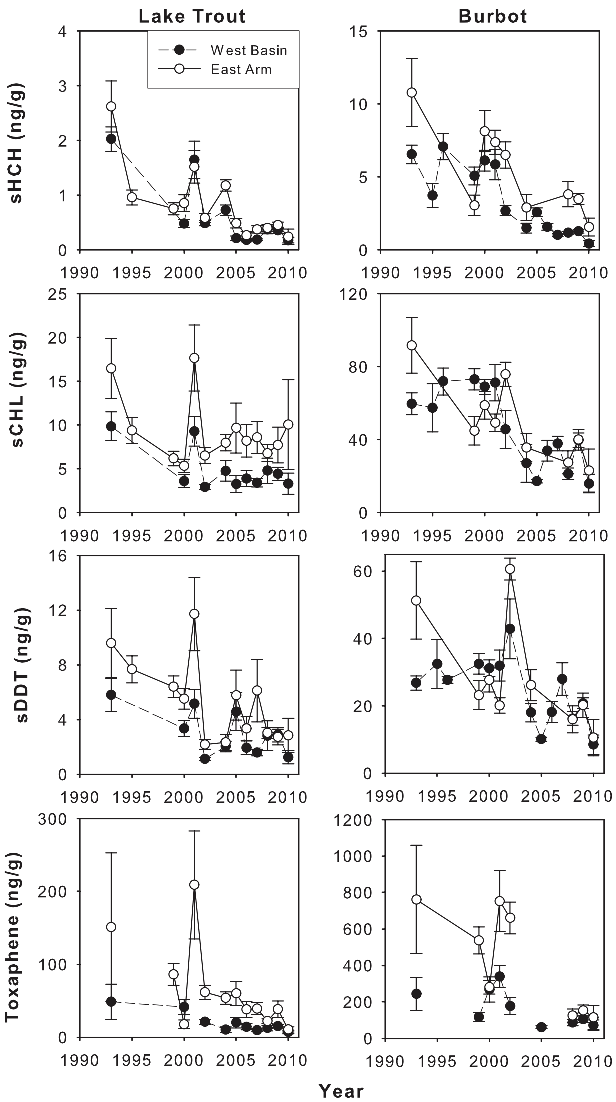
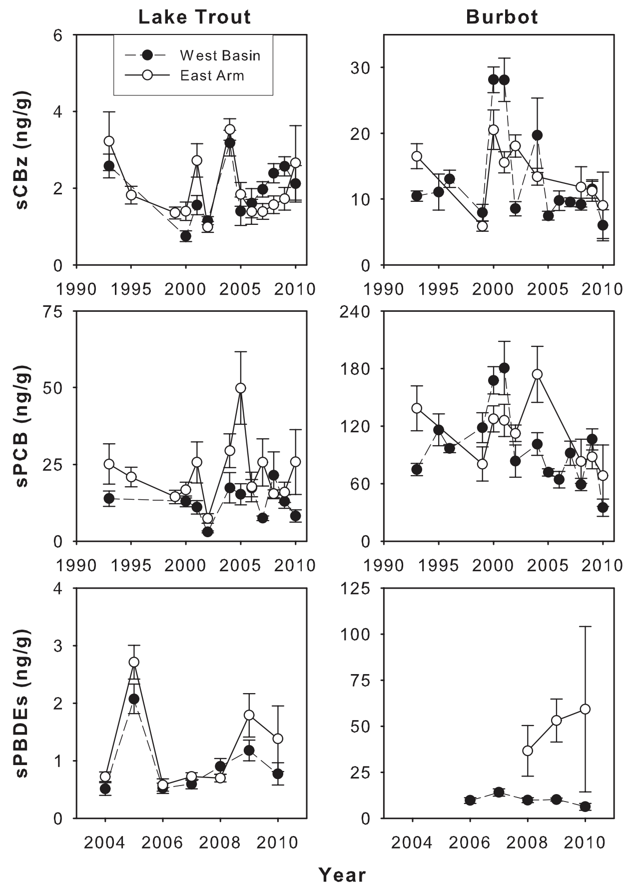


Figure 2. Time trends in CBZ, PCBs, and PBDE concentrations (wet weight) in lake trout (fillet) and burbot (liver) collected from the West Basin and East Arm. Data are shown as means ± 1 standard deviation.



Discussion and Conclusions

As reported in Evans and Muir (2010a), HCH, DDT and chlordane are showing significant trends of decline for lake trout and burbot in our two study regions. Such declines are anticipated given the reduced usage of these compounds globally. In contrast there is no evidence of a long-term decline in CBz concentrations with spikes in concentrations occurring in the 2000s and for unknown reasons. Similarly PCBs are showing no evidence of declines again with spikes in concentrations in the 2000s which sometimes exceeded 1993 values. With our data base developing over 17 years and involving different laboratories and techniques it is possible that some differences in methodology may be masking trends. Our HCH trends are similar to observed HCH trends in burbot at Fort Good Hope (Stern 2011) and lake trout from Lake Laberge and Kusawa Lake in the Yukon (Stern et al. 2011) but we are not observing increases in PCB and DDT concentrations. One reason for the difference

Figure 3. Time trends in mercury concentrations (wet weight) in lake trout (fillet) and burbot (fillet) collected from the West Basin and East Arm and northern pike from the West Basin. Data are shown as means ± 1 standard deviation. West Basin data includes data from the commercial fisheries and the Fish Inspection record (see Lockhart et al. 2005).

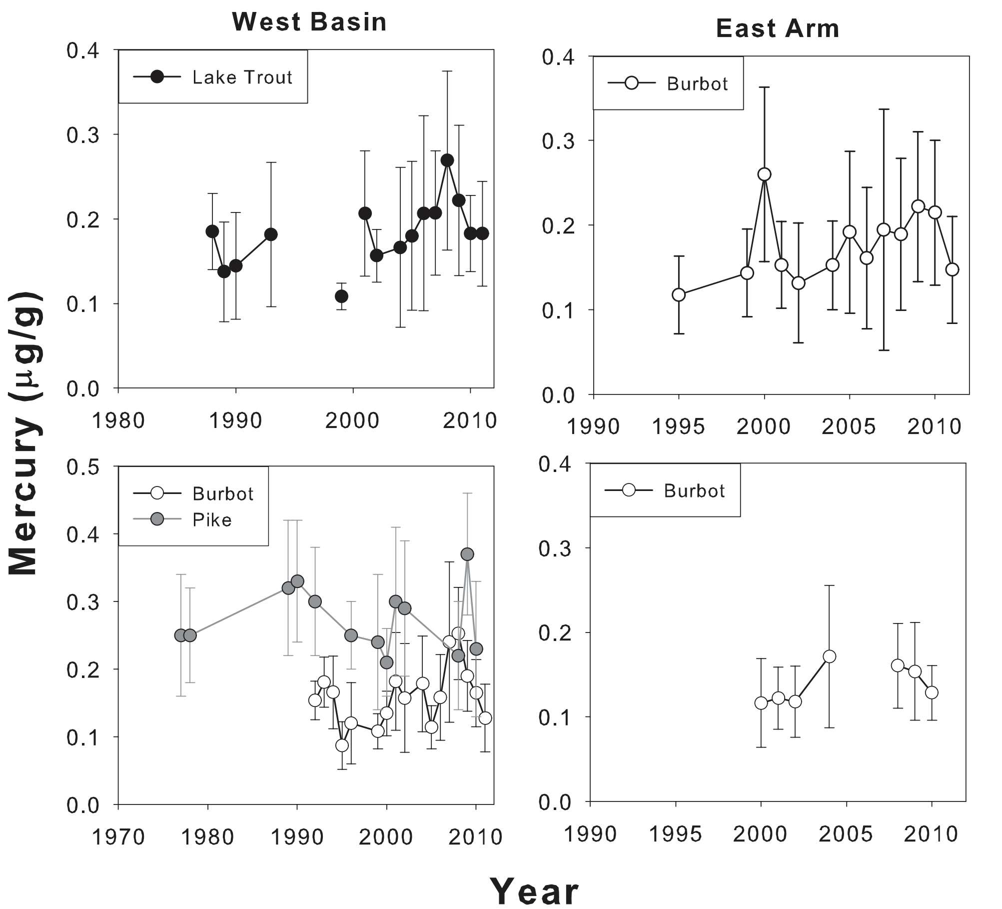
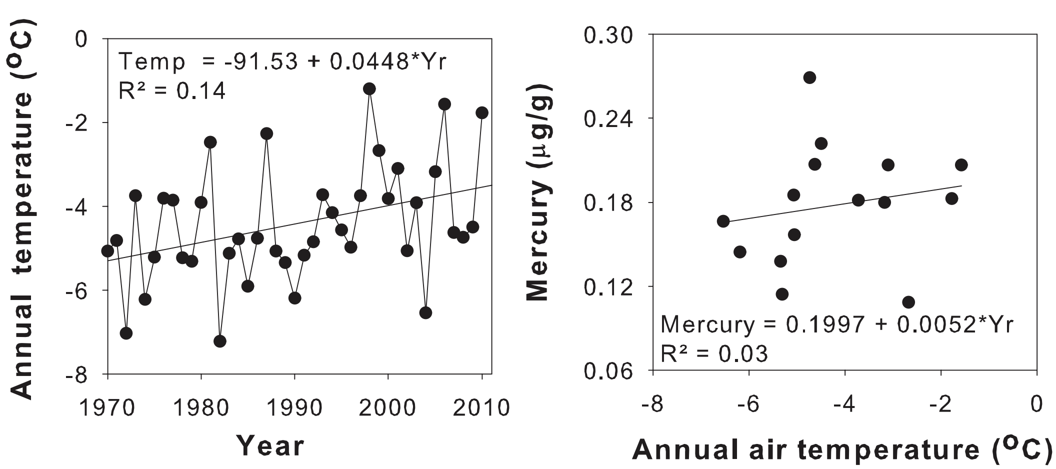


Figure 4. Long-term trend in mean annual air temperatures at Yellowknife. Also shown is the relationship between mean mercury concentrations in lake trout and mean annual air temperature for West Basin fish



in the studies is that our data are expressed on a wet weight basis while the Stern studies are based on lipid-adjusted concentrations. Alternately with Lake Laberge downstream of Whitehorse and Fort Good Hope downstream of Norman Wells, their data are reflective of local contaminant sources which are now being mobilized.

Mercury concentrations in lake trout and burbot have declined in more recent years although a long-term trend of increase is persisting for West Basin lake trout and burbot and East Arm lake trout; there is no significant trend for burbot from the East Arm and northern pike from the West Basin but additional analyses including fish length and weight may reveal such a trend. Carrie et al. (2010) observed a significant trend of increase in mercury concentrations in burbot collected from the Mackenzie River at Fort Good Hope which continues to be observed (Stern 2011); no trend has been observed for Lake Laberge trout (Stern et al. 2011). While it has been hypothesized that increased mercury concentrations in fish are associated with warming trends which enhanced mercury fluxes to lake sediments and increased levels in fish (Outridge et al. 2007; Carrie et al. 2010), the issue of time trends in mercury fluxes to lakes is complex, varying with the lake and location within the lake (Muir et al. 2008; Evans and Muir 2010a,b; Kirk et al. 2011). For our study, there was a poor correlation between mercury levels in lake trout (the species for which we have the longest record) and mean air temperature. This suggests that other variables must be affecting mercury trends in fish.

NCP Performance Indicator

Performance Indicator	Number	Detail / Description
Number of northerners engaged in your project		We work with the communities of Fort Resolution and Lutsel K'e with two-three people in each community involved in this study. At Hay River, we work directly with Shawn Buckley (commercial fisheries). Minimally, there were 5-7 northerners involved in this study. In related studies, we have worked with Mike Low and George Low in the periodic assessments of mercury concentrations in small lakes in the Fort Simpson area, and with Lutsel K'e and Fort Resolution on CIMP studies.
Number of meetings/workshops held in the north		Delivered an invited presentation at the GeoScience meeting in Yellowknife which highlighted the link between NCP and CIMP. Also presented at an invited Fisheries and Oceans Workshop in Yellowknife to discuss contaminants in sediments in he Mackenzie River Basin.
number of students involved in the project	none	However, Elizabeth Giroux who is completing her grade 12 is involved in our CIMP study which has gathered traditional knowledge on environmental change in the Fort Resolution area and long-term water quality data from the water intake.
number of citable publications	1	Rigét et al. 2011) CACAR and AMAP reports; submitted scientific paper in revision.

Expected Project Completion Date

This project is a core NCP biomonitoring study with an indeterminate end date.

Acknowledgements

Special appreciation is extended to Gab Lafferty at Fort Resolution and Ernest Boucher at Lutsel K'e for collecting the pike and burbot respectively and Shawn Buckley for collecting lake trout at Hay River.

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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.

Études sur les tendances temporelles des métaux traces et des composés organiques halogénés, y compris les composés persistants nouveaux et émergents, chez la lotte du fleuve Mackenzie à Fort Good Hope (Territoires du Nord-Ouest)

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Abstract

Tissues from burbot collected at Fort Good Hope (Rampart Rapids) in December 2011 were analysed for organohalogen contaminants (OCs/PCPs/BFRs/FOCs) and heavy metals (Hg/Se/As). Data from this time point was combined with the existing metal data (1985, 1988, 1993, 1995, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010) and OC (1988, 1994, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010) together covering time spans of 26 and 23 years, respectively. No significant correlation between length and mercury concentration was observed with muscle or liver for either sex. Mean Hg concentrations in muscle and liver over the entire data sets were 0.353 ± 0.142 (n = 479) and 0.089 ± 0.074 (n = 488)

Résumé

Des tissus de lotte prélevés à Fort Good Hope (rapides Rampart) en décembre 2011 ont été analysés pour déterminer s'ils contenaient des contaminants organohalogénés (pesticides organochlorés, biphényles polychlorés (BPC), produits ignifuges bromés et composés organiques fluorés) et des métaux lourds (Hg, Se et As). Ces données ont été combinées à celles qui existaient sur les métaux (1985, 1988, 1993, 1995, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010) et les composés organochlorés (1988, 1994, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010) sur une durée de 26 et de 23 ans, respectivement. Aucune corrélation significative entre la durée et les concentrations de mercure n'a été observée dans les muscles

μg g^{-1}, respectively. Muscle mercury levels are below the recommended guideline level of 0.50 μg g^{-1} for commercial sale. Major PBDE congener levels have increase significantly over the 19 year period from 1988 to 2008 but, are currently still about one order of magnitude less than those of PCBs. Since 1986, a consistent decline was observed in both PFOA and PFOS concentrations. Conversely, PFDA concentrations show a consistent increase overtime. PFNA and PFUA levels peaked in 2003.

et le foie des deux sexes. Les concentrations moyennes de Hg dans les muscles et le foie des ensembles complets de données étaient de 0,353 ± 0,142 (n = 479) et de 0,089 ± 0,074 (n = 488) μg g^{-1}, respectivement. Les concentrations de mercure dans les muscles se situent sous le seuil recommandé dans les lignes directrices, qui est de 0,50 μg g^{-1} pour la vente commerciale. Les concentrations des principaux congénères de PBDE ont augmenté de façon significative au cours de la période de 19 ans entre 1988 et 2008, mais sont encore actuellement d'un ordre de grandeur de moins que celles des BPC. Depuis 1986, une diminution régulière des concentrations de PFOA et de PFOS a été observée. En revanche, les concentrations de PFDA affichent une augmentation constante avec le temps. Les concentrations de PFNA et de PFUA ont atteint leur plus haut niveau en 2003.

Key Messages

- Mean Hg concentrations in muscle and liver over the entire data sets were 0.353 ± 0.142 (n = 479) and 0.089 ± 0.074 (n = 488) μg g^{-1}, respectively.
- Since the mid-1990s, an approximate 2- and 3-fold increase in mercury concentrations has been measured in Fort Good burbot muscle and liver, respectively.
- Muscle liver and mercury levels are below the recommended guideline level of 0.50 μg g^{-1} for commercial sale.
- Significant declines, 10- and 4-fold, occurred for both α- and γ-HCH over 23 year time period between 1988 and 2011.
- PBDE concentration seemed to have peaked in the mid-2000s and are now on the decline.
- Current ΣPBDE levels are approximately one order of magnitude less than those of PCBs.
- Since 1986, a consistent decline was observed in both PFOA and PFOS concentrations. Conversely, PFDA concentrations show a consistent increase overtime. PFNA and PFUA levels peaked in 2003.

Messages clés

- Les concentrations moyennes de Hg dans les muscles et le foie pour les ensembles complets de données étaient de 0,353 ± 0,142 (n = 479) et de 0,089 ± 0,074 (n = 488) μg g^{-1}, respectivement.
- Depuis le milieu des années 1990, une augmentation d'environ 200 % et 300 % des concentrations de mercure a été mesurée dans les muscles et dans le foie, respectivement, de la lotte de Fort Good.
- Les concentrations de mercure dans les muscles et dans le foie se situent sous le seuil recommandé dans les lignes directrices, qui est de 0,50 μg g^{-1} pour la vente commerciale.
- Des baisses importantes, de 10 et de 4 fois, des α- et γ-HCH sont survenues au cours de la période de 23 ans entre 1988 et 2011.
- Les concentrations de PBDE semblent avoir atteint au sommet au milieu des années 2000 et sont maintenant en déclin.
- Les concentrations actuelles de ΣPBDE sont environ d'un ordre de grandeur moindre, que celles des BPC.

- Depuis 1986, une diminution régulière des concentrations de PFOA et de PFOS a été observée. En revanche, les concentrations de PFDA affichent une augmentation constante avec le temps. Les concentrations de PFNA et de PFUA ont atteint leur plus haut en 2003.

Objectives

To continue to assess long term trends and to maintain current data on levels of bioaccumulating substances such as trace metals (e.g. mercury, selenium, arsenic, lead and cadmium), organochlorine contaminants (e.g. PCBs, DDT, toxaphene) and new contaminants (e.g. brominated flame retardants, fluorinated organic compounds) in Mackenzie River burbot at Rampart Rapids (Fort Good Hope).

Introduction

With a few exceptions, minimal or no direct temporal trend information on organhalogen (OCs/PCPs/BFRs/FOCs) contaminants and heavy metals (Hg/Se/As) in fish are available in either the Arctic marine or freshwater environments. Due to a lack of retrospective samples and of past studies, much of the temporal trend data that are available are too limited to be scientifically credible because they are based on 2 or at most 3 sampling times. In addition, much of this is confounded by changes in analytical methodology as well as variability due to age/size, or dietary and population shifts. By comparison, temporal trend data for contaminants in Lake Ontario lake trout (Borgmann and Whittle 1991) and in pike muscle from Storvindeln Sweden are available over a 15 to 30 year period.

In the Mackenzie Basin over the last 150 years a steady increase in temperatures has been recorded. In particular, over the last 35 years temperatures have increase about a degree a decade, in the centre of the basin (Rouse et al., 1997). Rising temperatures in the region may be responsible for the increasing Hg levels in the FGH burbot (see Results) for several reasons: (a) melted permafrost, increased erosion and forest fires may release increasing amounts of Hg into the river; (b) the rate of Hg methylation processes may be increased by increasing temperature and nutrients, particularly in the wetlands and peatlands in the basin; and (c) possible changes in food web structure may have an effect on methylmercury (MeHg) biomagnification.

As outlined in the Northern Contaminants Program 2011-2012 call for proposals, the goal of temporal trend monitoring is to be able to detect a 10% annual change in contaminant concentration over a period of 10-15 years with a power of 80% and a confidence level of 95%. This requires sample collection and analysis of a minimum of 10 fish annually for a period of 10 to 15 years. Because of the importance of burbot to the subsistence diet of northerners residing in the Sahtu Region and because of the availability of current data sets and archived samples (1986-2008), Fort Good Hope (and the continued analysis of burbot) was selected as one of the priority sampling location for long temp temporal trend studies.

FWI currently maintains a very extensive archive of Fort Good Hope burbot sample tissues and data on trace metals (25 years and 16 time points; 1985, 1988, 1993, 1995, 1999, 2000, 2001, 2002, 2003 2004, 2005, 2006, 2007, 2008, 2009, 2010 and POPs (22 years and 14 time points; 1988, 1994, 1999, 2000, 2001, 2002, Jan04 (2003), 2004, 2005, 2006, 2007, 2008, 2009, 2010).

Activities In 2011/12

In December 2011, 41 burbot were collected from the Mackenzie River at Fort Good Hope

Table 1. Mean (standard deviation) concentrations of mercury, selenium and arsenic in Fort Good Hope burbot muscle (mg g^{-1})

Collection	Sex	n	Length	Hg	Se	As
Apr-851	M	10	633 (84)	0.222 (0.035)	0.358 (0.087)	–
Dec-93	M	7	677 (109)	0.231 (0.113)	0.534 (0.163)	2.291 (3.151)
Sept-95	M	2	–	0.265 (0.035)	–	–
Dec-99	M	21	676 (107)	0.286 (0.095)	0.395 (0.107)	0.637 (0.637)
Dec-00	M	21	699 (104)	0.345 (0.097)	0.478 (0.136)	1.333 (1.944)
Dec-01	M	10	720 (164)	0.342 (0.151)	0.581 (0.272)	3.106 (3.897)
Dec-02	M	12	699 (92)	0.297 (0.139)	0.427 (0.132)	1.555 (2.746)
Jan-04	M	9	705 (79)	0.336 (0.179)	0.377 (0.061)	3.324 (4.506)
Dec-04	M	17	681 (112)	0.413 (0.130)	0.523 (0.199)	1.011 (1.680)
Dec-05	M	13	616 (67)	0.301 (0.118)	0.434 (0.420)	1.663 (2.271)
Dec-06	M	17	700 (78)	0.389 (0.118)	0.401 (0.080)	0.873 (0.913)
Dec-07	M	16	642 (61)	0.420 (0.110)	0.520 (0.132)	0.522 (0.717)
Dec-08	M	15	624 (75)	0.410 (0.115)	0.506 (0.157)	0.310 (0.294)
Dec-09	M	22	703 (94)	0.406 (0.096)	0.405 (0.094)	0.354 (0.327)
Dec-10	M	21	672 (66)	0.349 (0.126)	0.422 (0.074)	0.784 (0.905)
Dec-11	M	17	696 (119)	0.418 (0.141)	0.481 (0.112)	0.681 (0.838)
Apr-85[1]	F	6	714 (140)	0.337 (0.136)	0.480 (0.126)	–
Dec-93	F	3	812 (133)	0.297 (0.035)	0.321 (0.009)	6.450 (0.984)
Sept-95	F	2	–	0.180 (0.085)	–	–
Dec-99	F	21	735 (101)	0.259 (0.108)	0.219 (0.104)[2]	2.626 (3.815)
Dec-00	F	15	732 (127)	0.364 (0.140)	0.460 (0.175)	1.929 (1.621)
Dec-01	F	10	747 (122)	0.336 (0.180)	0.304 (0.096)	1.098 (1.821)
Dec-02	F	17	727 (118)	0.294 (0.126)	0.400 (0.297)	2.704 (3.258)
Jan-04	F	22	726 (98)	0.254 (0.179)	0.376 (0.125)	2.827 (3.425)
Dec-04	F	18	708 (115)	0.432 (0.138)	0.451 (0.114)	1.562 (2.075)
Dec-05	F	25	710 (104)	0.350 (0.112)	0.409 (0.120)	1.587 (1.942)
Dec-06	F	21	695 (106)	0.477 (0.174)	0.435 (0.121)	0.958 (1.179)
Dec-07	F	25	671 (111)	0.376 (0.115)	0.466 (0.152)	0.533 (0.777)
Dec-08	F	22	689 (118)	0.339 (0.114)	0.433 (0.156)	0.570 (0.706)
Dec-09	F	18	701 (110)	0.402 (0.125)	0.436 (0.098)	0.471 (0.706)
Dec-10	F	18	672 (105)	0.347 (0.179)	0.414 (0.137)	0.986 (1.518)
Dec-11	F	24	730(108)	0.448 (0.106)	0.458 (0.146)	1.032 (1.355)

[1]Wagemann 1985; [2]n = 20

Table 2. Mean (standard deviation) concentrations of mercury, selenium and arsenic in Fort Good Hope burbot liver (mg g^{-1}).

Collection	Sex	n	Length	Hg	Se	As
Apr-85[1]	M	9	643 (82)	0.044 (0.019)	1.759 (0.558)	–
Dec-88	M	8	706 (84)	0.054 (0.026)	1.230 (0.555)	3.119 (1.725)
Dec-93	M	7	677 (109)	–	–	1.016 (1.328)
Dec-99	M	21	676 (107)	0.046 (0.024)	1.071 (0.628)[2]	0.607 (0.326)
Dec-00	M	21	699 (104)	0.064 (0.026)	1.646 (0.733)	0.585 (0.412)
Dec-01	M	10	720 (164)	0.063 (0.048)	1.434 (1.278)	0.839 (0.822)
Dec-02	M	12	699 (92)	0.063 (0.031)	1.437 (0.808)	0.771 (0.539)
Jan-04	M	9	705 (79)	0.126 (0.179)	1.981 (1.370)	1.994 (1.447)
Dec-04	M	17	681 (112)	0.111 (0.065)	3.267 (2.437)	0.496 (0.605)
Dec-05	M	13	616 (67)	0.053 (0.047)	1.677 (0.782)	0.527 (0.540)
Dec-06	M	17	700 (78)	0.094 (0.064)	1.939 (1.117)	–
Dec-07	M	16	642 (61)	0.076 (0.035)	2.090 (0.837)	–
Jan-09	M	15	324 (75)	0.114 (0.055)	3.416 (1.722)	0.335 (0.300)
Dec-09	M	22	703 (94)	0.064 (0.030)	2.038 (0.985)	–
Dec-10	M	21	672 (66)	0.100 (0.075)	2.571 (2.118)	0.630 (0.568)
Dec-11	M	17	696 (119)	0.119 (0.079)	2.333 (1.407)	
Apr-85[1]	F	6	714 (140)	0.097 (0.098)	1.272 (0.715)	–
Dec-88	F	2	623 (86)	0.072 (0.035)	1.460 (1.529)	1.280 (1.018)
Dec-93	F	3	812 (129)	–	–	1.062 (0.546)
Dec-99	F	20	749 (77)	0.064 (0.069)	0.687 (0.552)[2]	1.353 (0.811)
Dec-00	F	15	732 (127)	0.094 (0.056)	1.203 (0.469)	0.632 (0.349)
Dec-01	F	10	747 (122)	0.098 (0.108)	1.235 (0.720)	1.074 (1.227)
Dec-02	F	17	727 (118)	0.082 (0.067)	1.488 (1.203)	1.063 (0.890)
Jan-04	F	22	726 (98)	0.057 (0.033)	1.245 (0.511)	1.522 (1.348)
Dec-04	F	17	700 (112)	0.138 (0.081)	2.616 (2.030)	0.489 (0.335)
Dec-05	F	25	710 (104)	0.080 (0.050)	1.585 (1.013)	0.489 (0.585)
Dec-06	F	21	695 (106)	0.125 (0.076)	1.906 (1.006)[3]	–
Dec-07	F	24	674 (113)	0.094 (0.098)	2.064 (1.096)	–
Jan-09	F	22	689 (118)	0.092 (0.059)	1.690 (1.095)	0.451 (0.401)
Dec-09	F	18	701 (110)	0.107 (0.141)	1.752 (1.023)	–
Dec-10	F	18	672 (105)	0.122 (0.135)	1.399 (0.688)	0.556 (0.571)
Dec-11	F	24	730 (108)	0.128 (0.043)	1.664 (0.973)	

[1]Wagemann 1985; [2,3]n = 19

Figure 1. Mean Hg concentrations in muscle (left) and liver (right) from Fort Good Hope burbot (males + females).

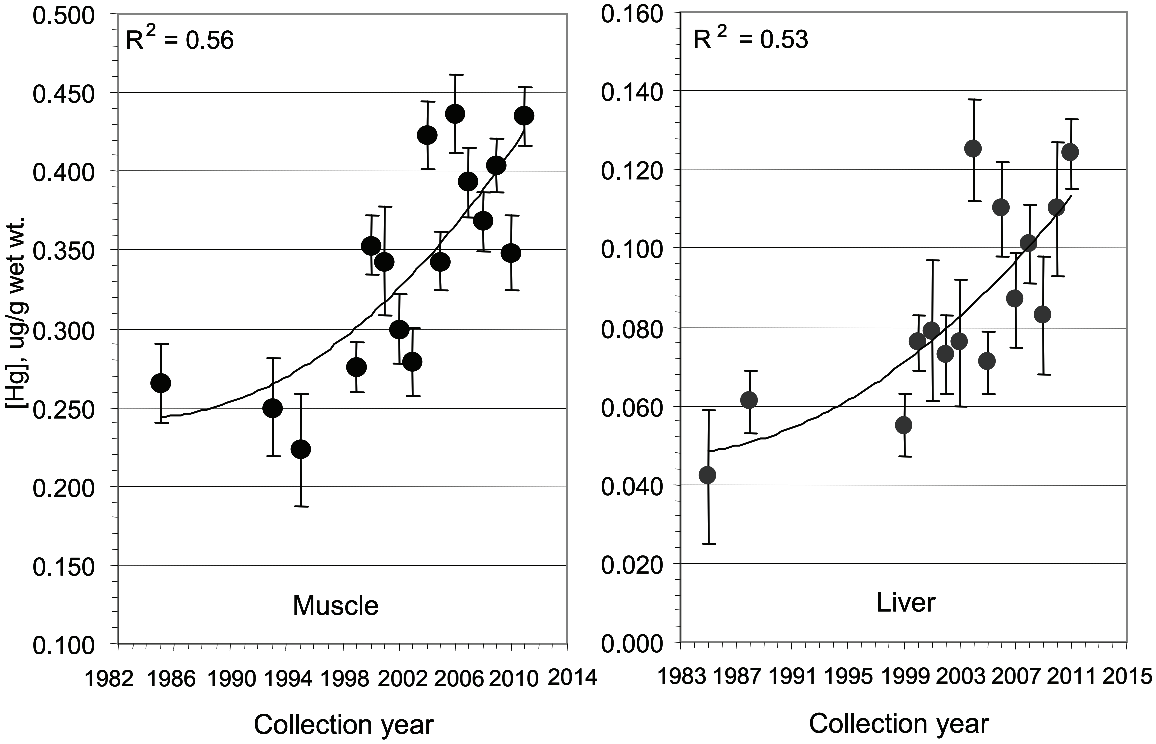
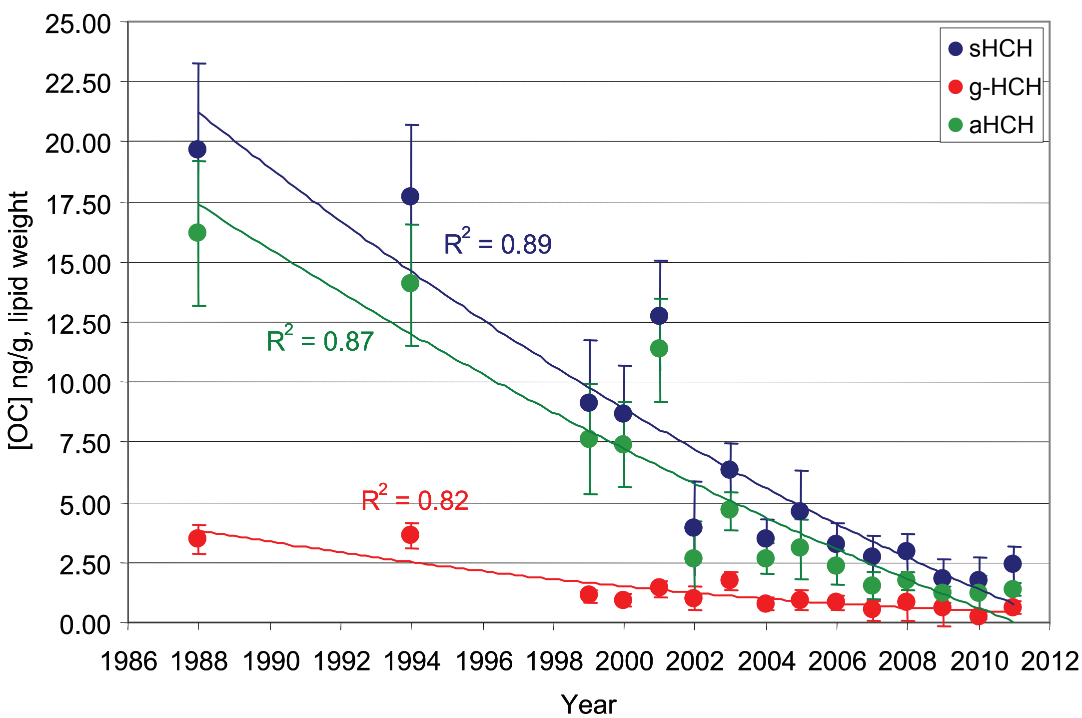


Figure 2. Lipid normalized ΣHCH, α, γ-HCH concentrations in FGH burbot liver (1988–2011).



(Rampart Rapids) by community residents. Heavy metal and HOC analyses for these samples are now complete and the results discussed below.

Results

Hg, Se, As: Currently heavy metal (mercury, selenium and arsenic) time trend data from Fort Good Hope (Rampart Rapids) burbot tissues cover 25 years and 16 time points (1985, 1988, 1993, 1995, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011). Mean Hg concentrations in muscle and liver over the entire data sets were 0.353 ± 0.142 (n = 479) and 0.089 ± 0.074 (n = 488) μg g^{-1}, respectively. Mean mercury levels in muscle are below the recommended guideline level of 0.50 μg g^{-1} for commercial sale.

Table 3. OCs in Burbot liver from Fort Good Hope (mean and standard deviation, ng g^{-1}, ww)

Year	Sex	n	% Lipid	SCBz	SHCH	SCHL	SDDT	SPCB	SCHB	HCBz	Oxy-chlor
1988	M + F	10	30.20 (13.47)	13.63 (4.21)	5.53 (1.71)	23.83 (7.37)	16.17 (5.25)	58.11 (18.45)	121.66 (38.62)	13.07 (4.06)	9.46 (1.58)
1994	M + F	9	30.56 (11.59)	8.63 (2.63)	5.13 (1.53)	17.34 (6.14)	18.96 (8.28)	50.05 (17.55)	93.70 (28.92)	8.17 (2.48)	9.23 (1.42)
1999	M + F	21	42.10 (13.31)	10.04 (3.81)	3.78 (1.38)	21.00 (8.04)	22.84 (8.59)	62.77 (22.29)	108.06 (40.74)	5.43 (2.17)	8.49 (1.70)
2000	M + F	20	36.22 (15.22)	8.72 (5.24)	3.29 (1.98)	19.02 (12.50)	21.24 (14.92)	54.62 (36.25)	94.02 (58.08)	4.78 (2.89)	8.28 (2.44)
2001	M + F	20	30.14 (15.00)	6.36 (3.06)	3.79 (1.67)	13.68 (6.99)	8.99 (5.96)	41.88 (21.26)	75.36 (48.54)	4.33 (1.90)	10.60 (2.67)
2002	M + F	12	27.33 (16.06)	4.69 (2.93)	1.40 (0.94)	17.83 (10.10)	22.18 (12.19)	37.97 (16.50)	143.61 (119.82)	4.54 (2.85)	17.64 (14.33)
2003	M + F	10	24.90 (5.77)	3.83 (3.08)	1.62 (0.57)	17.25 (18.71)	15.19 (12.72)	29.95 (21.29)	118.13 (109.79)	3.80 (3.00)	12.82 (11.27)
2004	M + F	9	24.73 (14.27)	4.05 (3.72)	0.87 (0.45)	25.35 (21.84)	35.65 (26.15)	57.62 (32.22)	201.65 (167.60)	3.90 (2.66)	24.89 (20.06)
2005	M + F	10	24.50 (12.12)	4.71 (2.14)	1.09 (0.61)	22.16 (12.40)	19.46 (9.28)	29.23 (8.49)	110.33 (67.35)	4.42 (2.01)	42.50 (23.38)
2006	M + F	10	32.74 (15.87)	3.77 (1.99)	1.00 (0.46)	21.42 (19.01)	35.53 (15.68)	61.84 (44.44)	158.00 (149.07)	3.59 (2.00)	5.25 (4.86)
2007	M + F	9	31.89 (10.25)	7.53 (3.20)	0.90 (0.44)	24.67 (11.80)	42.13 (15.73)	38.19 (17.57)	119.16 (72.60)	6.96 (3.03)	5.79 (2.78)
2008	M + F	9	39.09 (9.74)	8.83 (2.41)	1.19 (0.44)	15.26 (10.06)	38.59 (17.71)	101.86 (55.71)	289.16 (210.32)	6.52 (1.74)	3.38 (2.58)
2009	M + F	10	30.68 (14.59)	5.19 (2.63)	0.54 (0.33)	39.32 (15.85)	32.32 (22.51)	85.31 (39.57)	271.53 (187.86)	4.12 (2.36)	5.33 (3.15)
2010	M + F	10	33.2 (13.8)	2.31 (0.89)	0.69 (0.28)	10.67 (9.28)	16.06 (13.03)	37.22 (26.41)	115.87 (112.18)	2.01 (0.82)	1.68 (1.38)
2011	M + F	9	42.85 (11.47)	5.47 (3.58)	1.02 (0.42)	20.63 (16.24)	22.60 (24.86)	51.90 40.81)	114.06 (96.09)	5.22 (3.49)	6.03 (4.46)

Mean mercury, selenium and arsenic concentrations for burbot muscle and liver samples for each collection year are shown in Tables 1 and 2, respectively. No significant correlation between length and mercury concentration was observed with muscle or liver for either sex. Mercury trends and levels in male and female burbot muscle and liver follow quite closely from the early 1990's to 2008. Figure 1 shows an approximate 2- and 3-fold increase in mercury concentrations in Fort Good burbot muscle and liver, respectively, since the mid-1990s. For selenium and arsenic no trends were observed in either the muscle or liver (Tables 1 and 2). The highest measured As concentration, 17.16 μg g^{-1}, occurred in a muscle sample from a female burbot collected in 1999.

Table 4. Lipid normalized OCs concentrations in Burbot liver from Fort Good Hope (mean and standard deviation, ng g^{-1})

Year	sex	n*	ΣCBz	ΣHCH	α-HCH	γ-HCH	SCHL	ΣDDT	ΣPCB	ΣCHB	Oxy-chlor
1988	M + F	10	48.50 (9.02)	19.67 (3.61)	16.19 (3.00)	3.48 (0.62)	84.67 (15.40)	57.34 (11.15)	206.05 (37.45)	215.97 (40.74)	9.46 (1.58)
1994	M + F	9	30.29 (8.48)	17.66 (3.03)	14.05 (2.51)	3.61 (0.52)	58.92 (11.35)	61.55 (6.42)	168.80 (22.62)	160.38 (27.00)	9.23 (1.42)
1999	M + F	21	23.55 (3.87)	9.12 (2.61)	7.64 (2.31)	1.10 (0.25)	49.18 (8.10)	53.58 (7.76)	148.85 (28.67)	126.74 (22.84)	8.49 (1.70)
2000	M + F	20	22.40 (5.31)	8.64 (2.09)	7.41 (1.79)	0.91 (0.26)	47.77 (13.83)	52.98 (16.76)	137.50 (40.16)	119.41 (32.92)	8.28 (2.44)
2001	M + F	19	21.05 (3.64)	12.76 (2.31)	11.34 (2.14)	1.42 (0.35)	44.58 (7.37)	27.52 (6.72)	138.19 (7.59)	117.55 (21.82)	10.91 (2.34)
2002	M + F	12	15.63 (11.88)	3.89 (1.96)	2.66 (1.56)	1.02 (0.48)	80.63 (64.60)	95.62 (67.66)	162.67 (107.09)	487.58 (523.81)	17.64 (14.33)
2003	M + F	10	14.59 (9.64)	6.34 (1.08)	4.63 (0.82)	1.71 (0.38)	63.29 (58.34)	57.27 (41.69)	113.99 (62.86)	446.99 (350.00)	12.82 (11.27)
2004	M + F	9	16.75 (9.42)	3.39 (0.91)	2.62 (0.66)	0.76 (0.26)	133.85 (124.50)	168.22 (103.73)	257.46 (159.14)	883.24 (823.31)	25.38 (21.39)
2005	M + F	8	18.81 (8.02)	4.63 (1.69)	3.08 (1.24)	0.94 (0.39)	83.67 (41.03)	69.12 (36.06)	103.47 (46.49)	408.43 (208.31)	42.50 (20.38)
2006	M + F	8	16.62 (4.37)	3.20 (0.95)	2.30 (0.74)	0.85 (0.29)	62.22 (54.07)	112.70 (80.80)	151.22 (105.33)	445.42 (410.90)	15.04 (13.90)
2007	M + F	9	23.56 (6.03)	2.73 (0.87)	1.53 (0.59)	0.52 (0.41)	78.62 (30.26)	143.95 (68.04)	129.20 (59.81)	363.09 (168.67)	18.40 (6.81)
2008	M + F	8	17.13 (4.37)	3.03 (0.75)	1.69 (0.38)	0.96 (0.78)	41.20 (7.52)	102.71 (52.23)	283.38 (200.27)	803.57 (648.00)	9.54 (8.29)
2009	M + F	9	16.93 (6.49)	1.78 (0.87)	1.17 (0.33)	0.61 (0.73)	107.70 (61.18)	115.56 (73.82)	293.91 (166.30)	1032.16 (745.13)	22.22 (13.64)
2010	M + F	10	5.79 (3.02)	1.75 (0.94)	1.24 (0.74)	0.22 (0.09)	26.53 (23.94)	43.87 (43.62)	101.13 (93.38)	289.96 (284.94)	4.23 (3.67)
2011	M + F	9	12.45 (6.56)	2.40 (0.74)	1.39 (0.29)	0.63 (0.54)	49.36 (35.55)	60.01 (68.37)	136.86 (125.72)	276.71 (222.36)	14.41 (10.14)

*only liver samples with lipid > 10 % included.

Organohalogens: Table 3-7 list the mean wet weight of major HOC group concentration for collection periods between 1988 and 2010. After lipid normalization, significant declines, 10 - and 4-fold, occurred for both α- and γ-HCH over this 22 year time period (Figure 2). β-HCH concentrations were below the detection limit in most samples. ΣPCBs and ΣDDT concentration increased significantly since the mid-1990s (see Carrie et al. 2010) but, seem have decline in over the last two years.

Major PBDE congener and homologue concentrations in selected burbot liver samples are listed in Table 5 (1988 to 2010). PBDE 47 is the most predominant PBDE congener residue in the burbot liver followed by PBDE 99, 100, 153 and 154. In general, PBDE concentrations seemed to have peaked in the mid-2000s and are now on the decline. Results for perfluoroalkyl compounds are shown in Table 6.

Expected Project Completion Data

Temporal trend studies are long-term propositions and thus annual sampling is projected into the foreseeable future

Table 5. Major PBDE congener concentrations in Burbot liver from Fort Good Hope (mean and standard deviation, pg g^{-1} ww)

Year	Sex	n	% Lipid	PBDE 47	PBDE 99	PBDE 100	PBDE 153	PBDE 154
1988	M + F	10	30.2 (13.5)	226.3 (280.3)	84.5 (130.6)	35.2 (46.7)	29.4 (44.7)	20.5 (28.9)
1999	M + F	4	35.0 (9.6)	582.8 (522.3)	370.1 (269.6)	207.7 (154.6)	161.3 (124.8)	157.5 (116.4)
2000	M + F	11	33.3 (13.1)	620.3 (628.9)	319.7 (273.9)	180.5 (182.7)	135.2 (133.9)	81.3 (84.2)
2002	M + F	10	24.8 (14.5)	680.5 (305.4)	383.3 (258.3)	200.6 (87.1)	111.9 (74.2)	191.4 (95.7)
2003	M + F	10	28.1* (11.5)	814.7 (618.9)	745.3 (583.2)	297.7 (190.9)	435.5 (330.1)	311.4 (216.0)
2005	M + F	10	17.3 (9.4)	718.4 (370.7)	516.0 (248.9)	210.7 (102.9)	111.7 (60.2)	170.1 (62.2)
2006	M + F	9	21.7 (16.3)	1822.9 (1914)	1281.5 (717.7)	1010.4 (522.9)	539.6 (359.8)	529.7 (344.7)
2007	M + F	9	23.56 (6.03)	800.4 (878.0)	709.1 (967.0)	361.8 (314.4)	86.8 (192.8)	72.7 (39.0)
2008	M + F	9	39.1 (9.74)	498.5 (228.0)	105.1 (110.7)	48.3 (62.7)	21.4 (25.6)	264.7 (64.1)
2009	M + F	9	30.68 (14.59)	808.7 (521.6)	926.4 (244.1)	476.8 (244.1)	242.0 (114.5)	191.2 (136.8)
2010	M + F	10	33.2 (13.8)	1054 (1381)	774.1 (932.6)	513.3 (804.8)	296.4 (509.3)	282.0 (483.4)
2011	M + F	9	42.9 (11.5)	910.0 (1180)	722.5 (1008)	311.3 (434.5)	249.8 (306.8)	181.0 (306.7)

*Some sample not the same as for OCs in Table 3

Table 6. FOC levels in Burbot liver from Fort Good Hope (mean and standard deviation, ng g^{-1} ww)*

Year	Sex	n	PFOA	PFNA	PFOS[a]	PFDA	PFUA	Total
1986	M + F	10	4.59 (6.84)	0.89 (0.72)	10.44 (5.90)	1.91 (2.13)	2.25 (4.90)	20.08
1999	M + F	10	4.03 (6.57)	3.89 (9.29)	9.89 (10.16)	1.20 (1.73)	1.44 (2.92)	20.45
2000	M + F	10	1.58 (5.01)	0.98 (3.11)	5.62 (7.81)	2.59 (2.66)	0.75 (1.65)	11.52
2001	M + F	10	1.44 (2.62)	1.57 (3.00)	4.52 (7.75)	36.85* (94.21)	0.70 (1.71)	45.08*
2003	M + F	10	2.03 (3.28)	7.97 (8.03)	9.88 (10.16)	4.28 (3.96)	5.31 (3.96	29.47
2006	M + F	10	1.07 (1.10)	4.71 (4.47)	1.93 (0.78)	8.27 (9.39)	mdl	15.98
2007	M + F	9	0.44 (0.99)	1.01 (1.13)	1.39 (1.25)	7.47 (7.52)	1.36 (1.42)	11.67
2008	M + F	10	0.76 (0.97)	6.74 (7.21)	2.07 (1.75)	7.07 (6.94)	mdl	16.64
2009	M + F	10	0.35 (0.67)	1.18 (1.93)	1.27 (1.39)	1.10 (1.98)	1.10 (1.07)	4.90
2010	M + F	10	mdl	mdl	1.88 (1.83)	0.30 (0.49)	2.43 (3.61)	4.61
2011	M + F	10	1.26 (2.10)	1.96 (3.24)	1.65 (1.58)	5.01 (5.96)	0.92 (2.39)	10.8

PDDoDA = mdl = 0.05; PFUA (mdl = 0.05); *Higher value due to one sample with a measured concentration of 304.24 ng g^{-1}. If this value is excluded then the mean value for PFDA and total FOCs for the 2001 samples are 7.15 (7.47) and 15.38 ng g^{-1}, respectively.

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Trace Metals and Organohalogen Contaminants in Fish from Selected Yukon Lakes: A Temporal and Spatial Study

Contamination aux métaux traces et aux composés organiques halogénés de poissons vivant dans des lacs choisis du Yukon : étude temporelle et spatiale

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Abstract

Lake trout muscle samples collected from two Yukon Lakes, Kusawa and laberge, were analysed for a range of organohalogen (OCs/PCBs/BFRs/FOCs) and heavy metals (Hg/Se/As) contaminants. Currently heavy metal time trend data from Laberge and Kusawa Lake trout muscle cover 18 years, 15 and 13 time points, respectively. Mean Hg levels over the entire data sets for the Laberge and Kusawa samples were 0.48 ± 0.22 (n=133) and 0.37 ± 0.24 (n=124)µg g^{-1}, respectively. In both lakes, levels are below the recommended guideline level of 0.50 µg g^{-1} for commercial sale. No significant trends have been observed in the Laberge lake trout Hg levels over the last 18 years. In Kusuwa Lake, after a significant drop in the length adjusted mean Hg trout muscle concentrations in 2001, levels increased consistently until 2007, dropped in 2008, and are again on the rise. The current length adjusted mean Hg concentration is now at its highest level since 1999. As was observed with the mercury, after a rapid decline, the

Résumé

Nous avons analysé un éventail de contaminants organohalogénés (pesticides organochlorés, biphényles polychlorés, produits ignifuges bromés et composés organiques fluorés) et de métaux lourds (Hg, Se et As) dans des échantillons de muscle de touladis qui ont été capturés dans les lacs Kusawa et Laberge, au Yukon. La série chronologique des concentrations de métaux lourds dans ces échantillons s'étend sur 18 ans et est constituée de 15 dates d'échantillonnage pour le lac Laberge et de 13 dates pour le lac Kusawa. Pour l'ensemble des données, la concentration moyenne de Hg est de 0,48 ± 0,22 µg g^{-1} (n = 133) dans le lac Laberge et de 0,37 ± 0,24 µg g^{-1} (n = 124) dans le lac Kusawa. Ainsi, dans les deux lacs, les concentrations sont inférieures à la limite de 0,50 µg g^{-1} recommandée pour la vente commerciale de poisson. Au cours des 18 dernières années, aucune tendance significative des concentrations de Hg dans les touladis du lac Laberge n'a été observée. Quant au lac

lipid adjusted OC concentrations seem to start to increase again around 2003/04. Significant variability in the Laberge samples is observed and as a result no temporal trends are evident.

Kusuwa, on y a signalé une baisse significative des concentrations moyennes de Hg corrigées en fonction de la longueur dans les muscles des touladis en 2001, qui a été suivie d'une augmentation constante de ces concentrations jusqu'en 2007. Les concentrations ont ensuite baissé en 2008, puis ont recommencé à augmenter. La concentration moyenne actuelle de Hg corrigée en fonction de la longueur est maintenant à son niveau le plus élevé depuis 1999. Comme on l'a observé pour le mercure, après une baisse rapide, les concentrations d'organochlorés corrigées en fonction de la teneur en lipide ont recommencé à augmenter vers 2003 2004. On a noté une variation significative des échantillons du lac Laberge, ce qui fait qu'aucune tendance temporelle n'a été décelée.

Key Messages

- Currently heavy metal (mercury, selenium and arsenic) time trend data from Laberge and Kusawa Lake trout cover 18 years, 15 and 13 time points, respectively
- The mean Hg levels in the Laberge and Kusawa trout muscle samples over the entire data sets were 0.48 ± 0.22 (n=133) and 0.37 ± 0.24 (n=124) µg g^{-1}, respectively. In both lakes, levels are just below the recommended guideline level of 0.50 µg g^{-1} for commercial sale.
- No significant trends have been observed in the Laberge lake trout Hg levels over the last 18 years.
- In Kusuwa Lake, after a significant drop in the length adjusted mean Hg trout muscle concentrations in 2001, levels increased consistently until 2007, dropped in 2008, and are again on the rise. The current length adjusted mean Hg concentration is now at its highest level since 1999.
- As was observed with the mercury, after a rapid decline, the lipid adjusted OC concentrations seem to start to increase

Messages clés

- À l'heure actuelle, la série chronologique des concentrations de métaux lourds (mercure, sélénium et arsenic) dans les muscles de touladis des lacs Laberge et Kusawa s'étend sur 18 ans, et est constituée de 15 dates d'échantillonnage pour le lac Laberge et de 13 dates pour le lac Kusawa.
- Pour l'ensemble des données, la concentration moyenne de Hg dans les muscles de touladi est de 0,48 ± 0,22 µg g^{-1} (n = 133) dans le lac Laberge et de 0,37 ± 0,24 µg g^{-1} (n = 124) dans le lac Kusawa. Ainsi, dans les deux lacs, les concentrations sont tout juste inférieures à la limite de 0,50 µg g^{-1} recommandée pour la vente commerciale de poisson.
- Au cours des 18 dernières années, aucune tendance significative des concentrations de Hg dans les touladis du lac Laberge n'a été observée.
- Quant au lac Kusuwa, on y a signalé une baisse significative des concentrations de mercure corrigées en fonction de la longueur dans les muscles de touladis en 2001, qui a été suivie d'une augmentation

again around 2003/04. Significant variability in the Laberge samples is observed and as a result no temporal trends are evident.

constante de ces concentrations jusqu'en 2007. Les concentrations ont ensuite baissé en 2008, puis ont recommandé à augmenter. La concentration moyenne actuelle de Hg corrigée en fonction de la longueur est maintenant à son niveau le plus élevé depuis 1999.

- Comme on l'a observé pour le mercure, après une baisse rapide, les concentrations d'organochlorés corrigées en fonction de la teneur en lipide ont recommencé à augmenter vers 2003 2004. On a noté une variation significative des échantillons du lac Laberge, ce qui fait qu'aucune tendance temporelle n'a été décelée.

Objectives

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), 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.

Introduction

Historical studies have demonstrated that halogenated organic contaminants (HOCs) and mercury levels in top predators can vary considerably from lake to lake within a small geographic region but temporal trends of these contaminants have rarely been monitored in a sub-Arctic area for a long period of time. This study examines concentrations of a wide range of HOCs and trace metals in lake trout from two Yukon lakes (Laberge, Kusawa), over a span of 13 years (1993-2006). In 2005, Ryan et al. reported that OC pesticide and PCB concentration were declining at various rates in lake trout (*Salveninus namaycush*) in three different Yukon lakes (Laberge, Kusawa and Quiet). For example, ΣDDT concentrations have decreased 39%, 85% and 84% in Kusawa, Quiet and Laberge lakes respectively. Spatial variations in OC/PCB levels were quite evident as Lake Laberge trout continued to maintain the highest levels over the 10 year period from 1992 to 2003 followed by Kusawa and then Quiet. These differences were related to a variety of factors especially the species morphological characteristics such as log age, log weights and fish lipid content. A decreasing trend in Quiet and Laberge lake trout lipid content, coupled with fluctuating condition factors and increases in body masses, suggest biotic changes may be occurring within the food webs due to fish population variations related to the cessation of commercial fishing or potentially an increase in lake plankton productivity related to annual climate variation.

Because of the importance of lake trout and burbot to the subsistence diet of northerners, the need to continue to assess the effect of climate variation on fish contaminant levels, the availability of current data sets and archived samples, Lakes Laberge and Kusawa were selected as the priority Yukon sampling location for long term temporal trend studies.

Activities In 2011/12

INAC (Whitehorse)/DFO (Winnipeg) together maintain a very extensive archive of fish tissues and data for Hg, Se, As, and HOCs in Yukon lakes (see Tables 1-4). In 2011, 10 lake trout were collected each from lakes Kusawa, Laberge.

Results and Discussion

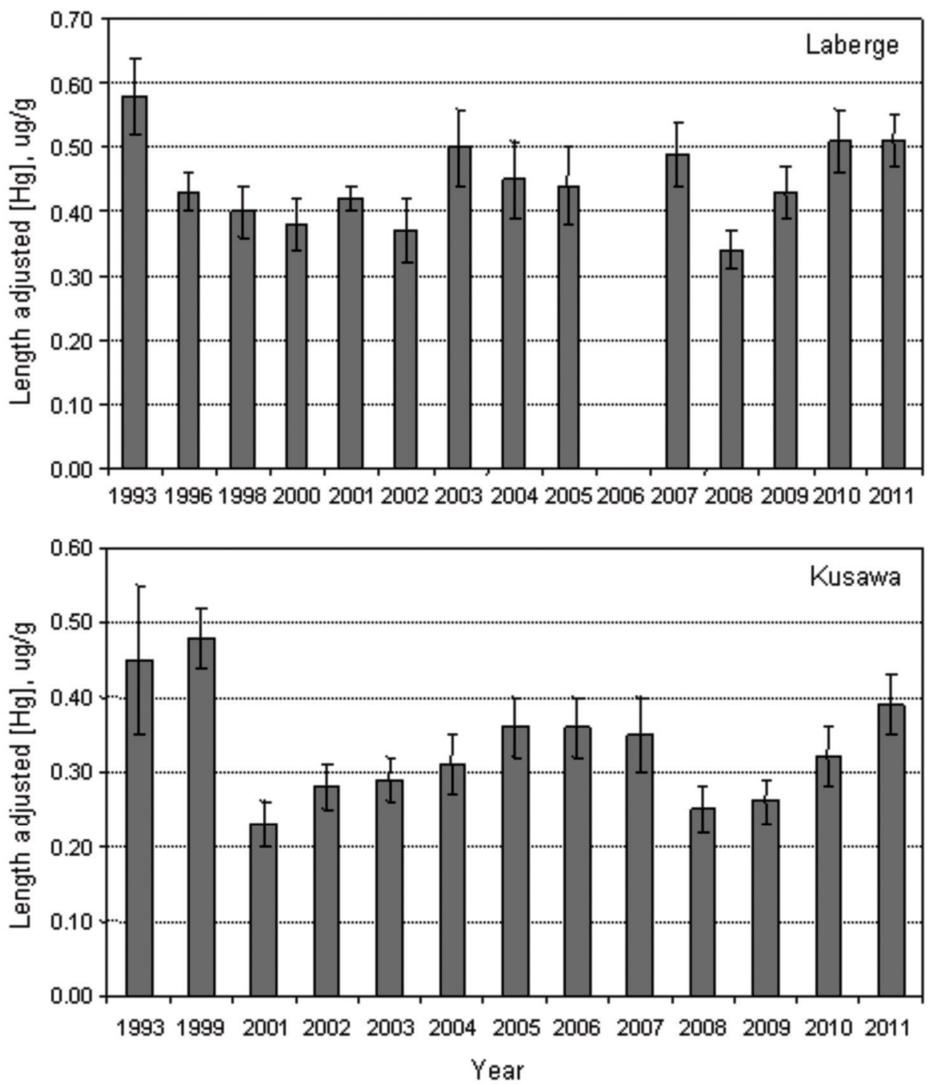
- **Hg, Se, As:** Currently heavy metal (mercury, selenium and arsenic) time trend data from Laberge and Kusawa Lake trout cover 18 years, 15 and 13 time points, respectively (Table 1). Mean Hg concentrations in the

Table 1. Mean (standard deviation) concentrations of mercury, selenium and arsenic in lake trout muscle from Laberge and Kusawa Lakes. All levels are in µg/g.

	Year	n	Length	Hg	Se	As
Laberge	1993	13	483 (110)	0.44 (0.11)	0.45 (0.08)	0.15 (0.04)
	1996	18	472 (93)	0.32 (0.10)	0.32 (0.12)	0.12 (0.06)
	1998	7	700 (125)	0.61 (0.24)	0.42 (0.07)	0.18 (0.12)
	2000	6	590 (108)	0.43 (0.21)	0.66 (0.14)	0.13 (0.04)
	2001	22	639 (92)	0.54 (0.23)	0.57 (0.13)	0.10 (0.04)
	2002	5	570 (120)	0.38 (0.15)	0.61 (0.12)	0.11 (0.05)
	2003	8	593 (98)	0.56 (0.25)	0.47 (0.10)	0.10 (0.03)
	2004	5	614 (68)	0.54 (0.23)	0.38 (0.09)	0.09 (0.04)
	2005	10	606 (97)	0.50 (0.19)	0.47 (0.09)	0.06 (0.03)
	2006	1	800	0.68	0.45	0.08
	2007	9	674 (109)	0.70 (0.27)	0.42 (0.05)	0.08 (0.03)
	2008	10	580 (78)	0.37 (0.19)	0.43 (0.07)	0.06 (0.02)
	2009	10	538 (58)	0.41 (0.18)	0.41 (0.03)	0.06 (0.02)
	2010	10	547 (49)	0.49 (0.19)	0.45 (0.07)	0.08 (0.03)
	2011	10	553 (64)	0.52 (0.29)	0.41 (0.09)	0.08 (0.04)
Kusawa	1993	3	535 (72)	0.54 (0.21)	0.43 (0.17)	na
	1999	14	515 (106)	0.51 (0.17)	0.46 (0.11)	0.12 (0.07)
	2001	9	551 (108)	0.29 (0.11)	0.52 (0.09)	na
	2002	10	500 (74)	0.29 (0.09)	0.55 (0.07)	0.02 (0.01)
	2003	10	487 (90)	0.35 (0.13)	0.35 (0.24)	0.03 (0.02)
	2004	9	553 (117)	0.39 (0.13)	0.64 (0.14)	0.03 (0.01)
	2005	10	510 (118)	0.43(0.31)	0.60 (0.11)	0.01 (0.01)
	2006	9	568 (168)	0.56 (0.38)	0.59 (0.17)	0.02 (0.01)
	2007	10	446 (80)	0.36 (0.24)	0.57 (0.08)	0.02 (0.01)
	2008	10	471 (94)	0.24 (0.07)	0.54 (0.08)	0.02 (0.01)
	2009	10	453 (54)	0.23 (0.08)	0.56 (0.08)	0.02 (0.01)
	2010	10	449 (97)	0.31 (0.19)	0.47 (0.09)	0.04 (0.03)
	2011	10	433 (43)	0.32 (0.06)	0.51 (0.07)	0.02 (0.01)

Laberge and Kusawa muscle samples over the entire data sets were Mean Hg levels over the entire data sets for the Laberge and Kusawa samples were 0.48 ± 0.22 (n=133) and 0.37 ± 0.24 (n=124) µg g^{-1}, respectively. In both lakes, levels are just below the recommended guideline level of 0.50 µg g^{-1} for commercial sale. A significant correlation between length and muscle mercury concentration was observed in the Laberge ($[Hg_T]$ = m*length + b, m=0.0013, b=-0.2892, $r^2 = 0.59$, p<0.001, n=143) and Kusawa ([Hg] = m*length + b, m=0.0018, b=-0.5046, $r^2 = 0.52$, p<0.001, n=124) trout. ANCOVA was used to assess the effects of year to year collections (temporal trends), length and length*year interactions (homogeneity of the slope between length and [Hg]). No significant trends have been observed in the Laberge lake trout Hg levels over the last 18 years. In Kusuwa Lake, after a significant drop in the length adjusted mean Hg trout muscle concentrations in 2001, levels increased consistently until 2007, dropped in 2008, and are again on the rise. The current length adjusted mean Hg concentration is now at its highest level since 1999.

Figure 1. Length adjusted Hg concentrations in trout muscle from Lake Laberge (1993-2011) and Kusawa (1993 – 2011). Only Kusawa trout less than 700 mm in length were used in the ANCOVA.



Organohalogens: Tables 2 and 3 list the mean wet weight HOC concentration in trout from Lake Laberge and Kusawa Lake, respectively, over the 18 year time period from 1983 to 2011. Figure 2 show the lipid adjusted concentration for several of the HOC groups in trout from both lakes. As was observed with the mercury, after a rapid decline, the lipid adjusted OC concentrations seem to start to increase again around 2003/04. Significant variability in the Laberge samples is observed and as a result no temporal trends are evident. A review by Health Canada of the organohalogen data indicated that all levels are below those of concern.

Major PBDE congener concentrations in Lake trout from Lakes Laberge, Kusawa and Quite are shown in Table 4. Levels in trout from Quite Lake are 1 to 2 orders of magnitude lower than those from Laberge and Kusawa. Health Canada has reviewed the data and indicated that levels are too low for PDBEs and FOC to be of concern. The levels of FOC for Canada remain so low that there is no Canadian guideline for consumption.

FOC levels in Kusawa and Laberge lake trout liver are noted below:

Laberge

2006 (n=1); PFOS = 2.18 ng g^{-1}, wet wt.

2007 (n=9); PFOS = 2.47 (1.86); PFNA = 5.78 (6.33); PFDA = 32.40 (30.34) ng g^{-1}, wet wt.

2008 (n=10); PFOS = 1.28 (2.31); PFNA = 0.06 (0.14); PFOSA = 1.31 (1.24) ng g^{-1}, wet wt.

2009 (n=10); PFOS = 1.93 (1.60); PFNA = 1.39 (1.48); PFDA = 4.87 (6.55) ng g^{-1}, wet wt.

2010 (n=10); PFOS = 2.66 (3.93); PFNA = 3.11 (6.01); PFDA = 1.65 (2.86) ng g^{-1}, wet wt.

2011 (n=10); PFOS = 1.61 (1.62); PFNA = 3.86 (7.45); PFDA = 1.11 (1.57) ng g^{-1}, wet wt.

Kusawa

2006 (n=9); PFOA = 2.93 (7.78) ng g^{-1}, wet wt.

2007 (n=9); PFOS = 0.50 (0.54); PFNA = 0.36 (1.08); PFDA = 12.78 (16.93) ng g^{-1}, wet wt.

2008 (n=9); PFOS = 0.44 (0.88); PFNA = 0.06 (0.14); PFDA = 0.10 (0.24); PFOSA = 0.32 (0.65), wet wt.

2009 (n=10); PFOS = 0.55 (0.60); PFNA = 0.40 (0.14); PFDA = 3.76 (5.24) ng g^{-1}, wet wt.

2010 (n=10); PFOS = 0.19 (0.60); PFNA = 2.93 (3.48); PFDA = 3.85 (5.25) ng g^{-1}, wet wt.

2011 (n=10); PFOS = 0.21 (0.40); PFNA = 1.53 (2.51); PFDA = 5.68 (5.71) ng g^{-1}, wet wt.

Expected Project Completion Date

Temporal trend studies are long-term propositions and thus annual sampling is projected until well into the future.

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Table 2. Mean (S.D.) HOC levels (ng/g wet wt.) in lake trout muscle from Lake Laberge

Laberge	N	Age	% lipid	SPCB	SDDT	SCHL	SHCH	SCHB	SCBz
1993	24	15 (2)	7.9 (0.9)	328.28 (121.49)	391.54 (132.69)	47.60 (8.84)	4.69 (0.78)	310.96 (62.36)	3.92 (0.57)
1996	13	22 (5)	9.6 (1.4)	209.32 (52.08)	236.51 (41.39)	53.38 (13.74)	6.50 (1.79)	212.23 (28.31)	4.90 (1.24)
2000	6	12 (2)	3.7 (0.8)	138.95 (60.89)	96.46 (14.21)	22.36 (5.84)	2.30 (1.08)	207.33 (49.90)	2.26 (0.59)
2001	16	14 (2)	4.9 (0.5)	139.71 (53.75)	89.46 (14.04)	26.37 (5.14)	0.80 (0.07)	154.20 (60.46)	2.11 (0.17)
2002	5	12 (4)	4.2 (0.9)	48.60 (8.81)	54.50 (11.58)	7.26 (1.59)	1.58 (0.50)	139.23 (16.88)	1.15 (0.25)
2003	8	12 (1)	4.7 (0.8)	81.01 (29.83)	61.48 (8.55)	7.44 (2.24)	0.54 (0.10)	179.31 (42.79)	1.21 (0.28)
2004	6	12 (4)	8.7 (3.9)	48.93 (34.30)	94.09 (60.68)	7.46 (4.90)	0.19 (0.09)	79.92 (52.01)	0.49 (0.28)
2005	10	14 (7)	2.0 (1.22)	28.94 (20.27)	50.91 (30.27)	2.61 (1.28)	0.16 (0.10)	34.50 (19.97)	0.35 (0.27)
2006	1	21	1.0	25.52	31.25	4.82	0.07	76.87	0.35
2007	9	14 (5)	1.2 (0.80)	37.36 (25.89)	43.98 (29.93)	5.32 (4.05)	0.10 (0.09)	25.78 (14.58)	0.27 (0.80)
2008	10	12 (5)	2.3 (1.1)	50.23 (36.89)	70.06 (41.29)	4.04 (2.88)	0.18 (0.08)	24.48 (16.85)	0.77 (0.23)
2009	10	10 (3)	2.9 (1.1)	28.92 (14.89)	35.33 (20.81)	2.30 (1.06)	0.14 (0.06)	37.60 (19.57)	0.60 (0.34)
2010	10	9 (2)	2.3 (1.3)	12.08 (3.74)	40.43 (12.12)	1.18 (0.47)	0.12 (0.05)	24.91 (13.84)	0.29 (0.12)
2011	10	8 (3)	2.2 (1.0)	23.13 (12.65)	31.24 (13.24)	1.94 (0.93)	0.12 (0.05)	10.48 (4.09)	0.39 (0.16)

Table 3. Mean (S.D.) OC levels (ng/g wet wt.) in lake trout muscle from Kusawa Lake

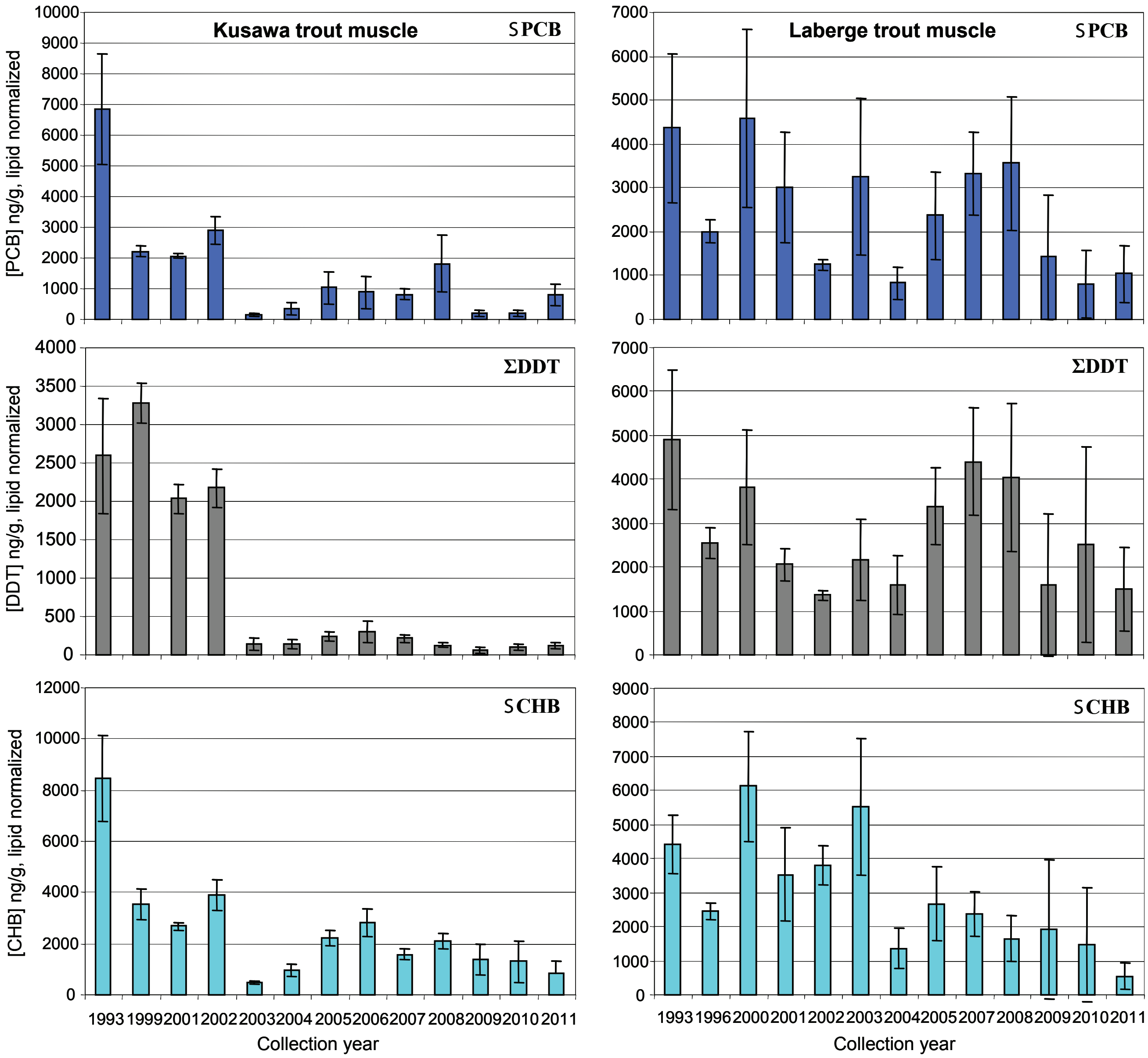
Kusawa	N	Age	% lipid	SPCB	SDDT	SCHL	SHCH	SCHB	SCBz
1993	10	19 (2)	1.8 (1.6)	85.62 (26.07)	44.16 (21.50)	17.33 (2.78)	1.21 (0.36)	120.80 (24.94)	1.15 (0.28)
1999	14	18 (1)	4.6 (3.0)	91.09 (11.85)	139.16 (19.72)	17.82 (2.74)	1.68 (0.23)	148.38 (29.29)	1.52 (0.20)
2001	9	12 (1)	2.4 (1.4)	48.55 (7.91)	56.58 (15.30)	7.45 (2.35)	0.91 (0.14)	61.03 (8.55)	0.84 (0.14)
2002	10	12 (1)	1.4 (0.8)	32.45 (3.66)	26.66 (4.15)	3.01 (0.48)	0.62 (0.08)	43.47 (5.02)	0.61 (0.09)
2003	9	9 (3)	5.8 (3.6)	8.16 (5.86)	8.21 (15.67)	3.50 (2.28)	0.14 (0.08)	45.05 (32.20)	0.44 (0.30)
2004	9	13 (4)	7.9 (4.7)	11.29 (3.78)	5.70 (3.70)	4.52 (2.16)	0.15 (0.07)	49.73 (30.17)	0.50 (0.27)
2005	10	15 (6)	0.61 (0.51)	5.48 (4.84)	2.35 (3.02)	1.17 (0.88)	0.03 (0.03)	12.37 (11.57)	0.12 (0.10)
2006	9	12 (4)	1.82 (1.49)	6.28 (4.58)	2.97 (2.57)	2.49 (1.84)	0.09 (0.06)	42.63 (34.97)	0.47 (0.26)
2007	9	10 (4)	1.52 (1.43)	9.88 (9.93)	2.35 (1.88)	2.78 (2.90)	0.10 (0.06)	22.44 (23.88)	0.42 (0.33)
2008	10	9 (2)	1.16 (0.42)	18.30 (27.27)	2.35 (0.94)	1.30 (0.40)	0.13 (0.26)	22.55 (7.87)	0.47 (0.13)
2009	10	9 (1)	1.51 (1.11)	2.55 (1.59)	0.78 (0.67)	0.95 (0.72)	0.05 (0.03)	21.20 (17.20)	0.18 (0.11)
2010	10	10 (3)	1.9 (1.6)	3.20 (2.24)	2.12 (2.13)	0.93 (0.81)	0.06 (0.03)	22.00 (23.05)	0.20 (0.12)
2011	10	8 (2)	0.80 (0.51)	5.49 (2.09)	0.81 (0.35)	0.80 (0.39)	0.13 (0.07)	5.86 (3.57)	0.22 (0.10)

Table 4. Mean (S.D.) PBDE levels (pg g[-1], wet wt.) in lake trout muscle from Lakes Laberge, Kusawa and Quiet Lakes

	Laberge	n	% Lipid	BDE 47	BDE 49	BDE 99	BDE 100	BDE 153	BDE 154
Laberge	1993	10	2.0 (1.7)	1481 (728)	348 (112)	2943 (1531)	700 (341)	642 (491)	1530 (1009)
Laberge	2000	6	0.5 (0.3)	4900 (1680)	2100 (240)	8590 (1170)	3380 (630)	5740 (1320)	4460 (1190)
Laberge	2003	8	0.4 (0.2)	3170 (1430)	1290 (750)	5890 (2860)	2450 (1200)	3920 (4050)	3200 (2810)
Laberge	2005	10	2.0 (1.2)	2659 (1977)	165 (117)	4093 (2389)	1848 (1235)	740 (580)	986 (732)
Laberge	2006	1	1.0	24920	1630	35900	11370	4120	3240
Laberge	2007	9	1.2 (0.8)	5500 (901)	1100 (1130)	9680 (1627)	6700 (5850)	200 (560)	1900 (1450)
Laberge	2008	10	2.3 (1.1)	2389 (1207)	2175 (1476)	1721 (1222)	139 (99)	258 (152)	560 (211)
Laberge	2009	10	2.9 (1.1)	1590 (1815)	1546 (1476)	2799 (1165)	1421 (729)	347 (141)	250 (355)
Laberge	2010	10	2.3 (1.3)	2907 (3266)	2640 (2525)	3124 (3989)	1271 (1457)	365 (487)	566 (646)
Kusawa	1999	10	3.0 (2.2)	4377 (2490)	nd	3636 (2011)	2573 (1623)	894 (622)	1495 (895)
Kusawa	2001	10	2.8 (1.6)	700 (990)	130 (160)	720 (1090)	250 (250)	260 (480)	230 (330)
Kusawa	2003	5	0.2 (1.1)	960 (1220)	360 (47)	2630 (3510)	950 (1260)	1180 (1590)	870 (1150)
Kusawa	2006	9	1.8 (1.5)	1103 (1231)	66 (99)	824 (911)	446 (514)	136 (140)	202 (236)
Kusawa	2007	9	1.6 (1.4)	9900 (1216)	300 (700)	12300 (1271)	3900 (5990)	1100 (830)	600 (790)
Kusawa	2008	10	1.2 (0.4)	4178 (1781	6475 (2398)*	1653 (1394)	294 (113)	58 (103)	1653 (609)
Kusawa	2009	10	1.5 (1.1)	417 (135)	73 (88)	273 (106)	121 (53)	27 (10)	69 (38)
Kusawa	2010	10	1.9 (1.6)	359 (640)	231 (471)	252 (510)	138 (283)	33 (64)	65 (124)
Quiet	1992	6	2.5 (0.7)	25 (20)	nd	18 (31)	3 (5)	6 (6)	11 (14)
Quiet	2001	5	0.9 (0.9)	28 (40)	nd	19 (32)	8 (10)	11 (7)	12 (14)
Quiet	2003	5	0.1 (0.1)	51 (106)	7 (4)	127 (273)	18 (41)	32 (71)	17 (35)

nd = non detect; *The value is being checked

Figure 2. Lipid adjusted OC group concentrations in trout muscle from Kusawa and Laberge (1992-2011).



Arctic Caribou Contaminant Monitoring Program

Programme de surveillance des contaminants chez le caribou de l'Arctique

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Abstract

The objective of this project is to determine contaminant levels in caribou in the Canadian Arctic to determine if the animal 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. In 2011/12 samples were collected from 16 Porcupine caribou and from 20 Qamanirjuaq caribou. Neither cadmium nor mercury are increasing or decreasing significantly over time in either caribou herd. Lead concentrations in both herds are declining over time, likely reflecting reductions in lead in the environment due to the prohibition of the use of leaded gasoline in Canada. Zinc appears to be increasing over time in the Porcupine caribou herd, but this may be part of normal annual fluctuations. These concentrations are not of concern toxicologically, but should continue to be monitored. Levels of most elements measured in both herds were not of concern toxicologically, although renal mercury and cadmium concentrations may cause some concern for human health depending on the quantity of organs consumed. Yukon Health has advised restricting intake of kidney and liver from Yukon caribou, the recommended

Résumé

Le projet a pour but d'établir les concentrations de contaminants chez le caribou de l'Arctique canadien afin de déterminer si les populations restent saines (en ce qui concerne les charges de contaminants), si ces importantes ressources demeurent des aliments sûrs et sains pour les résidents du Nord et si les concentrations de contaminants varient au fil du temps. En 2011 2012, des tissus ont été prélevés chez 16 caribous de la harde de la Porcupine et 20 caribous de la harde Qamanirjuaq. Ni les concentrations de cadmium ni les concentrations de mercure n'augmentent ou ne diminuent de façon significative au fil du temps au sein de ces deux hardes. Les concentrations de plomb dans les deux hardes sont à la baisse, ce qui est sans doute attribuable aux réductions du plomb dans l'environnement résultant de l'élimination de l'essence au plomb au Canada. Les concentrations de zinc semblent cependant augmenter chez le caribou de la Porcupine, mais cela pourrait être dû à des fluctuations annuelles normales. Ces concentrations ne constituent pas une préoccupation sur le plan toxicologique, mais devraient continuer d'être surveillées. La concentration de la plupart des éléments mesurés dans les tissus des deux hardes ne constituait pas une préoccupation sur le plan

maximum varying depending on herd. The health advisory confirms that heavy metals are very low in the meat (muscle) from caribou and this remains a healthy food choice.

de la toxicologie, bien que les concentrations de mercure et de cadmium dans les reins puissent être préoccupantes pour la santé humaine, selon la quantité d'organes consommée. Le ministère de la Santé et des Services sociaux du Yukon a conseillé de limiter la consommation de foie et de rein de caribous du Yukon, le maximum recommandé variant selon la harde. L'avis de santé publique confirme que les concentrations de métaux lourds sont faibles dans la viande (les muscles) des caribous et que celle ci demeure un aliment sain.

Key Messages

- Levels of most elements measured in caribou tissues are not of concern, although kidney mercury and cadmium concentrations may cause some concern for human health depending on the quantity of organs consumed. Caribou meat (muscle) does not accumulate high levels of contaminants and is a healthy food choice.
- Lead concentrations in the Porcupine and Qamanirjuaq herds are declining over time, likely reflecting reductions in lead in the environment due to the prohibition of the use of leaded gasoline in Canada.
- Over the long term, mercury in the Porcupine caribou is stable, but does undergo a cycle. More research is required to determine causes of the cycle and mercury dynamics within the caribou food chain.
- Zinc appears to be increasing in the Porcupine caribou and although not of concern toxicologically at this time, should continue to be monitored.

Messages clés

- La concentration de la plupart des éléments mesurés dans les tissus de caribou ne constitue pas une préoccupation, bien que les concentrations de mercure et de cadmium dans les reins puissent être préoccupantes pour la santé humaine, selon la quantité d'organes consommée. La viande (les muscles) des caribous n'accumule pas de grandes concentrations de contaminants et constitue donc un aliment sain.
- Les concentrations de plomb au sein de la harde de la Porcupine et la harde Qamanirjuaq sont à la baisse, ce qui est sans doute attribuable aux réductions du plomb dans l'environnement résultant de l'élimination de l'essence au plomb au Canada.
- À long terme, les concentrations de mercure chez le caribou de la Porcupine sont stables, mais sont soumises à des variations cycliques. D'autres études sont nécessaires pour déterminer les causes de ces variations ainsi que la dynamique du mercure dans la chaîne alimentaire du caribou.
- Les concentrations de zinc semblent à la hausse chez le caribou de la Porcupine et, même si elles ne constituent pas une préoccupation sur le plan toxicologique pour l'instant, devraient continuer d'être surveillées.

Objectives

To determine levels of and temporal trends in contaminants in Arctic caribou in order to:

- Provide information to Northerners regarding contaminants in these traditional foods, so that:
  - They may be better able to make informed choices about food consumption. This includes providing information for health assessments and/or advisories as required.
  - Wildlife managers can assess possible health effects of contaminants on Arctic caribou populations.
- Further understand the fate and effects of contaminant deposition and transport to the Canadian Arctic.

Introduction

Caribou provide an important food resource for Northerners across the Arctic, and have been designated in the NCP blueprint as key species for monitoring contaminants in the terrestrial Arctic ecosystem. Two barren-ground caribou herds, one from the eastern (Porcupine) and one from the western (Qamanirjuaq) Arctic, have been designated for annual sampling.

Activities in 2010-2011

Samples were collected from 16 Porcupine caribou in the fall of 2011, 11 from a Yukon Government initiative working with hunters in Old Crow, and 5 from the Hunters and Trapper's Association in Aklavik. Unfortunately only one sample from Aklavik was suitable for analysis, so in total 12 kidneys from the Porcupine herd were analyzed. Complete samples were taken from 20 Qamanirjuaq caribou in the fall of 2011 by one hunter from Arviat, and 20 kidneys were analyzed. All kidneys were analyzed for a suite of 34 elements using ICP-MS by NLET, Environment Canada, Burlington (Xiaowa Wang; Derek Muir). Liver and muscle samples were archived and incisors were used to analyze age of the animal using the cementum technique (Angela Milani, Yukon Government).

In addition to these, four samples from 2010 and one sample from 2009 from the Porcupine caribou herd were received from communities. These samples were analyzed as described above and the results added to the database for temporal trend analysis.

Although kidneys were analyzed for 34 elements, only results for 7 elements of concern were analyzed in detail (arsenic, cadmium, copper, lead, mercury, selenium and zinc).

Temporal trends were assessed for the Porcupine and Qamanirjuaq caribou using a general linear model. In the case of the Porcupine caribou only males were considered since all samples collected in 2011 were male. In the case of the Qamanirjuaq caribou only females were considered since only 2 males were included in the 2011 collection. These two males were excluded from the statistical analyses. In all statistical analyses, age was tested as a cofactor, and where necessary data were log-transformed to achieve normality. If normality was not achieved by this transformation, non-parametric tests were used to analyze the data.

Results and Discussion

While there was a significant negative correlation between year of collection and renal arsenic in male, fall-collected Porcupine caribou, the absolute decline is small and particularly in the case of arsenic, may reflect an increased ability for the laboratory detection of smaller amounts of the element as well as an increase in precision and accuracy of measurement of this element rather than an actual decline in the caribou over time. It is notable that arsenic concentrations measured prior to 2004 were erratic and variable whereas from 2004 to the present measured renal concentrations have been uniformly low. Renal arsenic concentrations in the Qamanirjuaq caribou have only been measured since 2006 and are similarly uniformly low.

There is a statistically significant decline in renal copper concentrations in the Qamanirjuaq caribou. However, the apparent decline from 2006-2011 closely mirrors fluctuations in renal copper concentrations in the Porcupine caribou for which copper is stable over time (Figure 1). Likely this is simply an artifact of the short time span being analyzed for the Qamanirjuaq caribou.

Renal lead concentrations have declined in both the Porcupine and Qamanirjuaq caribou herds over time (Figure 2), although only the decline in the Porcupine herd is statistically significant (note that there is a much smaller data set for the Qamanirjuaq herd). This decline may reflect the reduction of the use of unleaded gasoline followed by the prohibition of leaded gasoline in Canada in 1990.

Neither cadmium nor mercury are increasing or decreasing significantly over time in either caribou herd. Mercury concentrations in the Qamanirjuaq caribou herd are significantly higher than in the Porcupine herd, likely reflecting environmentally available mercury (Figure 3). Associated research continues to try to explain annual fluctuations/cycles in mercury, particularly in the Porcupine caribou which has the longest-term data set. Future research will attempt to determine the source of the higher mercury concentrations in the Qamanirjuaq herd.

Renal selenium concentrations appear to be increasing in female fall-collected Qamanirjuaq caribou. However, the time span analyzed is short and the variability among years quite small, so whether this is an actual temporal increase remains to be seen. Selenium concentrations in these caribou do not approach concentrations thought to be toxic for domestic cattle (Puls 1994) and should not be a toxicological concern.

Zinc appears to be increasing over time in kidneys from male, fall-collected caribou, but not in the Qamanirjuaq herd. It is not clear why

Figure 1. Renal copper concentrations (dry weight) in male Porcupine and female Qamanirjuaq caribou.

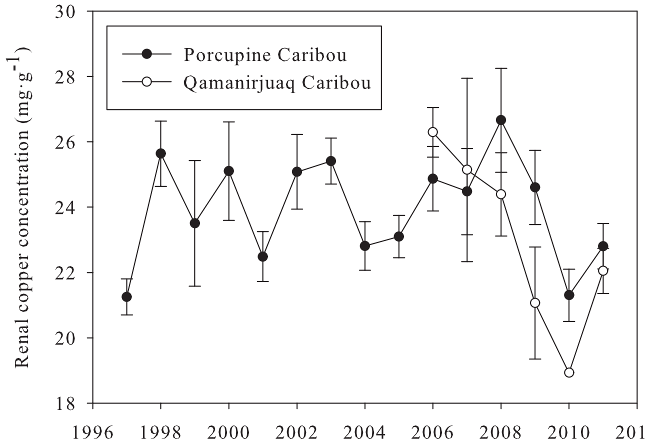


Figure 2. Renal lead concentrations (dry weight) in male Porcupine and female Qamanirjuaq caribou.

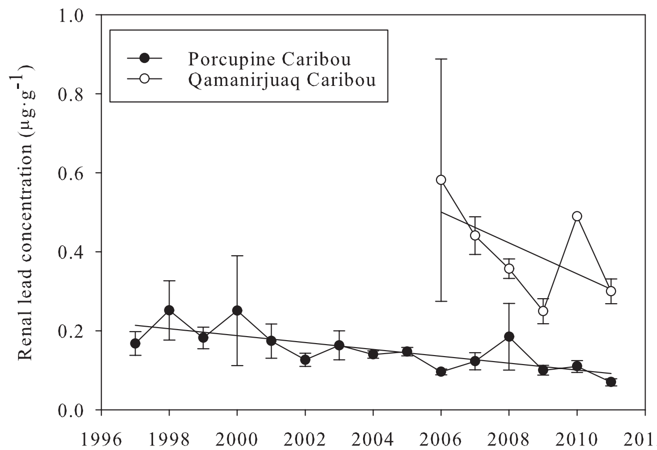


Figure 3. Renal total mercury concentrations (dry weight) in male Porcupine and female Qamanirjuaq caribou.

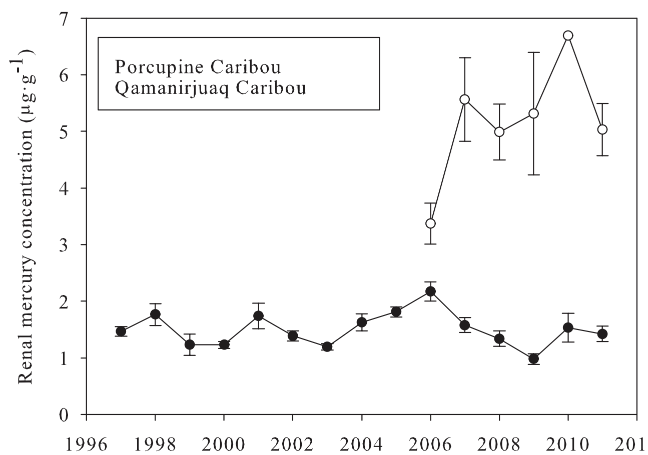
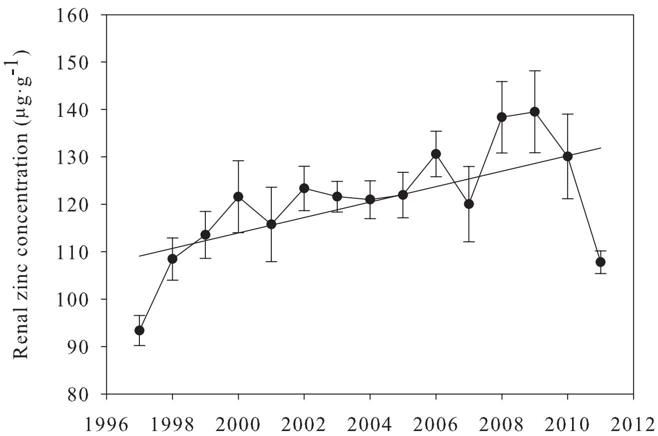


Figure 4. Renal zinc concentrations (dry weight) in male Porcupine caribou.



this increase is occurring, but Figure 4 shows that concentrations were low from 2002-06, then increasing until a drop in 2010 and 2011. These fluctuations may be part of a natural cycle for zinc in these caribou. Zinc is an essential and homeostatically controlled element and is unlikely to occur at toxic levels in a natural environment. Even the highest levels seen in these caribou do not approach levels that are thought to be toxic for domestic cattle (Puls 1994). Nevertheless, continuing to monitor zinc in this herd would be prudent.

Contaminants of concern in the Porcupine and Qamanirjuaq caribou are generally stable over time, although the increase in renal zinc in the Porcupine herd should continue to be monitored. Renal lead levels in both herds are declining and likely reflect reductions in levels of lead in the environment. Levels of most elements measured in both herds were not of concern toxicologically, although renal mercury and cadmium concentrations may cause some concern for human health depending on the quantity of organs consumed. Yukon Health has advised restricting intake of kidney and liver from Yukon caribou, the recommended maximum varying depending on herd (e.g. a maximum of 32 Porcupine caribou kidneys/year). The health advisory confirms that heavy metals are very low in the meat (muscle) from caribou and this remains a healthy food choice.

NCP Performance Indicator

Performance Indicator	Number
Number of northerners engaged in your project	15
Number of meetings/ workshops held in the north	1
number of students involved in the project	0
number of citable publications	1 anticipated (in addition to NCP synopsis report)

Expected Project Completion Date

This program is ongoing.

Acknowledgements

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References

Puls R. 1994. Mineral levels in animal health: diagnostic data. Sherpa International, Clearbrook, BC. 356 pp.

Table 1. Element concentrations (mg·g^{-1} dry weight) in fall collected male Porcupine caribou and fall collected female Qamanirjuaq caribou.

Porcupine fall-collected male caribou									
Year	N	Age	Arsenic*	Cadmium	Copper	Lead*	Mercury	Selenium	Zinc+
1997	14	4.1	0.42+0.32	23.2+12.1	21.2+2.1	0.17+0.11	1.47+0.32	3.8+0.6	93.4+11.8
1998	14	4.7	0.19+0.05	26.9+21.0	25.6+3.7	0.25+0.28	1.76+0.72	5.2+1.2	108.4+16.6
1999	11	4.7	0.08+0.04	36.0+25.9	23.5+6.4	0.18+0.09	1.23+0.63	4.6+0.8	113.5+16.3
2000	8	4.8	0.30+0.11	37.4+17.6	25.1+4.3	0.25+0.39	1.23+0.18	4.9+1.0	121.6+21.5
2001	12	5.1	0.36+0.12	29.8+11.9	22.5+2.6	0.17+0.15	1.74+0.78	4.4+1.1	115.8+27.2
2002	9	5.6	0.18+0.04	26.8+8.4	25.1+3.4	0.13+0.05	1.39+0.27	5.4+0.6	123.3+14.1
2003	23	5.8	0.25+0.06	37.5+18.1	25.4+3.4	0.16+0.18	1.19+0.25	6.1+0.7	121.6+15.4
2004	16	4.9	0.05+0.01	24.2+13.8	22.8+3.0	0.14+0.04	1.62+0.59	4.2+0.6	121.0+15.9
2005	14	3.5	0.05+0.04	23.1+14.8	23.1+2.4	0.15+0.04	1.81+0.33	4.5+0.6	121.9+18.0
2006	9	5.1	0.07+0.02	41.6+23.7	24.9+3.0	0.10+0.02	2.18+0.51	5.1+0.6	130.6+14.5
2007	12	4.7	0.04+0.01	28.3+12.2	24.5+4.6	0.12+0.08	1.58+0.45	4.4+0.7	120.0+27.5
2008	20	6.1	0.03+0.02	27.3+16.8	26.7+7.1	0.18+0.38	1.34+0.60	4.3+0.5	138.4+33.7
2009	21	6.3	0.05+0.04	38.1+16.6	24.6+5.2	0.10+0.06	0.98+0.43	4.6+0.7	139.5+39.5
2010	4	6.8	0.07+0.01	26.6+9.9	21.3+1.6	0.11+0.03	1.53+0.51	5.3+0.8	130.1+17.8
2011	11	4.9	0.05+0.04	23.0+12.7	22.8+2.3	0.07+0.03	1.42+0.45	4.5+0.6	107.8+8.0
Qamanirjuaq fall-collected female caribou									
Year	N	Age	Arsenic	Cadmium	Copper*	Lead	Mercury	Selenium+	Zinc
2006	7	7.3	0.03+0.02	18.7+13.9	26.3+2.0	0.58+0.81	3.37+0.96	3.6+8.5	104.1+8.5
2007	10	5.1	0.04+0.01	24.0+15.7	25.1+8.9	0.44+0.15	5.57+2.33	4.1+30.5	110.1+30.5
2008	10	8.1	0.04+0.02	29.7+11.8	24.4+4.0	0.36+0.08	4.99+1.57	4.0+16.0	105.7+16.0
2009	4	0.5	0.04+0.02	19.8+14.7	21.1+3.4	0.25+0.06	5.32+2.16	3.5+11.3	94.7+11.3
2010	1		0.05	21.5	18.9	0.49	6.69	3.8	96.5
2011	17	6.0	0.04+0.02	21.0+24.6	22.0+2.8	0.30+0.13	5.04+1.90	4.2+10.9	107.9+10.9

* indicates a significant decrease over time
+ indicates a significant increase over time

Determining Rate Constants for Reduction and Oxidation of Mercury Species in Arctic Ocean Water Snow and Snowmelt: Understanding Variability Under Different Radiation And Chemical Regimes, and Use in Arctic Multimedia Mercury Modeling

Détermination des taux de réduction et d'oxydation des espèces de mercure dans l'eau de fonte et dans la neige de l'océan Arctique : comprendre la variabilité dans différentes conditions d'irradiation et chimiques, et utilisation de ces connaissances pour la modélisation multimédia du mercure dans l'Arctique.

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Abstract

Frozen and melted snow samples were collected from 3 sites near Resolute, NU from March 8 to 12, 2012, for laboratory analyses. Samples were exposed to ultra violet radiation of controlled intensity at constant temperature. Gas phase elemental mercury (Hg(0)) emissions were measured over a 24 hour periodin order to generate pseudo first order curves of Hg(0) produced. Curve fitting using SigmaPlot 12 software was used to derive the kinetic rate constants of reduction in frozen and melted snow, and oxidation in melted snow. Measurements of chemical properties of the snow (chloride ion concentration, dissolved organic carbon concentration, pH, ORP, dissolved oxygen content, total mercury and total reducible mercury) are in progress. Statistically significant factors will be used to generate empirical equations thus developing a predictive model for the rate of photochemical reduction or oxidation of mercury in frozen or melted snow. This report presents the method validation data and preliminary reduction data collected for the 2012 field sampling campaign.

Résumé

Des échantillons de neige gelée et d'eau de fonte ont été prélevés dans trois sites près de Resolute, au Nunavut, du 8 au 12 mars 2012, aux fins d'analyses en laboratoire. Les échantillons ont été soumis à un rayonnement ultraviolet d'une intensité contrôlée à température constante. Les émissions de mercure élémentaire en phase gazeuse (Hg(0)) ont été mesurées sur une période de 24 heures afin de générer les courbes de pseudo premier ordre du Hg(0) produit. L'ajustement des courbes a été effectué à l'aide du logiciel SigmaPlot 12 afin de calculer les constantes cinétiques des taux de réduction des espèces de mercure dans la neige gelée et fondue et les taux d'oxydation dans la neige fondue. La détermination des propriétés chimiques de la neige (concentration en ions chlorure, concentration du carbone organique dissous [COD], pH, potentiel d'oxydoréduction [POR], concentration d'oxygène dissous [OD], mercure total et mercure total réductible) est en cours. Des facteurs statistiquement significatifs seront utilisés pour générer des équations empiriques, menant ainsi au développement d'un modèle de prévision du taux de réduction ou d'oxydation photochimiques du mercure dans la neige gelée et dans l'eau de fonte. Ce rapport présente les données de validation de la méthode et les données de réduction préliminaires recueillies pour la campagne d'échantillonnage sur le terrain de 2012.

Key Messages

- Activities to date have focussed on development of the analysis methodology, and sample collection in Resolute, NU.
- Analysis of the collected samples for snow chemical characteristics (DOC, DIC, ORP, DO, pH, ions) and net mercury reduction in snow and melted snow, and oxidation of mercury in melted snow is presently underway and will be completed in 2012.
- Mercury reduction rate constants have been quantified for several intensities for all sites (completion is expected by June). To date, for Resolute frozen snow, mercury reduction rate constants (k) are between 0.1 ± 0.07

Messages clés

- À ce jour, les activités ont été axées sur le développement de la méthode d'analyse et la collecte d'échantillons à Resolute, au Nunavut.
- L'analyse des échantillons prélevés pour déterminer les propriétés chimiques de la neige (COD, carbone inorganique dissous, POR, OD, pH, ions), la réduction nette du mercure dans la neige et dans l'eau de fonte, et l'oxydation du mercure dans l'eau de fonte est en cours et se terminera en 2012.
- Les constantes des taux de réduction du mercure sont actuellement quantifiées pour plusieurs intensités dans tous les sites (on

and 0.5 ± 0.07 h^{-1} and the maximum mass of mercury released from irradiated samples ($Hg(II)_{red}$) are between 493 ± 110 and 45 ± 14 pg (average ± standard deviation for three trials; see Figure 3 and Table 3), for irradiation of samples with UVA bulbs (1.26 - 5.78 Wm^{-2} for 280 to 400 nm wavelengths). Both k and $Hg(II)_{red}$ values appear to be proportional to UV (280 to 400 nm) radiation intensity (Figure 4).

- Mercury reduction rates will be related to the experimental conditions and snow characteristics, and used in a mercury fate model to better understand the behaviour of mercury in snow and snow melt water in the Arctic.

prévoir avoir terminé en juin). À ce jour, pour l'eau de fonte recueillie à Resolute, les constantes des taux de réduction du mercure (k) varient entre 0,1 ± 0,07 et 0,5 ± 0,07 h^{-1}, et la masse maximale de mercure libéré par les échantillons irradiés ($Hg(II)_{réd}$) varie entre 493 ± 110 et 45 ± 14 pg (moyenne ± écart type pour trois essais; voir la figure 3 et le tableau 3), pour l'irradiation d'échantillons en utilisant des ampoules UVA (1,26 5,78 Wm^{-2}; longueurs d'onde de 280 à 400 nm). Les valeurs k et $Hg(II)_{réd}$ semblent être proportionnelles à l'intensité de rayonnement UV (280 à 400 nm) (figure 4).

- Des liens seront établis entre les taux de réduction du mercure et les conditions expérimentales et les propriétés de la neige, et les résultats seront utilisés dans un modèle du devenir du mercure afin de mieux comprendre le comportement du mercure dans la neige et l'eau de fonte dans l'Arctique.

Objectives

The overall objectives of the present study are:

- To collect Arctic snow, and determine environmental parameters and snow characteristics for the sampling locations.

- To analyse the rate of mercury reduction in snow and melted snow, and mercury oxidation in melted snow and relate the kinetic rates of these reactions back to the snow chemical composition (DOC, DIC, ORP, DO, pH, ions) and environmental properties (irradiation conditions), using empirical mathematical equations.

- To develop predictive models for mercury reduction rate constants using these properties.

Introduction

Mercury transport to the Arctic:
Mercury (Hg) is an environmental contaminant of concern due to toxicity and the ability of some species to bioaccumulate. A one year atmospheric lifetime for mercury (Schroeder et al., 1998) means that it can be transported into Arctic regions, where it is deposited to snow and aqueous environments (Mitchell et al., 2008; Stern et al., 2012). Mercury cycling between snow and the atmosphere is an area of on-going research and is critical for accurate predictions of mercury transport into receiving water bodies with melting snow (Bartels-Rausch et al., 2011; Lalonde et al., 2003).

Mercury deposition to and re-emission from snow:
Mercury (Hg) in the atmosphere, present primarily as elemental mercury (Hg(0)) (Schroder and Munthe, 1998), is oxidized to less atmospherically stable forms, such as divalent mercury (Hg(II)) and deposited with snow

(Constant et al., 2007; Lindberg et al., 2002; Poissant et al., 2008; Schroeder et al., 1998). In the late 90s, episodic depletion of atmospheric Hg was discovered in the Arctic (Schroeder et al., 1998) and many groups have since identified such phenomena, called atmospheric mercury depletion events (AMDEs), in polar environments (Ariya et al., 2004; Dommergue et al., 2003b; Ebinghaus et al., 2002; Gauchard et al., 2005; Kirk and Sharp, 2006; Lindberg et al., 2002). AMDEs result in elevated concentrations of divalent mercury in the underlying snowpack during the event (Constant et al., 2007; St. Louis et al., 2005; Steffen et al., 2008); however, once present in the snowpack, this mercury is subject to further reactions, such as reduction to Hg(0) (Poulain et al., 2004). Since Hg(0) does not readily sorb to snow crystals (Bartels-Rausch et al., 2008) it will volatilize to the atmosphere (Kirk et al., 2006). As such, 24 to 48 hours after an AMDE, snowpack mercury concentrations can return to near pre-AMDE levels (Dommergue et al., 2010). Some argue that AMDEs are still a significant net source of Hg to the surface (Dommergue et al., 2003a; Hirdman et al., 2003; Johnson et al., 2008; Lindberg et al., 2002; Loseto et al., 2004; Poulain et al., 2007; Steffen et al., 2005), while others maintain that AMDEs are a negligible net source of surface mercury (Aspmo et al., 2006; Kirk et al., 2006; Lahoutifard et al., 2005; St. Louis et al., 2007). It is clear that mercury in the Arctic undergoes sequential oxidation and reduction that is thought to be primarily photochemical in nature (Durnford and Dastoor, 2011; Lalonde et al, 2002; Poulain et al., 2004), resulting in deposition to and emission from snow. However the mechanisms and kinetic rates controlling these processes are poorly quantified (Durnford and Dastoor, 2011). To better model retention of mercury in snow and its potential as a source of Hg to surface waters, controlled analysis of photochemical reduction is required. The goal of this work is to quantify mercury reduction in snow and to develop empirical relationships between reduction rate constants and snow physical/chemical properties. This research will facilitate a better prediction of areas and food webs that may be at risk for mercury contamination in Arctic ecosystems and how this may change with a warming climate.

Activities 2012

Activities to date have been centred around development and testing of controlled methodology and collection of samples near the Polar Continental Shelf Program base in Resolute Bay, NU, Canada in March 2012. The current focus is on analysis of these samples using this methodology we have developed.

Method Development

Temperate (Nova Scotia) Test-Snow Collection: Snow was collected on January 10, 2012 at 7 pm during a snowfall at Acadia University in Wolfville, NS. Samples were collected in 2.2L Teflon bottles in the dark, double bagged in Ziploc® bags and stored frozen until analysis. This snow was used for initial experimental method development.

Method Development
From January to March 2012, development and testing of the experimental method for mercury reduction in frozen snow was undertaken. For this, snow was collected near Acadia University in Wolfville, NS, Canada into 2.2L Teflon bottles. The analysis method makes use of a Luzchem ORG photoreactor, placed in a freezer at -10 °C, equipped with up to 10 UVB or UVA bulbs, emitting the majority of their radiation in the 280 – 320 nm and 320 – 400 nm range respectively. Figure 1 shows the spectrum of irradiation from 5 UVB or 5 UVA bulbs reaching snow in a Teflon bottle with associated irradiation intensities for wavelength intervals of interest presented in Table 2.

For mercury reduction in temperate test snow a 2.2L Teflon bottle filled with snow is used. Before irradiation begins, Hg(0) in the interstitial pore space is removed by passing zero air from a Tekran model 1100 zero air generator, through the snow and into the Tekran model 2537A cold vapour atomic fluorescence spectroscopy (CVAFS) automated mercury analyser at a rate of 1 $L \bullet min^{-1}$ for 5 minute analysis intervals. This continues until the Hg concentration in the snow falls

Table 1: Sampling site descriptions and collected environmental parameters at the time of sampling.

	Site 1	Site 2	Site 3
Sampling date and time	March 8, 2012 10:45 - 12:00 CST	March 9, 2012 12:45 – 13:30 CST	March 12, 2012 10:00 – 10:30 CST
GPS location (Degree·min-1·sec-1)	74°43′05 N 095°00′16 W	74°44′13 N 094°56′28 W	74°41′31 N 094°56′08 W
Description	Flat, wind scoured location between PCSP base camp and Arctic Ocean (ice covered, no open water); thin hard snow cover with shallow drifts and rocks visible.	Hilly location with many snow drifts. Deep snowpack, sampled on the on the shaded side of a hill, with no underlying rock visible. Snow moderately hard and windblown.	Flat, wind scoured location near an ice covered lake. Very hard packed snow in relatively deep drifts, with no visible rock, overlaid in places by a thin layer of newer windblown snow.
Air temperature (°C)	-38.1	-33.3	-31.2
Snow temperature (°C)	-39.7	-35.5	-31.0
Wind speed ($km \cdot h^{-1}$)	2.6	8.1	10.2
Relative humidity (%)	100	100	100

below instrumental detection. Snow is then irradiated with 4 to 10 UVB bulbs, with zero air flowing through the sample into the Tekran 2537A where Hg(0) mass is quantified with time (Figure 2). Using SigmaPlot 12 software curve fitting an assumed pseudo-first order rate constant is derived (Equation 1), where k is the rate constant in h^{-1}, $Hg(II)_{red}$ is the photoreducible mercury for the irradiation intensity. Due to the higher reducible mercury present in the Arctic snow as compared with Nova Scotia snow (493 ± 110 pg and 164 ± 78 pg respectively), the method for mercury reduction analysis in Arctic snow makes use of a smaller sample size, 175 to 200 mL of frozen snow in a clean quartz beaker, and has a minimum irradiation intensity of 2 UVA bulbs.

$$Hg(0)= Hg(II)\ red \cdot (1- e^{-k \cdot t}) \qquad \text{(Equation 1)}$$

Gross mercury reduction in Nova Scotia snow – Method Testing:
Using fresh "test" snow collected near Acadia University in Wolfville, NS, Canada, the method for mercury photoreduction in snow was tested. Figure 2 shows the results of irradiating these samples with 4, 6, 8 or 10 UVB bulbs respectively. It can be seen that the highest concentration of Hg(0) was produced in the sample exposed to the greatest UVB irradiation intensity (Figure 2D). Samples had a high initial Hg(0) concentration, followed by a slow dropping off to a constant Hg(0). The time to reach this constant concentration appeared to be dependent on the irradiation intensity, with a higher irradiation intensity meaning a longer time for the sample to reach that low constant Hg(0) concentration. These times ranged from roughly 2 to 32 hours.

Experimental Analysis of Snow

Arctic (Resolute) Experimental Snow Collection: Three sites near the Polar Continental Shelf Program research base in Resolute, NU were sampled during March 8 to March 15, 2012 (Table 1). At each site 7 x 2.2L Teflon bottles of frozen snow were collected, double bagged and stored frozen in coolers. Care was taken to compress the snow as little as possible.

Table 2: Radiation intensities (Watt·m^{-2}) for the wavelength intervals reported for incoming solar radiation measured during Resolute sampling campaign in March 2012, as well as laboratory radiation intensities for 5 UVB bulbs installed in the Luzchem photoreactor through a Teflon bottle. In all cases, the intensities have been dark subtracted to remove any artificial signal generated by the instrument.

Date/time	Conditions	UVB 280-320 nm (W·m-2)	UVA 320-400 nm (W·m-2)	Total UV 280-400 nm (W·m-2)	Visible 400-800 nm (W·m-2)	UV+VIS 280-800 nm (W·m-2)
Mar 8/ 3:25 pm	Probe in full sun, clear conditions	1.05	2.32	3.37	55.21	58.57
Mar 9/ 3:45 pm	Probe in full sun, ice fog conditions	1.55	1.74	3.29	11.01	14.30
Mar 10/ 1:15 pm	Probe in partial shade, pointed towards sun, clear conditions	1.09	3.35	4.44	22.14	26.56
Mar 10/ 3:40 pm	Probe in full sun, ice fog beginning	1.82	2.68	4.50	56.55	61.03
Mar 10/ 3:45 pm	Probe in full sun, ice fog beginning, repositioned probe to point directly at sun	1.55	2.32	3.86	51.51	55.36
Mar 11/ 11:10 am	Probe in shade, cloudy conditions, had been snowing/ice fog earlier	0.58	1.86	2.44	12.30	14.73
Mar 11/ 1:40 pm	Probe in shade, mostly clear sky	0.51	2.78	3.29	19.05	22.33
Mar 11/ 3:40 pm	Probe nearly in full sun, mostly clear sky	0.51	2.68	3.19	31.35	34.52
Mar 12/ 1:30 pm	Probe in shade, some haze/ice fog obscuring sun	0.47	3.07	3.54	23.19	26.72
Mar 12/ 3:40 pm	Probe in full sun, some haze/ice fog obscuring sun	0.55	2.92	3.46	30.28	33.72
Mar 12/ 3:45 pm	Probe in full sun, pointed at sun; some haze/ice fog	0.71	3.05	3.76	57.01	60.75
Mar 13/ 11:15 am	Probe in shade, bright but uniform whiteness, no sun visible, no horizon (blizzard)	0.39	2.80	3.19	21.45	24.63
Mar 14/ 2:10 pm	Probe in shade, sun visible, but wind scour reducing near ground visibility	0.53	4.48	4.99	40.09	45.07
Mar 14/ 4:15 pm	Probe in full sun, high winds and blowing snow creating some obstruction, but sun sometimes visible (blizzard conditions)	0.55	3.31	3.85	44.33	48.17
5 UVB bulbs	Probe at the position of the edge of the beaker for irradiation experiments	4.12	1.28	5.39	2.44	7.83
5 UVA bulbs	Probe at the position of the edge of the beaker for irradiation experiments	0.26	2.72	2.98	1.28	4.26

In addition, 6 x 2L samples of snow melt water was collected, melted in 2.2L Teflon bottles at room temperature and pooled in 6 Teflon bottles, which were then frozen until analysis. Trace sampling protocols were followed (e.g. full clean suits with hood, powder free gloves and double bagging). All samples were shipped, frozen, back to Acadia University in Wolfville, NS for analysis.

In addition to snow collection, several other data were collected at each sample location, including:

- GPS location of the sampling site and time of sample collection
- Air and snow temperature
- Wind speed
- Snow grain appearance

For the duration of the sampling campaign, irradiation conditions were monitored at the Polar Continental Shelf Program base camp, with irradiation spectra and intensities of wavelength intervals of interest (UVA, UVB, total UV, visible, UV- visible) collected daily (Table 2) using an Ocean Optics USB 4000 scanning spectraradiometer with a 10 m fibre optic probe with a 4.3 mm diameter cosine corrected integrating probe.

Preliminary Results and Discussion

Arctic Irradiation Intensities:
Figure 1 shows a typical UV spectrum recoded during the campaign, and Table 2 gives irradiation intensities and outdoor conditions for all spectra. All irradiation measurements were taken at the same location, at the Polar Continental Shelf Program base. A maximum UV irradiation intensity of 4.50 W•m^{-2} was measured on March 10, 2012 at 3:40 during clear sunny conditions, while minimum UV irradiation of 0.39 W•m^{-2} was recorded at 11:15 am during a blizzard which spanned from late evening on March 12 to 15, 2012. It can be seen that these UVB conditions can be generated by 5 UVB bulbs in the photoreactor (Table 2).

Environmental conditions during sampling:
The conditions under which samples were collected were cold and clear, with low winds and high relative humidity (Table 1). Surface snow and air temperatures were within 2 °C of each other. Samples were collected near the ice-covered Arctic Ocean shore, at a site past the Resolute Bay airport on the shaded side of a hill, and near the shore of an ice covered lake (Table 1). Snow collected had small column-like grains, 0.05 to 0.2 mm in diameter, indicating crystals formed in very cold conditions (Fierz et al., 2009).

Figure 1. A typical UV irradiation spectrum (280-400nm) for natural insolation at the Polar Continental Shelf Program research base in Resolute, NU (A) and the spectrum produced by 5 UVB bulbs (B) through a Teflon bottle or 5 UVA bulbs through quartz (C) in the Luzchem photoreactor at -10 °C.

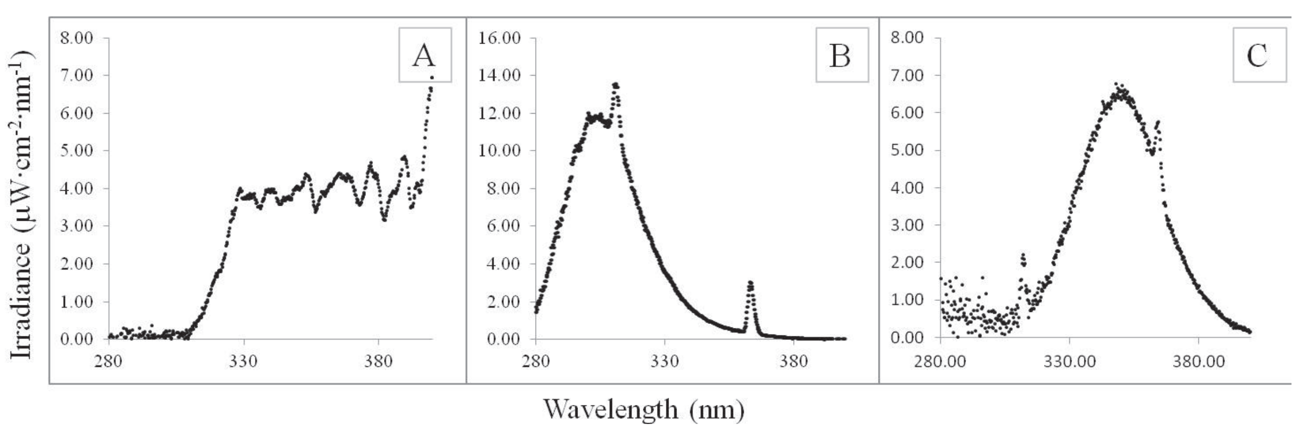
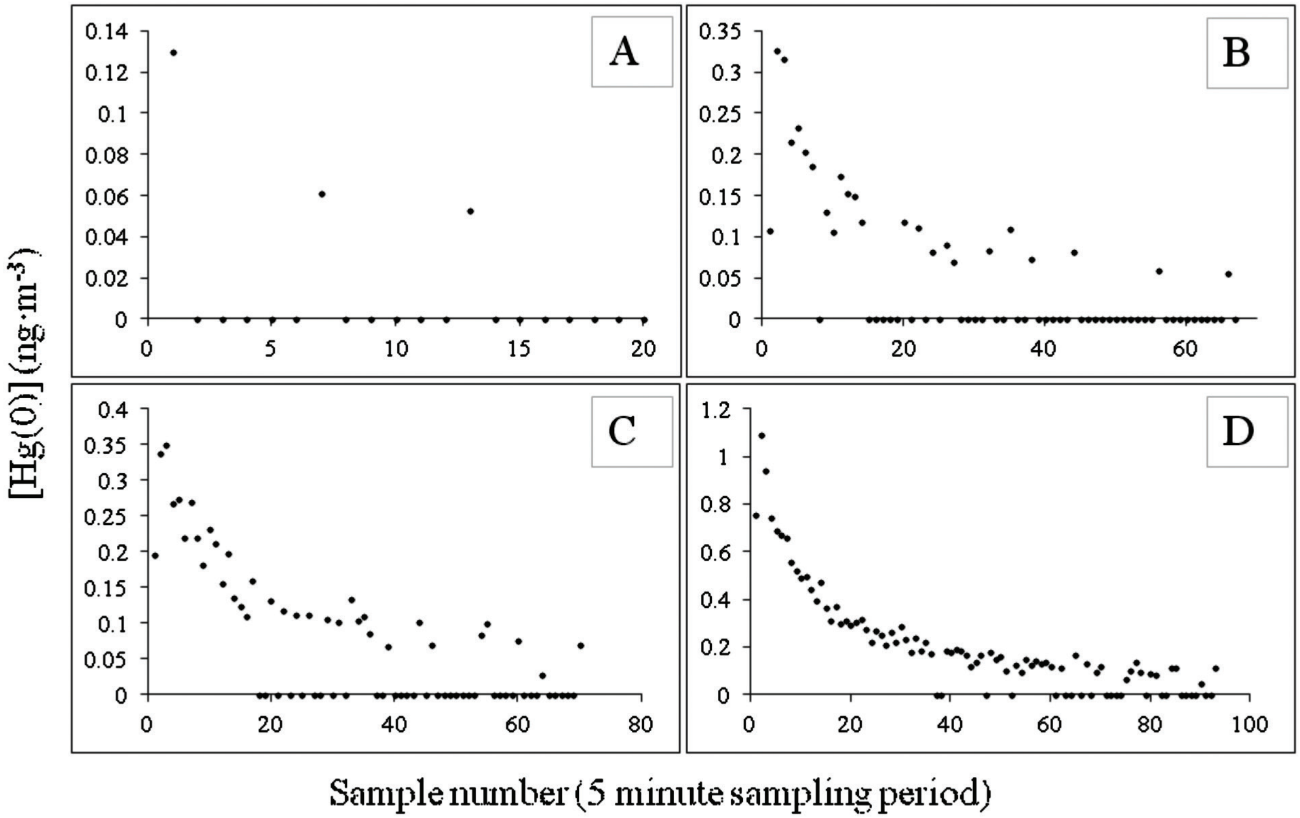


Figure 2. AHg(0) concentration evolved from a 2.2L Teflon bottle filled with snow collected near Acadia University in Wolfville, NS, irradiated with 4 (A), 6 (B), 8 (C) or 10 (D) UVB bulbs.



Gross mercury reduction in Resolute snow – Initial results:
At present, mercury reduction rate constants (k) and reducible mercury ($Hg(II)_{red}$) have been determined for all sites at the highest irradiation intensity (10 UVA bulbs = 5.78 Wm^{-2} of 280 - 400 nm radiation) (Figure 3), and for all remaining irradiation intensities for one site (2 to 8 UVA bulbs = 1.26 - 4.65 Wm^{-2} of 280 - 400 nm radiation). These rate constants range between 0.5 ± 0.07 and 0.1 ± 0.07 h^{-1}, with total reducible mercury in samples between 496 ± 110 and 45 ± 14 pg mercury (average standard ± deviation for three trials). Figure 3 the SigmaPlot graphs with the average ± standard deviation cumulative mercury data for triplicate analyses and curve with the fitted Equation 1 and Table 3 gives results for all reduction experiments run to date.

Expected Project Completion Date

At present, the Arctic frozen and melted snow samples have been collected and analysis is ongoing. The expected completion date for analysis of these frozen snow and meltwater samples is December 2012. A second year of sampling will take place in 2013, with frozen and melted snow samples collected from a location in NS, Canada. Analysis of this second set of samples will be complete by December 2013. Modelling work incorporating the developed rate constant data, in collaboration with Asif Qureshi, will be ongoing from 2012 to 2013. In late 2012 or early 2013 a flux chamber will be deployed in Resolute, NU to examine mercury flux in situ; these results will be used to evaluate the developed model.

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Figure 3. Cumulative elemental mercury production in Resolute site 3 samples irradiated with: 1.26 (A), 2.39 (B), 3.52 (C), 4.65 (D) or 5.78 (E) W•m^{-2} of radiation in the UV (280 – 400 nm) range, with SigmaPlot fitted curve and generated rate equation (Equation 1).

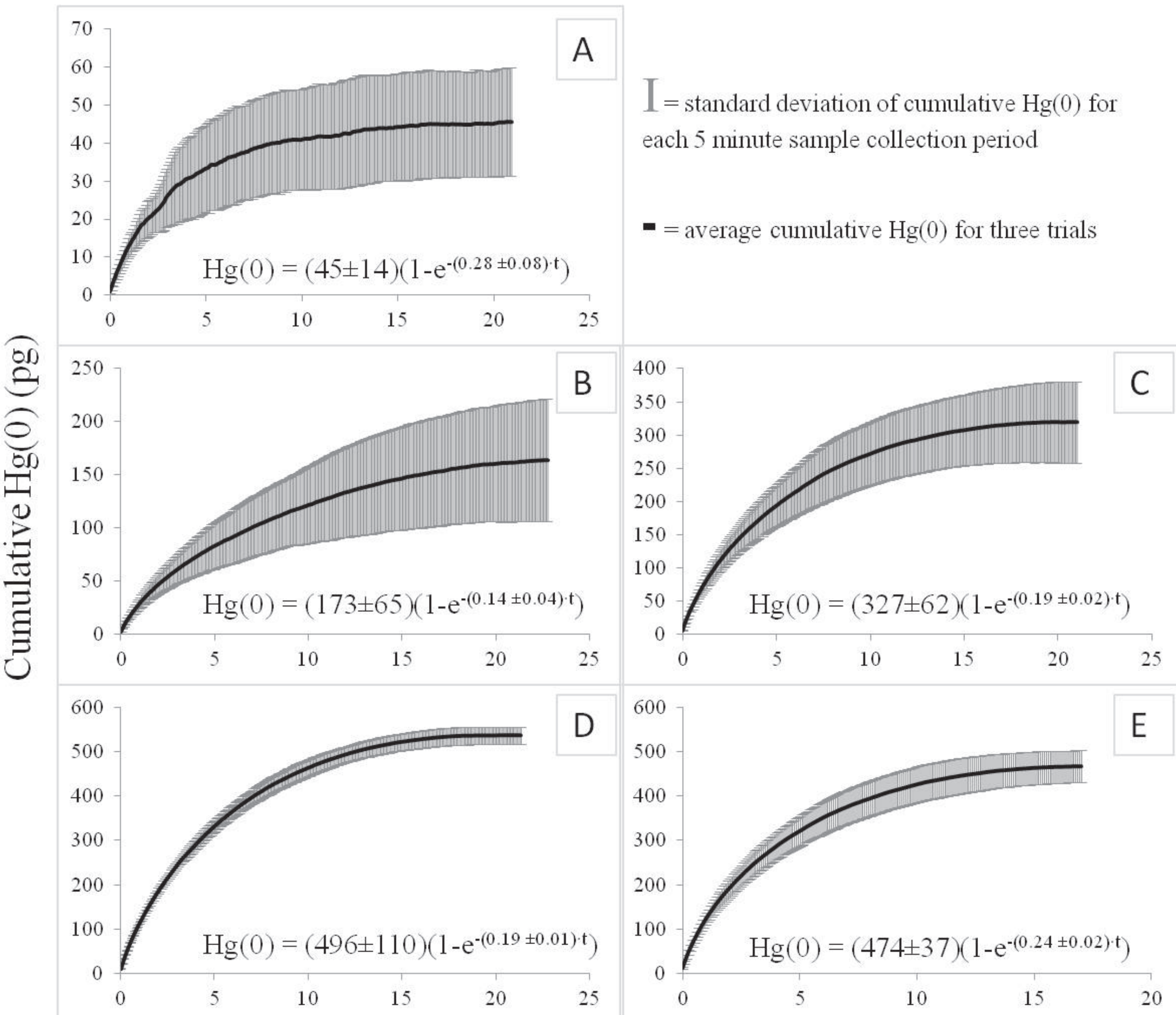

Figure 4. Mercury reduction rate constant (k) or total reducible mercury (Hg(II)red) plotted against the irradiation intensity for individual experiments. Note that the dark coloured circle datum in the k plot is excluded from the regression fit.

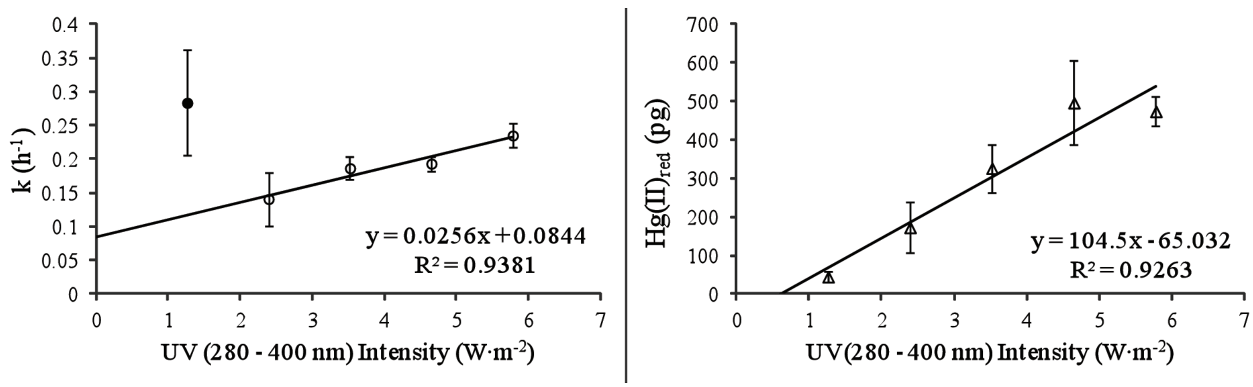

Table 3: The pseudo first order reaction rate for reduction of mercury in snow (k) and total available reducible mercury ($Hg(II)_{red}$). Note that "CS" denoted the "check sample" which is a site 3 sample 18 aliquot to be run at the end of the 8 UVA irradiations for all 3 sites to monitor long-term instrumental variability.

Site - Sample - expt - date performed	R2	k (h^{-1})	std error (h-1)	p	Hg(II)red (pg Hg)	std error (pg)	p
3 - 24 - 10 UVA trial 1 - April 11	0.9977	0.1603	0.0008	<0.0001	611.3881	1.0168	<0.0001
3 - 24 - 10 UVA trial 2 - April 12	0.9957	0.1990	0.0014	<0.0001	500.3500	1.0511	<0.0001
3 - 24 - 10 UVA trial 4 - April 14	0.9957	0.2050	0.0015	<0.0001	479.5003	1.0953	<0.0001
3 - 24 - 10 UVA at end - April 20	0.9966	0.2082	0.0014	<0.0001	470.9314	0.9886	<0.0001
2 - 34 - 10 UVA trial 1 - April 15	0.9841	0.2799	0.0037	<0.0001	378.9215	1.2800	<0.0001
2 - 34 - 10 UVA trial 2 - April 16	0.9902	0.5514	0.0079	<0.0001	158.8015	0.5678	<0.0001
2 - 34 - 10 UVA trial 3 - April 16	0.9932	0.5425	0.0073	<0.0001	150.9606	0.5627	<0.0001
2 - 34 - 10 UVA trial 4 - April 17	0.9926	0.2500	0.0025	<0.0001	283.9612	0.7942	<0.0001
2 - 34 - 10 UVA trial 5 - April 20	0.9918	0.4224	0.0050	<0.0001	182.4726	0.5408	<0.0001
1 - 28 - 10 UVA trial 1 - April 18	0.9909	0.3951	0.0067	<0.0001	146.4054	0.8174	<0.0001
1 - 28 - 10 UVA trial 2 - April 18	0.9927	0.3865	0.0047	<0.0001	148.9488	0.5051	<0.0001
1 - 28 - 10 UVA trial 3 - April 19	0.9932	0.3984	0.0049	<0.0001	141.7031	0.4987	<0.0001
3 - 18 - 10 UVA trial 1 - April 21	0.9940	0.2249	0.0019	<0.0001	486.6306	1.1952	<0.0001
3 - 18 - 10 UVA trial 2 - April 22	0.9943	0.2250	0.0020	<0.0001	432.4110	1.2101	<0.0001
3 - 18 - 10 UVA trial 3 - April 23	0.9954	0.2558	0.0021	<0.0001	502.6439	1.2134	<0.0001
3 - 17 - 8 UVA trial 1 - April 24	0.9983	0.1905	0.0009	<0.0001	573.2974	0.8229	<0.0001
3 - 17 - 8 UVA trial 2 - April 25	0.9967	0.1943	0.0012	<0.0001	533.6472	1.0354	<0.0001
3 - 17 - 8 UVA trial 3 - April 26	0.9974	0.1819	0.0011	<0.0001	544.9369	0.9997	<0.0001
3 - 18 - 8 UVA CS site 3 - April 27	0.9975	0.2074	0.0011	<0.0001	333.1465	0.5052	<0.0001
3 - 17 - 6 UVA trial 1 - April 28	0.9935	0.1906	0.0017	<0.0001	260.0384	0.7336	<0.0001
3 - 17 - 6 UVA trial 2 - April 29	0.9973	0.1681	0.0009	<0.0001	383.3706	0.6443	<0.0001
3 - 17 - 6 UVA trial 3 - May 2	0.9972	0.2013	0.0011	<0.0001	336.5262	0.5346	<0.0001
3 - 17 - 4 UVA trial 1 - May 3	0.9961	0.1201	0.0010	<0.0001	227.2172	0.7142	<0.0001
3 - 17 - 4 UVA trial 2 - May 5	0.9952	0.1166	0.0010	<0.0001	190.4752	0.6868	<0.0001
3 - 18 - 4 UVA trial 3 - May 6	0.9872	0.1863	0.0022	<0.0001	101.1715	0.3546	<0.0001
3 - 17 - 2 UVA trial 1 - May 7	0.9743	0.2074	0.0035	<0.0001	38.4167	0.1925	<0.0001
3 - 21 - 2 UVA trial 2 - May 8	0.9935	0.3644	0.0025	<0.0001	35.4450	0.0437	<0.0001
3 - 21 - 2 UVA trial 3 - May 9	0.9971	0.2791	0.0015	<0.0001	61.3494	0.0736	<0.0001

NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	0	Planned to recruit one Northerner to help with field site locations, but poor weather (blizzard coming) meant that sampling locations were chosen close to the PCSP base camp instead.
number of project-related meetings/workshops held in the North (April 1, 2011 – March 31, 2012)	0	A meeting with the Hunters' and Trappers' association was scheduled and agreed to; however, as a result of the blizzard, this was cancelled and is tentatively re-scheduled for summer 2012.
number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	1	Erin Mann
number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	2011: 0 2012: 0	Project began in January 2012, results are, as yet, forthcoming.

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Methylmercury Pathways in the Water Column and Sediments along Canada's Arctic Margin

Cheminement du méthylmercure dans la colonne d'eau et les sédiments le long de la frontière Arctique canadienne

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Abstract

In this project, we are studying the distribution and cycling of total mercury (Hg) and methylmercury (MeHg), which is the bioaccumulative and toxic form of mercury, within the water column and sediments along a wide oceanographic section along Canada's Arctic margin. The section extends from the Bering Sea to the western Beaufort Sea through the Canadian Arctic Archipelago (CAA) and into Baffin Bay. This report addresses the distribution of Hg and MeHg in 25 sediment cores collected along the section during the International Polar Year (2007-2008) and analyzed in 2011-2012 in laboratories at the Université du Québec (INRS) and Ifremer, France.

Résumé

Dans le cadre de ce projet, nous étudions la répartition et le cycle du mercure total (Hg) et de sa forme bioaccumulable toxique, le méthylmercure (MeHg), dans la colonne d'eau et les sédiments le long d'une vaste section océanographique bordant la frontière arctique canadienne, de la mer de Béring à la portion occidentale de la mer de Beaufort, en passant par l'archipel arctique canadien et la baie de Baffin. Le présent rapport traite de la répartition du Hg et du MeHg dans 25 carottes de sédiments prélevées le long de la section océanographique susmentionnée durant l'Année polaire internationale (2007-2008) et analysées en 2011-2012 dans les laboratoires de l'Université du Québec (INRS) et de l'Ifremer, en France.

The Hg concentrations measured in the Arctic margin sediment cores are generally similar to those reported previously for Arctic sediments and also similar to shelf and slope sediments elsewhere. However, cores from the Beaufort shelf/slope and Barrow Canyon in the northeast Chukchi Sea have unusually high Hg concentrations, providing a spatial pattern that is not inconsistent with the spatial patterns in Hg in the marine food web (e.g., beluga whales). High organic carbon (OC) content of the Chukchi and Beaufort sediments appears to be one factor underlying the high Hg concentrations, and unusually high Hg loadings (per unit of OC) in these areas appears to also contribute. MeHg concentrations in the sediment cores were generally very low (≤0.1 ng/g) except for a few cores from the Chukchi Sea, which had average MeHg concentrations in the order of 0.67-0.97 ng/g. MeHg in the sediments are largely independent of both total Hg concentrations and OC content, although a minimum OC content appears to be a requisite for elevated MeHg concentrations. Vertical profiles of MeHg in the cores contrast sharply with profiles of Hg and suggest that very different factors control their accumulation in the sediments. We are further investigating the reasons for the regional variability in sedimentary Hg and MeHg and the geochemical controls on the vertical profiles and anticipate further data interpretation toward a publication in the peer-reviewed literature in late 2012/early 2013.

Les concentrations de Hg décelées dans les carottes de sédiments prélevées le long de la frontière arctique étaient dans l'ensemble comparables à celles détectées antérieurement dans des échantillons de sédiments arctiques et des échantillons de sédiments prélevés en d'autres endroits de la plate-forme et du talus de Beaufort. Toutefois, des concentrations de Hg inhabituellement élevées ont été décelées dans des carottes provenant du talus de la plate-forme de Beaufort et du canyon de Barrow, dans la portion nord-est de la mer de Tchoukotka. Une telle répartition spatiale concorde dans l'ensemble relativement bien avec la répartition spatiale du Hg dans la chaîne trophique marine (p. ex. bélugas). Les fortes teneurs en carbone organique (Corg) des sédiments des mers de Beaufort et de Tchoukotka semblent un des facteurs expliquant les fortes concentrations de Hg, et les charges inhabituellement élevées de Hg (par unité de Corg) dans ces régions semblent également jouer un rôle à cet égard. Les concentrations de MeHg dans les carottes de sédiments étaient généralement faibles (≤ 0,1 ng/g), sauf dans le cas de quelques carottes prélevées dans la mer Tchoukotka, dont les teneurs oscillaient entre 0,67 et 0,97 ng/g. Les concentrations de MeHg dans les sédiments sont en grande partie indépendantes des concentrations de Hg total et de Corg, bien que la présence d'une concentration minimale de Corg semble nécessaire à l'existence de fortes concentrations de MeHg. Les profils verticaux des concentrations de MeHg dans les carottes diffèrent considérablement des profils de Hg, ce qui donne à croire que des facteurs très différents gouvernent l'accumulation du MeHg et du Hg dans les sédiments. Nous nous employons actuellement à déterminer les facteurs qui expliquent la variabilité régionale des concentrations de Hg et de MeHg dans les sédiments et les facteurs géochimiques qui influent sur les profils verticaux du Hg et du MeHg. Une fois l'interprétation des résultats effectuée, nous prévoyons de publier les résultats de nos travaux dans une revue comportant un comité de lecture à la fin de 2012 ou au début de 2013.

Key Messages

- A long section of 25 sediment cores spanning Canada's Arctic margin reveals intriguing spatial patterns in Hg and MeHg concentrations, which roughly conform to previously reported spatial patterns in the marine food web.

- Differences both in the spatial distribution of MeHg and Hg and in the vertical distribution of Hg and MeHg within cores point to very different factors controlling their accumulation in the sediments. This underscores the importance of not using total Hg concentrations in sediments as an indicator of risk from, or bioavailability of, sedimentary Hg.

Messages clés

- L'analyse d'une longue section de 25 carottes de sédiments prélevées le long de la frontière arctique canadienne a mis en évidence des tendances spatiales intrigantes liées aux concentrations de Hg et de MeHg qui concordent assez bien avec les tendances spatiales déjà observées dans la chaîne trophique marine.

- Les différences relevées dans les carottes de sédiments entre la répartition spatiale du MeHg et celle du Hg et entre la répartition verticale du Hg et celle du MeHg donnent à croire que des facteurs très différents influent sur l'accumulation du Hg et du MeHg dans les sédiments. Ces résultats démontrent l'importance de ne pas utiliser les concentrations de Hg total dans les sédiments comme indicateur du risque posé par le Hg ou de la disponibilité du Hg dans les sédiments.

Objectives

The long-term goal of our research is to improve our understanding of the linkages between mercury sources and pathways of mercury methylation, which ultimately give rise to the relatively high levels in Arctic marine food webs. Ultimately, we envision these data being used together with data from other ongoing studies and community knowledge to develop a practical Hg monitoring strategy for Canada's Arctic waters. Specifically, the goals of the project reported here, are:

- To assess the spatial patterns of Hg and MeHg distribution along Canada's Arctic margin, for comparison to geographic trends identified in the marine food web.

- To improve our understanding of the MeHg sources and production pathways in the Arctic Ocean along the Canadian Arctic margin by examining the inter-relationships between Hg, MeHg, organic carbon and other geochemical properties of the sediments.

Introduction

Mercury (Hg), and specifically the organic species methylmercury (MeHg), which is the form presenting the greatest toxic risk, has accumulated to sufficiently high levels in Arctic marine food webs to pose risks to top predators and northern peoples who consume traditional/country foods (Van Oostdam et al., 2005). Elevated levels of Hg observed in higher trophic levels of Arctic marine food webs are often presumed to reflect enhanced deposition partly due to global emissions of anthropogenic Hg and partly due to a unique deposition process within the Arctic itself (e.g., Schroeder et al., 1998). However, a growing body of evidence suggests that post-deposition processes that convert Hg(0) to Hg(II) and thence to MeHg in the Arctic Ocean may provide the determining role in the accumulation and distribution of Hg in higher trophic levels, and the toxic risks associated with Hg: presently, we know far less about these post-depositional, aquatic processes (Macdonald and Loseto, 2009).

MeHg may be produced within the oxic water column as a byproduct of organic matter remineralization (Cossa et al., 2009 and Heimburger et al., 2010, Mediterranean Sea; Sunderland et al. 2009, North Pacific Ocean). Additionally, MeHg is produced by sulfate-reducing bacteria in mildly- to strongly reducing sediments typical of productive estuaries and continental margin areas (Hammerschmidt and Fitzgerald, 2004; Mason et al., 2006; Hollweg et al., 2009, 2010) and also in offshore marine sediments (cf., Ogrinc et al., 2007). However, the extent to which MeHg production occurs in sediments and what factors (inorganic Hg bioavailability, organic carbon content, redox conditions, etc.) control sedimentary MeHg production in the Arctic Ocean are not known.

This project proposes to examine, over three years, both water column and sediment profiles of Hg and MeHg along a wide oceanographic section along Canada's Arctic margin. The section extends from the Bering Sea to the western Beaufort Sea through the Canadian Arctic Archipelago (CAA) and into Baffin Bay. This report addresses the distribution of Hg and MeHg in 25 sediment cores, which were collected along the section during the International Polar Year (2007-2008) and analyzed in 2011-2012 in laboratories at the Université du Québec (INRS) and Ifremer, France. The spatial and downcore distribution of Hg and MeHg are examined in the context of other oceanographic and sediment geochemical data toevaluate the importance of biogeochemical controls on sedimentary production of MeHg.

Activities in 2011-2012

The focus of our activities in 2011-2012 was the analysis of archived sediment samples from 25 sediment cores, which were collected along an oceanographic section spanning Canada's Arctic margin during the International Polar Year (2007-2008). All sediment samples were analyzed for Hg at INRS (Université du Québec) at no cost to NCP, and a subset of samples analyzed for MeHg at Ifremer, France. The analytical methods employed for MeHg in the sediments are based on the separation of organic mercury compounds by gas chromatography, followed by ionisation of analytes in argon plasma and Hg detection by mass spectrometry (GC-ICP-MS with isotopic dilution). Briefly, a known quantity of an internal standard ($Me^{202}Hg$) is added to an aliquot of freeze-dried sediment which is then leached with 4 mL of HNO3 (6N). After centrifugation and decantation, the pH is adjusted to 4 by adding ammonia and a sodium acetate-acetic acid buffer. MeHg is then propylated by adding sodium tetrapropylborate and the Hg compound is extracted in isooctane. The analysis of propylated Hg is performed by gas chromatography (GC) coupled to a quadrupole ICP-MS. The detection limit is around 1 pmol g^{-1}. Precision and accuracy, determined from replicate measurements (n = 6) of the CRM 405 material from IAEA, is usually better than 10%. Details are given in Feyte et al. (2010).

Additional lab analyses (e.g., ^{210}Pb, ^{137}Cs, organic carbon and nitrogen, lignin, redox-sensitive elements) and data analysis/modeling also were completed on the cores in 2011-2012 (at no cost to NCP) to establish the geochemical setting in each of the sediment cores, as a foundation from which to interpret THg and MeHg profiles. The cores were dated and modeled for mixing using ^{210}Pb and ^{137}Cs (Kuzyk et al., in review). The redox setting (oxic/anoxic conditions) of the cores has been determined using sediment Mn profiles (Macdonald and Gobeil, 2011) and we are continuing the interpretation of sediment redox cycles by focusing on other redox elements that shed light on sulfur reduction in sediments (Kuzyk et al., in preparation). Together, these redox element distributions and complementary organic carbon measurements (quantities and sources) provide a thorough understanding of the diagenetic processes that provide the basis to produce MeHg in Arctic continental margin sediments (Gobeil et al., 2010; Goñi et al., 2010; O'Connor et al., 2011).

Capacity Building
A post-doctoral research fellow (Dr. Z. Kuzyk) benefitted from training in the interpretation of the sediment core data and took up an Assistant

Professor position at the University of Manitoba in January 2012, where she is continuing to work on aspects of the Arctic Ocean's Hg cycle.

Communications

As part of communications efforts related to IPY, a summary of the research related to the sediment cores was provided to Nunavut IPY research representatives in March, 2011, for inclusion in a general regional update report. However, this report presents the first communication specifically addressing the results of the Hg and MeHg analyses. It will be followed up by publication of the results in a peer-reviewed scientific journal. A poster presenting the results will also be developed for display at the NCP Results Workshop in Inuvik.

Traditional Knowledge Integration

Because the project in 2011-2012 involved only the analysis of archived samples, there has been no opportunity for the Project Team to interact directly with Northerners, nor to incorporate traditional knowledge into the project. The intention is to use the broad distribution of results from sediment cores collected across Canada's Arctic marine system to plan further field work that would seek opportunities to engage northerners and use traditional knowledge to enhance the relevance of sampling locations and data interpretations.

Results

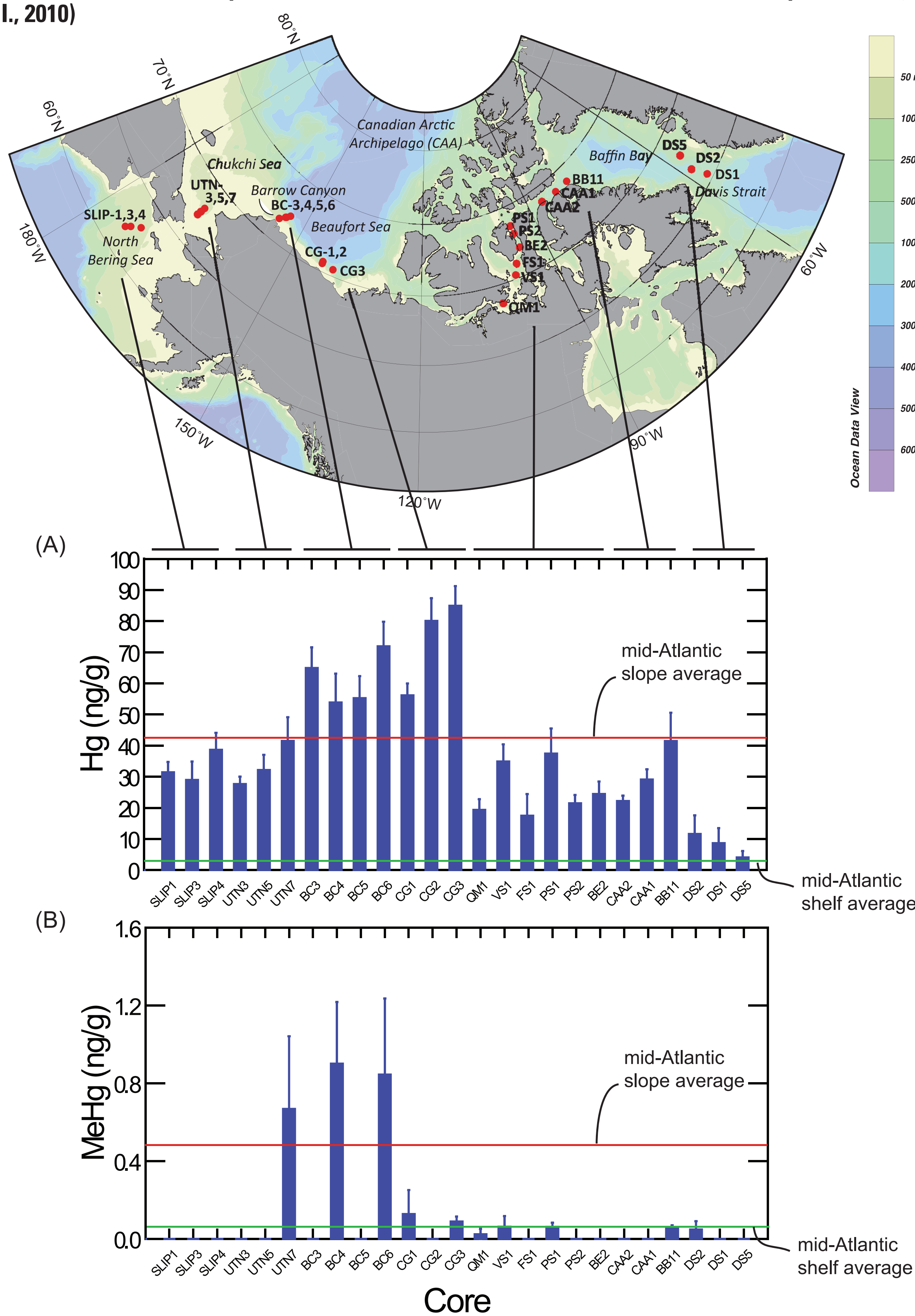
The locations and water depths of the 25 studied sediment cores are listed in Table 1 and the whole-core average Hg concentrations in the cores are shown in Figure 1. The average total Hg concentrations in the cores varied from 4.0 to 85 ng/g, with the lowest concentrations in Baffin Bay/Davis Strait (cores DS-1, 2, 5) and the highest concentrations in the Beaufort shelf/slope (CG-1, 2, 3) and Barrow Canyon in the northeast Chukchi Sea (cores BC-3, 4, 5- 6) (Figure 1A). MeHg concentrations in the sediment cores were generally ≤0.1 ng/g (Figure 1B) except for cores from the Chukchi shelf (UTN7) and Barrow Canyon in the northeast Chukchi Sea (BC4, BC6): these three cores exhibited MeHg concentrations in the order of 0.67 to 0.97 ng/g.

Vertical profiles of total Hg and MeHg concentrations in the cores are shown in Figures 2 and 3, respectively. As can be seen from these figures, total Hg generally remains reasonably constant within the core or, in many cases, increases upward to exhibit the highest concentrations at the surface (e.g., CG2, CG3; Figure 2) or just below the surface (e.g., DS1, FS1; Figure 2). The total Hg distributions strongly contrast those of MeHg, which showed no consistent vertical pattern within cores (Figure 3).

Discussion and Conclusions

The overall range of Hg concentrations measured in the Arctic margin sediment cores (3.8 to 98 ng/g) is similar to that reported for sediments from the interior Arctic Ocean (10 to 120 ng/g (Gobeil et al., 1999)), the Beaufort Shelf (1 to 130 ng/g (Macdonald and Thomas, 1991)), Hudson Bay (8 to 58 ng/g (Hare et al., 2010)) and the Greenland coast (4 to 280 ng/g (Asmund et al., 2000)). The average whole-core Hg concentrations are also compared (in Figure 1) with the reported averages for mid-Atlantic shelf and slope sediments (Hollweg et al., 2010). From this comparison, it is clear that most of the Arctic margin sediment cores have Hg concentrations similar to shelf and slope sediments elsewhere. However, the cores from the Beaufort shelf/slope (CG-1, 2, 3) and Barrow Canyon in the northeast Chukchi Sea (cores BC-3, 4, 5- 6) have high Hg concentrations, both in comparison to other Arctic sediments, and in comparison to mid-Atlantic sediments (Figure 1A). The average concentrations in these cores significantly exceed the average for sediments from the mid-Atlantic continental shelf and slope (Hollweg et al., 2010). This finding that the northeast Chukchi and Beaufort Sea sediments have unusually high Hg concentrations compared to other regions along the Arctic margin is striking in view of previous reports that Hg levels tended to be higher in food webs of the western Canadian Arctic compared to the eastern Canadian Arctic and continue to be unusually high in the Mackenzie Delta (Lockhart et al., 2005). It is an intriguing possibility that the spatial variation in Hg in sediments along the

Figure 1. Whole-core average concentrations of (A) total Hg and (B) MeHg. Horizontal lines show average concentrations reported for sediments from the mid-Atlantic shelf and slope (Hollweg et al., 2010)



Arctic margin could either reflect the generally higher Hg concentrations and exposure in this region or, perhaps, provide a pathway *supporting* higher Hg exposure, and thus cause, in part, the variation observed in zooplankton and beluga Hg levels in the Western Arctic Ocean (Loseto et al., 2008a; Loseto et al., 2008b; Stern and Macdonald, 2005).

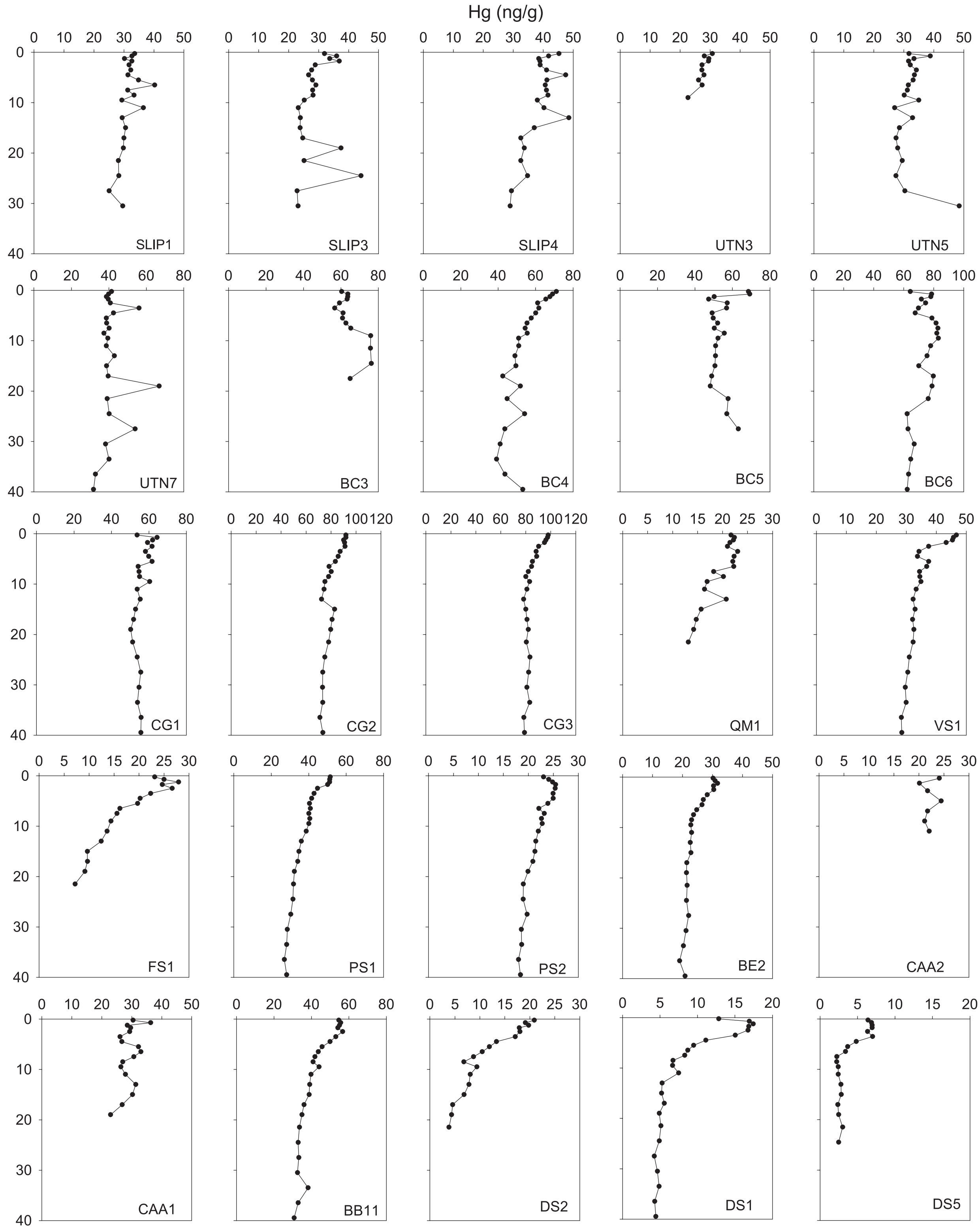
We are further investigating the reasons for the regional variability in sedimentary OC-Hg loadings by examining inter-relationships between Hg concentrations and indicators of organic matter composition (C/N ratios, $\delta^{13}C$). Hollweg et al. (2010) reported recently that OC-normalized Hg loadings decreased with distance from shore in the mid-Atlantic continental shelf and slope, possibly due to the changing character of organic matter along this gradient, and that this gradient affected Hg sediment:water partitioning and thus bioavailability for the production of MeHg.

One of the factors underlying the spatial trends in total Hg concentrations is variation in the sediment organic carbon content (%OC). Hg concentrations both within and among cores shows a strong, positive relationship with %OC (Figure 4). Thus, the high Hg concentrations in the northeast Chukchi Sea (Barrow Canyon) cores relates, in part, to the high %OC content of these cores (on average ≥1.4%). Likewise, the low Hg concentrations in Baffin Bay/Davis Strait relate, in part, to the low %OC (<0.5%) in cores DS-1, 2, 5.

However, the specific OC-Hg relationships vary from core to core (Figure 4) implying differences in the specific 'loading' of Hg per unit OC among sites. The steepest Hg-OC relationships, reflecting larger Hg loadings per unit of OC, occur among cores from the Beaufort shelf/slope (CG-1, 2, 3). The shallowest OC-Hg relationships, reflecting lower Hg loadings per unit of OC, occur among cores from the Chukchi shelf (UTN7) and Lancaster Sound (CAA1). The spatial variation in Hg loadings is illustrated in Figure 5 by expressing the Hg concentrations as OC-normalized concentrations (i.e., mg Hg/g OC). In general, large Hg loadings (per unit of sedimentary OC) occur in the Beaufort shelf/slope and Barrow Canyon areas, as well as some sites in the Canadian Arctic Archipelago (CAA), while lower Hg-OC loadings occur in the far western and eastern portions of the study area. The reasons for these regional differences in sedimentary OC-Hg loadings presently are being investigated by examining inter-relationships between Hg concentrations and indicators of organic matter composition and/or source (C/N ratios, $\delta^{13}C$). Hollweg et al. (2010) reported recently that OC-normalized Hg loadings decreased with distance from shore in the mid-Atlantic continental shelf and slope, possibly due to the changing character of organic matter along this gradient. We will test whether this factor (organic matter composition) is also important in determining sedimentary OC-Hg relationships along the Arctic margin and, if so, how this may affect Hg sediment:water partitioning and thus bioavailability for the production of MeHg.

The differences in the vertical profiles of Hg and MeHg in the cores (compare Figures 2 and 3) are intriguing and point to very different factors controlling their accumulation in the sediments. One hypothesis to explain the upward increases in total Hg concentration in the cores (Figure 1) is enhanced Hg deposition to sediments due to increases in atmospheric Hg emissions during the last ~130 years. It is possible that the sediment core Hg profiles reflect this emission history because the last ~130 years of sediment accumulation comprises the upper 6 to 30 cm across the sediment cores, depending on their individual sediment accumulation rates (Kuzyk et al., submitted). However, further investigation will be required to confirm this hypothesis because vertical gradients in marine sediment cores alternatively may be caused by natural changes in the oceanic or sedimentary environment (such as changes in organic matter composition or dynamics) (cf., Hare et al., 2010). Modeling of the sedimentation process within the cores, based on 210Pb and 137Cs profiles, will also be required to confirm the timing of the onset of Hg increases in each core and/or plausible deposition histories for Hg increases over background values.

Figure 2. Vertical profiles of Hg in the 25 sediment cores. The cores are ordered from west to east along Canada's Arctic margin.



In contrast to total Hg, the MeHg profiles are highly variable and tend towards subsurface rather than surface peaks (Figure 3). These profiles cannot simply be assigned to deposition history given that MeHg may be produced or destroyed within the sediment. There are also no clear relationships between MeHg concentrations and sedimentary OC content among the Arctic margin cores, other than the distinction that all cores with high MeHg concentrations contained at least 1% OC (Figure 6). However, not all cores with >1% OC contained elevated MeHg concentrations (e.g., BB11). The implication is that a minimum amount of OC is critical to create conditions under which MeHg production can occur, but that OC content alone is not sufficient. Examining relationships between MeHg and specific types of organic matter (as determined from various proxies) may make the OC-MeHg relationships more clear. The absence of any obvious relationship between total Hg and MeHg (e.g., compare the spatial patterns of average whole-core Hg and MeHg concentrations in Figure 1) underscores the importance of not using total Hg concentrations in sediments as an indicator of risk from, or bioavailability of, sedimentary Hg. The redox conditions in the sediments, which vary considerably along the Arctic margin (Macdonald and Gobeil, 2012; Kuzyk et al., in prep.), appear to provide a crucial factor in MeHg production (cf., Hollweg et al., 2009, 2010). Work is ongoing to compare the profiles of MeHg, OC, C/N and reduced sulfur species and Fe oxides within each core.

Expected Project Completion Date

Further data interpretation toward a publication in the peer-reviewed literature is underway and should be completed in late 2012/early 2013. Subsequent stages of the larger project, including specifically collecting new water-column Hg and MeHg data along Canada's Arctic margin, are presently uncertain because of the logistical challenges in securing ship-time appropriate for collecting uncontaminated samples along relevant sections. It is hoped that new Hg and MeHg water column data will be collected along the Arctic Ocean margin through this or other programs. Results from such sections together with the results of the sediment work would provide the basis to address the project's long-term objective of improving our understanding of the linkages between mercury sources and pathways of mercury methylation in both the water column and sediments, and the roles these pathways play in the relatively high levels in Arctic marine food webs. This synthesis would provide a basis for predicting at least qualitatively how the system may respond to changing Hg emission scenarios and a changing climate. Finally, the ensuing database could be used collectively to determine a MeHg budget for the Arctic Ocean.

NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)		
number of project-related meetings/workshops held in the North (April 1, 2011 – March 31, 2012)		
number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	1	Post-doctoral fellow
number of citable publications (e.g., in domestic/ international journals, conference presentations, book chapters, etc)	2011: 1 (M&G, 2011) 2012: 1 (K et al., submitted)	One manuscript containing geochemical characterizations of the cores is published and a second is submitted for publication

Figure 3. Vertical profiles of MeHg in sediment cores

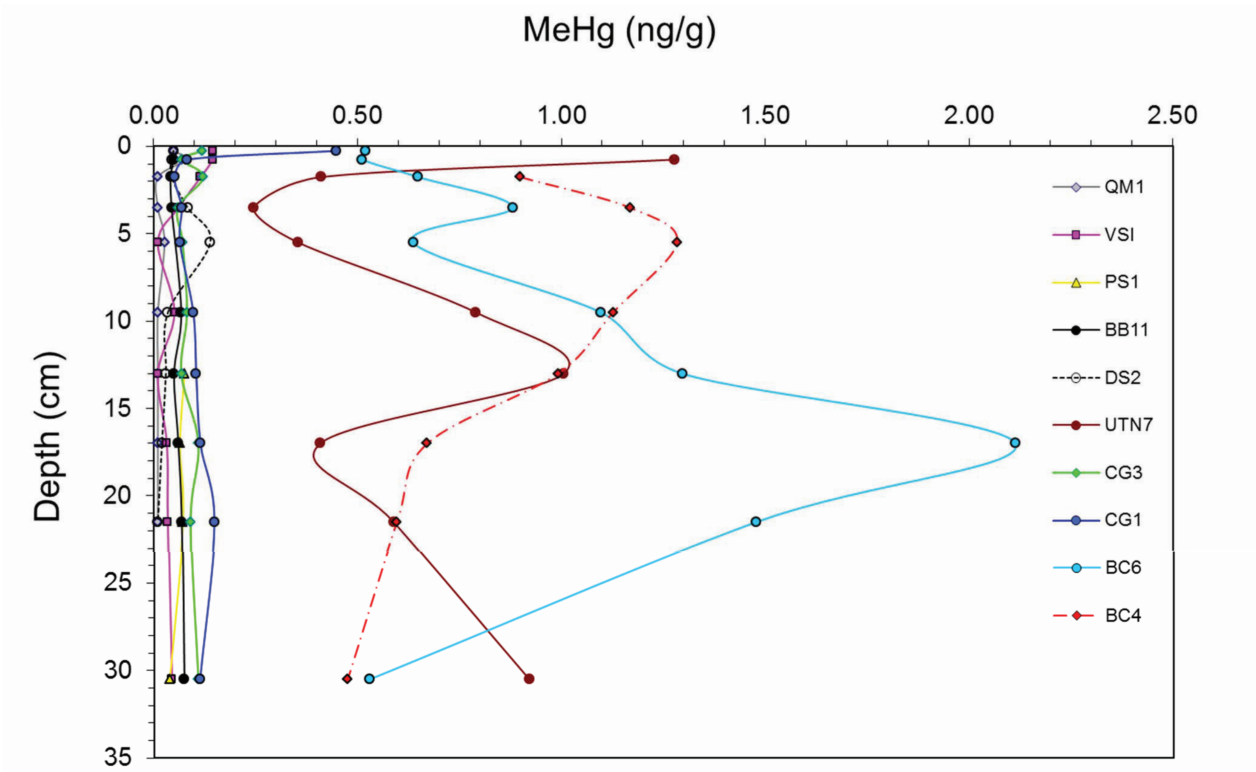


Figure 4. Relationship between Hg concentrations and sediment organic carbon content (%OC)

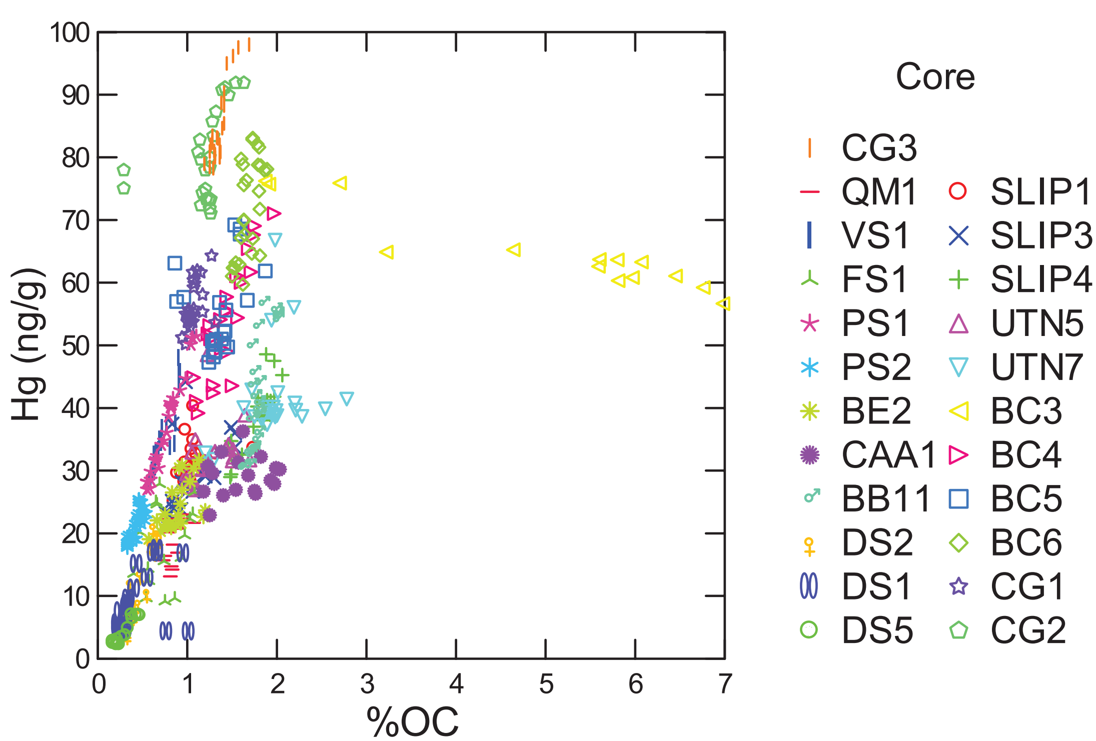


Figure 5. Organic carbon (OC)-normalized Hg concentrations in the cores (whole-core avrages).

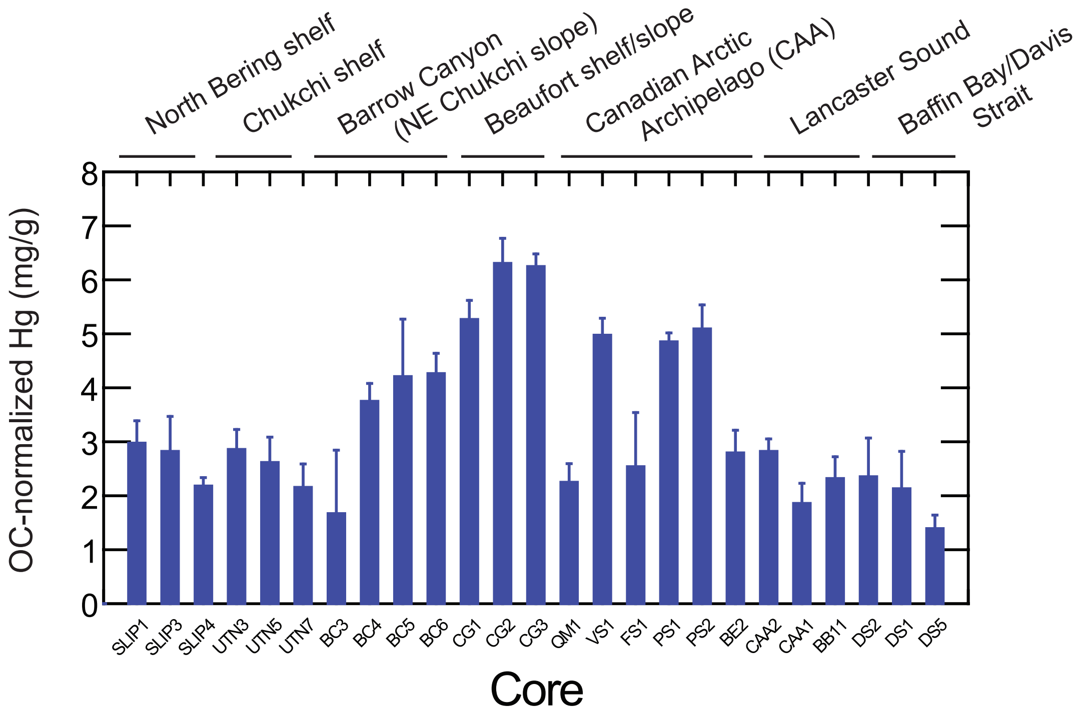
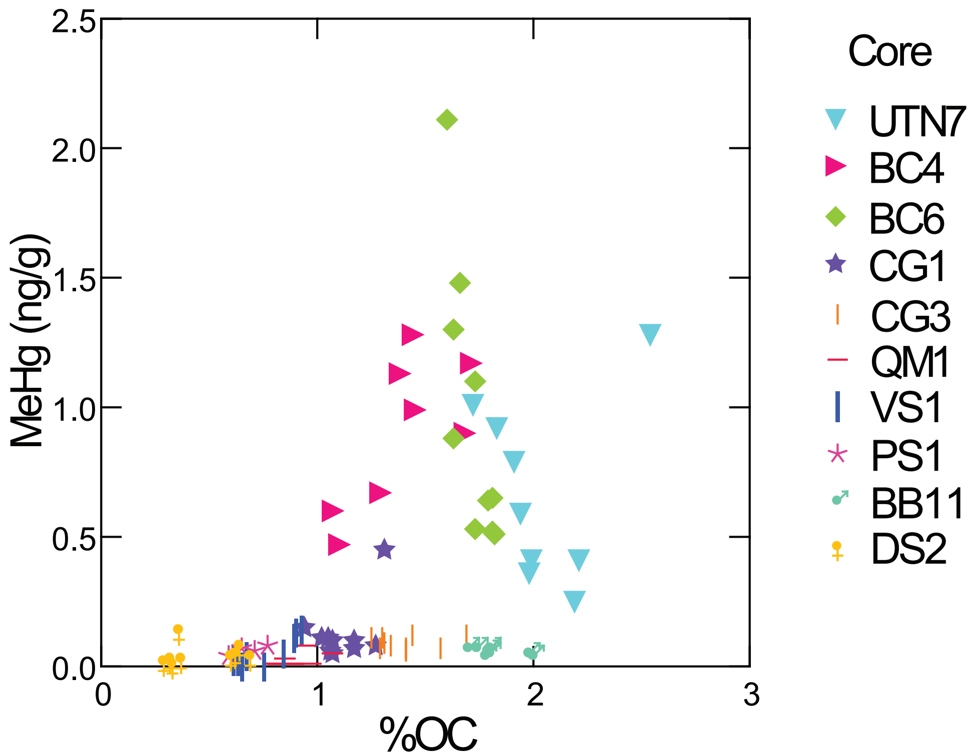


Figure 6. MeHg concentrations vs. %OC.



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Methylmercury Speciation at Different Trophic Levels in the Beaufort Sea Arctic Marine Ecosystem

Spéciation du méthylmercure à différents niveaux trophiques dans l'écosystème marin Arctique de la mer de Beaufort

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Abstract

Monitoring data have shown that the mercury concentrations in marine mammals from the Canadian Arctic Ocean have remained very high in recent decades. Toward a better understanding of how Arctic top predators cope with high levels of mercury and its toxicological implications, we report here on the molecular forms of mercury, especially methylmercury, in the tissue samples of beluga whales (muktuk, muscle, brain, liver and kidneys), the Pacific herring (muscle), the Arctic flounder (muscle) and zooplankton (bulk) collected in 2008 from the Beaufort Sea region. Speciation analysis was also done for selenium, which is known to have an antagonistic effect on mercury toxicity. In all the samples analyzed, methylmercury was found to be dominated by methylmercuric cysteinate, a specific form of methylmercury believed to be able to transport across the blood-brain barrier.

Résumé

Les données de surveillance montrent que les concentrations de mercure chez les mammifères marins de l'océan Arctique canadien sont restées très élevées au cours des dernières décennies. Afin de mieux comprendre les effets des concentrations élevées de mercure sur les prédateurs arctiques de niveau trophique supérieur et les répercussions de ces concentrations sur le plan toxicologique, nous présentons ici les formes moléculaires du mercure, particulièrement le méthylmercure, détectées dans les échantillons de tissus de bélugas (muktuk, muscles, cerveau, foie et reins), de harengs du Pacifique (muscles), de plies arctiques (muscles) et de zooplancton (entier) prélevés en 2008 dans la région de la mer de Beaufort. L'analyse de la spéciation a aussi été effectuée pour le sélénium, dont on sait qu'il a un effet antagoniste sur la toxicité

An inorganic mercury-selenium complex was also detected in the liver and brain tissues of belugas, though its molecular structure remains to be identified. Furthermore, the percentage of methylmercury in total mercury in all the tissue samples was found to decrease exponentially with an increasing ratio of oxidized selenium to reduced selenium, suggesting that in vivo demethylation of methylmercury may be accompanied by oxidative degradation of reduced organoselenium such as selenomethionine. While this may have protected the animals from the toxicity of mercury and methylmercury, it could make the animals more susceptible to oxidative damage as organoselenium is an important and essential antioxidant. Such oxidative damage is most likely to occur in the beluga liver, kidneys and brain where a considerable amount of methylmercury demethylates. Future epidemiological studies on beluga whales need to examine symptoms of oxidative damage due to methylmercury demethylation-induced deficiency in organoselenium.

du mercure. Dans tous les échantillons analysés, le méthylmercure était dominé par le cystéinate de méthylmercure, une forme précise de méthylmercure que l'on croit capable de traverser la barrière hématoencéphalique. Un complexe inorganique mercuresélénium a aussi été détecté dans les tissus cérébral et hépatique de bélugas, mais sa structure moléculaire n'a pas encore été identifiée. De plus, nous avons constaté que le pourcentage de méthylmercure dans le mercure total dans tous les échantillons de tissus diminue de façon exponentielle à mesure qu'augmente le rapport sélénium oxydésélénium réduit, laissant supposer que la déméthylation in vivo du méthylmercure pourrait être accompagnée de la dégradation oxydative de l'organosélénium réduit, comme la sélénométhionine. Même si cela pourrait avoir protégé les animaux de la toxicité du mercure et du méthylmercure, cela pourrait aussi les rendre plus vulnérables aux dommages oxydatifs, étant donné que l'organosélénium est un antioxydant important et essentiel. Il est plus probable que de tels dommages oxydatifs se produisent dans le foie, les reins et le cerveau des bélugas, où une importante quantité de méthylmercure se déméthyle. Dans le cadre d'études épidémiologiques futures sur les bélugas, il faudrait examiner les symptômes de dommages oxydatifs dus à la déficience en organosélénium induite par la déméthylation du méthylmercure.

Keys Messages

- Methylmercury is presented in the Arctic marine animals predominately in the form of methylmercuric cysteinate which can cross the blood-brain barrier;
- Arctic marine animals can detoxify methylmercury in vivo by a mechanism involving organoselenium;
- Methylmercury demethylation in belugas occurs primarily in the liver, kidneys and brain, and can thus result in deficiency in organoselenium in these tissues;
- The toxicity of methylmercury in top predators is more likely due to its induced

Messages clés

- Le méthylmercure est présent chez les animaux marins de l'Arctique, principalement sous la forme de cystéinate de méthylmecure, ce dernier pouvant traverser la barrière hématoencéphalique;
- Les animaux marins de l'Arctique peuvent éliminer le méthylmercure in vivo grâce à un mécanisme impliquant l'organosélénium;
- La déméthylation du méthylmercure chez les bélugas se produit principalement dans le foie, les reins et le cerveau, et peut donc entraîner une déficience en organosélénium dans ces tissus;

deficiency in organoselenium, making the animals more susceptible to oxidative damage.

- La toxicité du méthylmercure chez les prédateurs de niveau trophique supérieur est plus probablement attribuable à la déficience en organosélénium qu'il induit, rendant les animaux plus sensibles aux dommages oxydatifs.

Objectives

Our long-term goal is to develop a molecular-level understanding of the uptake pathway, transformation, toxicity and detoxification of methylmercury in the Arctic marine ecosystem. The specific objectives of this project are to:

- identify and quantify chemical forms of methylmercury and selenium in various tissues of animals at different trophic levels from the Beaufort Sea Arctic marine ecosystem; and,

- elucidate possible mechanisms involved in methylmercury detoxification in beluga whales.

Introduction

Mercury is a global contaminant and has been found to be present at very high concentrations in marine mammals (e.g., beluga whales, seals, and polar bears) in the Canadian Arctic Ocean (AMAP 2011). Of particular concern in these animals are the high levels of methylmercury, an organic form of mercury that is a known developmental neurotoxin (Grandjean and Landrigan 2006), raising concerns over the health of these animals and Northerners who consume tissues of these animals as part of their traditional diet (AMAP 2009). One major mystery is, however, the lack of evidence showing direct adverse effects of such high levels of methylmercury in Arctic marine mammals. While this may be simply due to a lack of extensive epidemiological studies on these animals, it may also suggest the presence of detoxification mechanisms in these animals.

Although most monitoring data for mercury in Arctic marine mammals distinguish between different chemical and toxicological behaviors of inorganic mercury and methylmercury (AMAP 2011), none have addressed the fact that methylmercury is not a single chemical species; instead, it includes CH_3Hg^+ complexes with various ligands that are known to possess markedly different mobility and biochemical reactivity. For instance, methylmercury preferentially binds to sulfur- and seleno-containing biomolecules in biological systems (Wang et al. 2012). Whereas binding with cysteine is thought to be primarily responsible for methylmercury transport across the blood-brain barrier (Aschner et al. 1992), binding with selenium-compounds is known to detoxify methylmercury (Khan and Wang 2010; Wang et al. 2012).

Therefore, molecular level information on in vivo methylmercury distribution and metabolism is critically needed for the understanding of how Arctic marine mammals cope with mercury contamination and for the development of remediation strategies. With our recent development of a highly sensitive, high performance liquid chromatography-inductively coupled plasma mass spectrometry (HPLC-ICP-MS) technique for methylmercury speciation (Lemes and Wang 2009), here we report the distribution of various methylmercury species, as well as selenium, in animals at different trophic levels in the Beaufort Sea region.

Activities in 2011-2012

Sampling and Analysis. Tissue samples of beluga whales (*Delphinapterus Leucas*; muscle, muktuk, liver, kidneys, brain - temporal lobe), Pacific herring (*Clupea pallasii*; muscle), Arctic flounder *(Liopsetta glacialis;* muscle*)*, and zooplankton (<500µm bulk, primarily the copepods) were retrieved from the DFO archive freezers at Freshwater Institute in Winnipeg. The beluga tissues (from 10 individuals) were collected from whales harvested in 2008 by local Inuit hunters at Hendrickson Island, Northwest Territories. The herring, flounder (n=3 each) and zooplankton (n=3) samples were collected in 2008 from the Beaufort Sea area as part of ArcticNet.

Total mercury (Hg_T) concentrations in the beluga tissue samples were analyzed by cold vapor atomic fluorescence spectroscopy on a Tekran 2600 Hg analyzer after closed-vessel microwave digestion. The analysis was done at PI Wang's Ultra-Clean Trace Elements Laboratory (UCTEL) at the University of Manitoba following U.S. Environmental Protection Agency Method 1631 (U.S.EPA 2002). The certified reference material (CRM) DOLT-3 (dogfish liver; National Research Council (NRC), Canada) was used for quality assurance/quality control.

Determination of total methylmercury ($MeHg_T$) was carried out at co-PI Stern's laboratory at DFO-Winnipeg. The freeze-dried samples were extracted into toluene as methylmercury bromide, partitioned into aqueous ethanol as a thiosulfate complex and re-extracted into benzene as methylmercury iodide, and then analyzed by gas chromatography - electron capture detector (GC-ECD) (Uthe et al. 1972). QA/QC was done through the analysis of CRMs TORT-2 (lobster hepatopancreas) and DORT-2 (dogfish liver; NRC, Canada).

Determination of methylmercury speciation in the tissue samples was done at UCTEL following our recently developed methods (Hu et al. 2009; Lemes and Wang 2009). In brief, freeze dried tissue was enzymatically extracted with trypsin in the dark at pH 8 and 37 ºC. The filtered and diluted extractant was analyzed for methylmercury and selenium speciation using reverse-phase (Lemes and Wang 2009) and anion-exchange (Hu et al. 2009) HPLC-ICP-MS. The former method separates methylmercuric cysteinate ($CH_3HgSCys$), methylmercuric glutathionate (CH_3HgSG), methylmercury complexes with simple inorganic ligands (CH_3HgX; X=H_2O, OH-, Cl-), and the inorganic Hg(II) species, HgX. The latter method resolves inorganic selenite Se(IV), selenate Se(VI)), and organic selenomethionine (SeMet), methylselenocysteine (CH3SeCys), and selenocystine (CysSeSeCys). Since no CRM is currently available for methylmercury speciation analysis, the QA/QC was done by 1) monitoring the difference between the sum of all methylmercury species determined by the speciation technique and the $MeHg_T$ concentration independently analyzed by GC-ECD in Stern's laboratory; and 2) monitoring the enzymatic digestion efficiency by analyzing $MeHg_T$ from enzymatically extracted CRM DOLT-3.

Capacity Building and Training. Capacity building and training of this primarily analytical project has been carried out as part of our ongoing studies under ArcticNet and FJMC. All the beluga samples used in this study were collected by community residents and in cooperation with local Hunters and Trappers Associations and Organizations. Sampling plans and remuneration were worked out through agreements between the DFO and the Inuvialuit Settlement Region.

Communications. The communications of this project were carried out via five major venues:

- In January 2011, co-PI Stern attended the NWT International Polar Year (IPY) Results Conference in Inuvik.
- Breanne Reinfort's ongoing community-embedded project "Sachs Harbour Inuvialuit Perceptions of Environmental Contaminants and Communication Processes": Details about her project can be found in the 2009-10 NCP Synopsis report "Reinfort, Stern, and Wang, Arctic contaminants: Exploring effective and appropriate communication between Inuvialuit communities and researchers, 331-338", as well as in her upcoming thesis.
- Rebecca Pokiak's ongoing communication project: Details can be found in the 2009-10 NCP Synopsis report "Pokiak, Loseto, and Loring, Beluga communication package for Inuvialuit Settlement Region (ISR), 339-343".

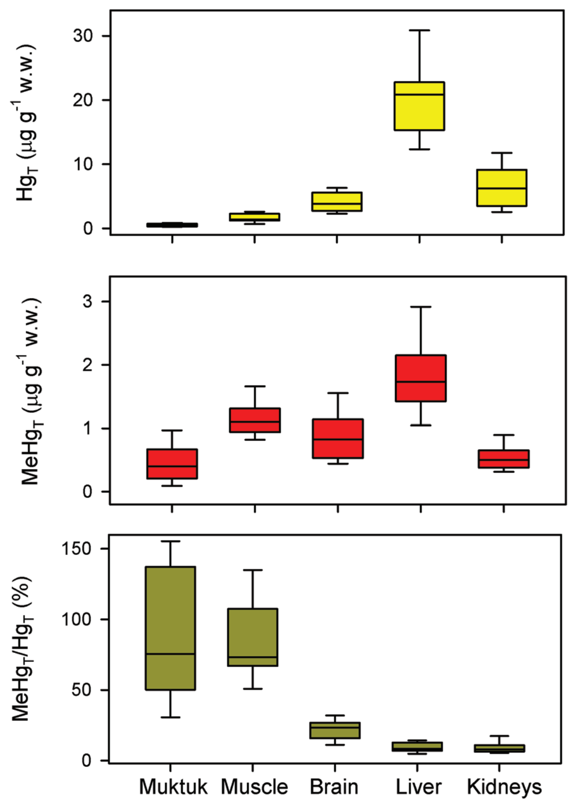
- Conferences: The results were presented at the IPY 2012 Conference (April 2012, Montreal), and will be presented at the upcoming annual symposium of NCP.
- Peer-reviewed journal publication: One paper has been published (Lemes M., Wang F., Stern G.A., Ostertag S., and Chan H.M. 2011. Methylmercury and selenium speciation in different tissues of beluga whales *(Delphinapterus leucas)* from the Western Canadian Arctic. Environ. Toxicol. Chem., 30, 2732-2738). A second manuscript is in preparation.

Traditional Knowledge Integration. The incorporation of Traditional Knowledge is part of our ongoing "Two Ways of Knowing" with the communities. Although this project is primarily analytical in nature, we have had many opportunities, primarily through Breanne Reinfort's extended stay in the Sachs Harbor community, to learn from the local people about their observations, ideas, and concerns. The beluga samples retrieved from the DFO archives were directly collected by the local hunters who shared with us their knowledge about the movement and behavior patterns of the animals.

Results

Mercury and Selenium in Beluga tissues: The Hg_T, $MeHg_T$, and methylmercury and selenium speciation results for the beluga tissues are summarized in Table 1 and Figures 1-3. Unless otherwise stated, all the concentrations reported are expressed on the basis of wet weight. Typical HPLC-ICP-MS chromatograms of the beluga tissue digestants are shown in Figures 2 and 3. The concentration of Hg_T varied greatly from 0.23 to 0.86 µg g^{-1} in the muktuk, 0.66 to 2.66 µg g^{-1} in the muscle, 2.32 to 6.35 µg g^{-1} in the brain (temporal lobe), 2.45 to 11.9 µg g^{-1} in the kidneys, and 12.2 to 31.6 µg g^{-1} in the liver. The values in the liver, kidneys and muscle and their relative abundance (i.e., liver > kidneys > muscle > muktuk; Figure 1) are comparable to those previously reported for beluga whales from the same region (Lockhart et al., 2005; Wagemann and Kozlowska 2005; Wagemann et al. 1998).

Figure 1. Box plots showing the distribution of Hg_T, $MeHg_T$, and the percentage of $MeHg_T$ in Hg_T in beluga tissues. The lower boundary of the box indicates the 25th percentile; the line within the box marks the median; the upper boundary indicates the 75th percentile. The error bars indicate the 90th and 10th percentiles.



Although the Hg_T concentration varied over more than one order of magnitude in different beluga tissues, the tissue $MeHg_T$ concentration varied to a lesser extent: 0.08 to 0.99 µg g^{-1} in the muktuk, 0.79 to 1.72 µg g^{-1} in the muscle, 0.39 to 1.11 µg g^{-1} in the brain, 1.03 to 2.92 µg g^{-1} in the liver, and 0.34 to 0.90 µg g^{-1} in the kidneys (Figure 1). The ratio of $MeHg_T$ to Hg_T is the highest in the muktuk (90.7 ± 46.9%) and muscle (84.0 ± 28.8%), followed by the brain (22.0 ± 6.8 %), liver (9.5 ± 3.4%), and kidneys (9.0 ± 3.8%). While the $MeHg_T$ concentration and $MeHg_T/Hg_T$ ratio in the muscle and liver are in good agreement with those from beluga collected in the early to mid-1990s (Wagemann et al. 1998), the $MeHg_T/Hg_T$

Table 1. Total Hg (Hg_T), total MeHg ($MeHg_T$), percentage of $MeHg_T$ in Hg_T, and dominant species of MeHg and selenium in beluga whales, fish and zooplankton from the Beaufort Sea (mean ± standard deviation)

	Hg_T µg g^{-1} (ww)	$MeHg_T$ µg g^{-1} (ww)	$MeHg_T/Hg_T$ (%)	Dominant MeHg species	Dominant Se species
Beluga (n=10)					
Muktuk	0.50 ± 0.05	0.45 ± 0.28	90.7	CH_3HgSCys	SeMet
Muscle	1.54 ± 0.67	1.16 ± 0.27	84.0	CH_3HgSCys	CH_3SeCys
Brain	4.13 ± 1.48	0.88 ± 0.37	22.0	CH_3HgSCys	CH_3SeCys; Se(IV)
Kidneys	6.67 ± 3.14	0.53 ± 0.20	9.0	CH_3HgSCys	CH_3SeCys
Liver	20.20 ± 5.60	1.83 ± 0.63	9.5	CH_3HgSCys	Se(IV)
Fish muscle					
Flounder (n=3)	0.43 ± 0.04	n.d.	n.d.	CH_3HgSCys	n.d.
Pacific herring (n=3)	0.20 ± 0.02	n.d.	n.d.	CH_3HgSCys	SeMet
Zooplankton					
Bulk (n=3)	0.03 ± 0.01	n.d.	n.d.	n.d.	CH_3SeCys; Se(VI)

n.d.: not determined

ratio in the brain of belugas is much lower than that reported to occur in pilot whales (Meador et al. 1993) and polar bears (Basu et al. 2009).

As shown in Table 1 and Figure 2, essentially all of the methylmercury (>97%) was present as CH_3HgSCys in all the tissues except for the muscle where a considerable fraction (up to 44%) was present as CH_3HgSG. CH_3HgSG was also detected in some brain and liver samples, though at much lower concentrations. While neither CH_3HgX nor HgX were detectable in the beluga tissues analyzed, three unknown peaks were observed: U1 in all the tissues, U2 in the kidneys and U3 in the muktuk samples. All these three unknown peaks were eluted before CH_3HgSCys. Identification and quantitation of U1, U2 and U3 were not possible due to the high noise-to-signal ratios.

Several selenium species were also identified in the beluga tissues (Figure 3): SeMet, CH_3SeCys, and inorganic Se(IV). Se(VI) and CysSeSeCys did not appear to be present. The highest concentration of selenium was found in the liver and was present predominantly as Se(IV). Se(IV) was also the most prevalent Se species measured in the brain and kidneys, while in the muscle SeMet and CH_3SeCys predominated. Two unknown Se species, U4 and U5, were also present in all the tissue samples analyzed (Figure 2). Since the retention time of inorganic Se(VI) is much longer (Hu et al. 2009), both peaks must be due to organoseleno species.

Methylmercury and Selenium in Fish muscles: Methylmercury speciation in the muscle of the Pacific herring and Arctic flounder was dominated by CH_3HgSCys (Table 1). Selenium in the muscle of the Pacific herring was dominated by SeMet. Due to its low concentrations, selenium speciation in the muscle of the Arctic flounder could not be analyzed.

Methylmercury and Selenium in Zooplankton: Due to its low concentrations, methylmercury speciation in the bulk zooplankton could not be analyzed. Selenium in the bulk zooplankton sample was found to be dominated by CH_3SeCys and Se(VI).

Figure 2. Reverse-phase HPLC-ICP-MS chromatograms showing the peaks of Hg (in red) and Se (in blue) species in beluga tissues (HI-08-11) from the Western Canadian Arctic. U1, U2 and U3 denote three unidentified Hg peaks. cps = counts per second. Note that the muktuk sample was analyzed on a different day which gives the difference in retention times.

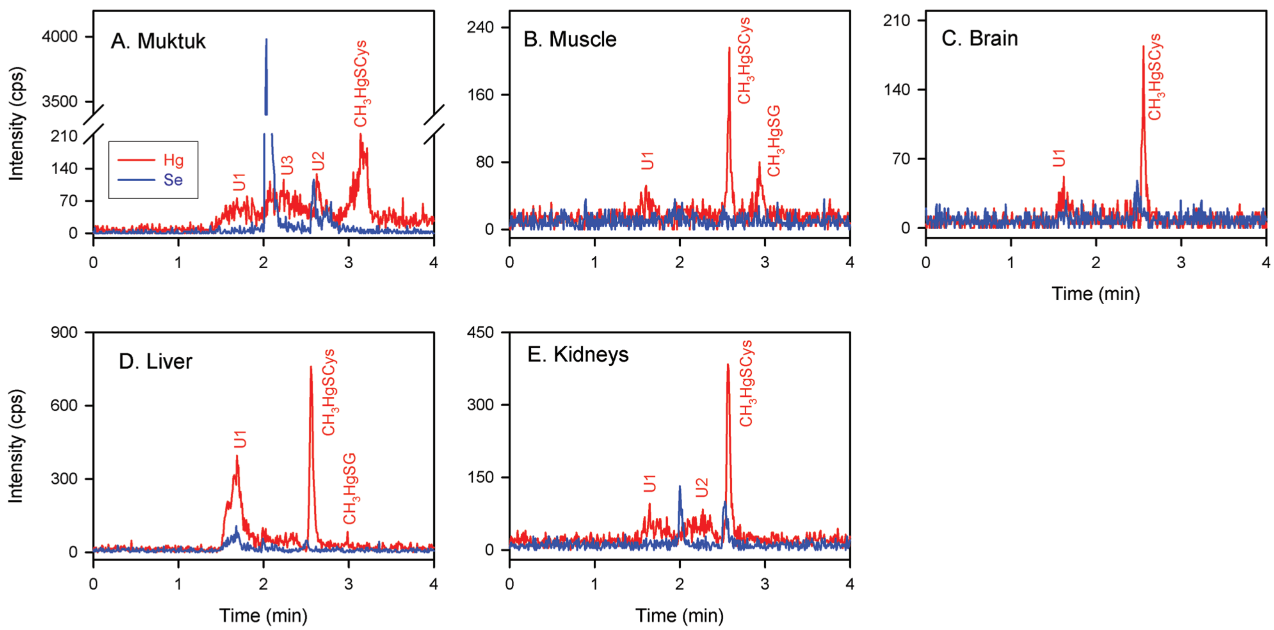


Figure 3. Anion exchange HPLC-ICP-MS chromatograms showing the peaks of Hg (in red) and Se (in blue) species in beluga tissues (HI-08-11) from the Western Canadian Arctic. U4 and U5 denote two unidentified Se peaks. cps = counts per second. Note that the muktuk sample was analyzed on a different day which gives the difference in retention times.

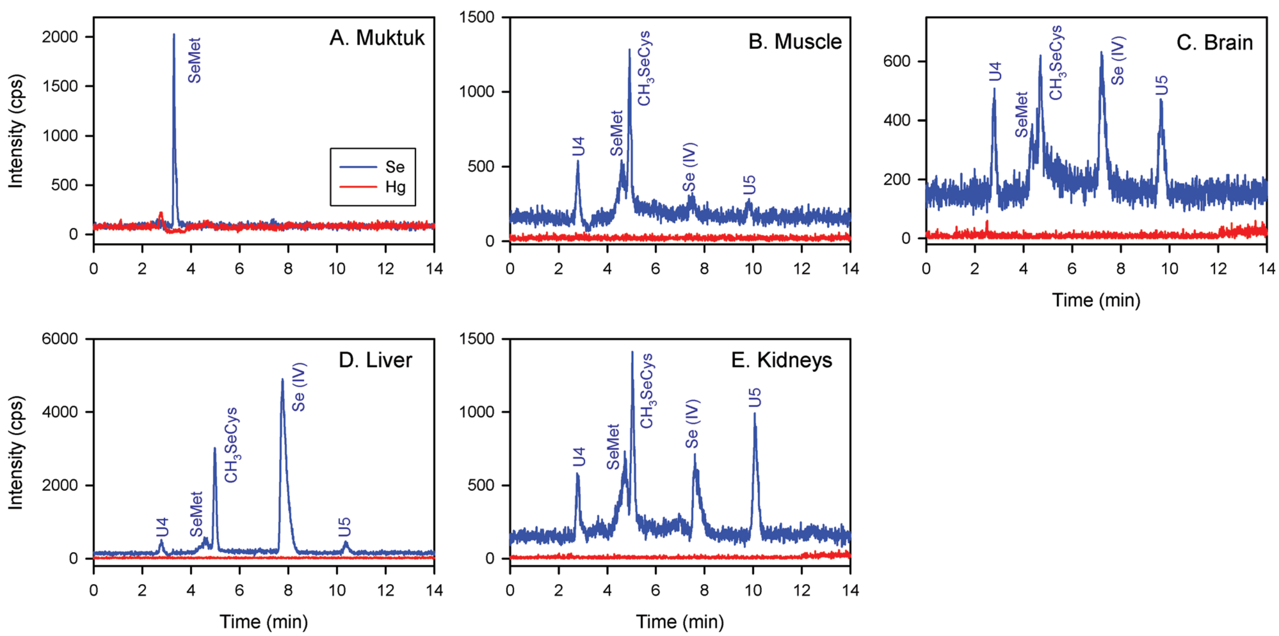
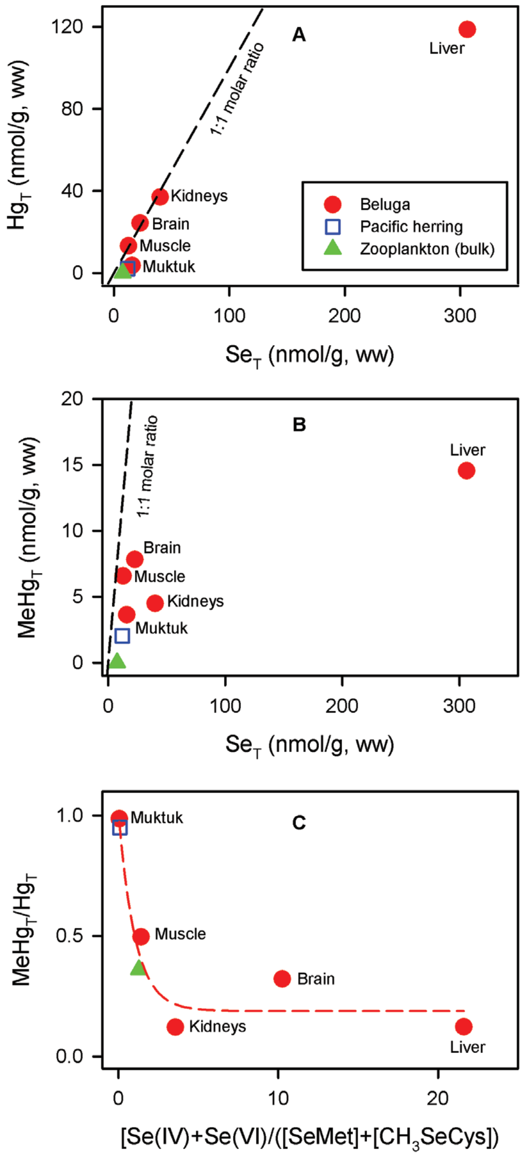


Figure 4. Relationship between mercury and selenium speciation in the Beaufort Sea marine ecosystem.



Discussion and Conclusions

The dominance of methylmercuric cysteinate in methylmercury speciation in all the beluga tissues and in muscle of the Pacific herring and Arctic flounder is consistent with our earlier studies on fish muscle (Lemes and Wang 2009) and rice grains (Li et al. 2010), suggesting free cysteine and cysteine moieties of proteins are the primary binding sites of methylmercury.

The observation that no mercury peak was detected along the selenium peaks in the selenium speciation method (Figure 3) suggests that mercury or methylmercury was not present as a complex of the identified Se species, such as SeMet, CH_3SeCys, or inorganic Se (IV or VI). However, two sets of mercury and selenium peaks overlapped in the methylmercury speciation method (Figure 2). One set of these peaks overlaps at a retention time of 2.5 min. The mercury peak is attributed to $CH_3HgSCys$ (Lemes and Wang 2009), but the overlapping selenium peak cannot be assigned to its selenium analog, methylmercuric selenocysteinate ($CH_3HgSeCys$), because its retention time (3.1 min) is significantly different from that of $CH_3HgSCys$. The second set of the overlapping peaks (U1), which are particular abundant in the brain and liver, appears at a retention time of ~1.7 min. A comparison of retention times with known mercury and methylmercury standards suggests that U1 could be due to inorganic mercury-selenium complexes such as $Hg(SeCys)_2$. Although we cannot conclude on the identity of U1, given the strong binding affinity between mercury and selenium, it is highly probable that U1 is less reactive and bioavailable and therefore could reduce the toxicity of mercury.

The role of selenium in mercury detoxification is further supported by the relationship between dominant mercury and selenium species in the Arctic marine ecosystem (Table 1 and Figure 4). There is a generally positive co-variation between Hg_T and Se_T (Figure 4A) and between $MeHg_T$ and Se_T (Figure 4B) in various tissues of belugas, which is in agreement with earlier literature studies (Lockhart et al. 2005; Wagemann et al. 1998), though the correlation may have been biased by the very high Se_T in the beluga liver. What is remarkable, however, is an apparent, exponential relationship between the ratio $MeHg_T/Hg_T$ and the ratio of inorganic, oxidized Se (Se(IV) + Se(VI)) to reduced organoselenium species (SeMet + CH_3SeCys) ($r^2 = 0.94$) (Figure 4C). This relationship applies not only to the beluga whales, but also to the Pacific herring and zooplankton. One plausible explanation for this relationship would be the in vivo mercury demethylation in beluga may be accompanied by oxidation of reduced selenium species such as SeMet and CH_3SeCys, which has

NCP Performance Indicators

Performance Indicator	Number	Details / Description
Number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	20	Breanne Reinfort's community visit to Sachs Harbour
Number of project-related meetings/ workshops held in the North (April 1, 2011 – March 31, 2012)	0	
Number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	2	Dr. Marcos Lemes, PDF Ms. Sonja Ostertag, Ph.D. student
Number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	2	– Lemes M., Wang F., Stern G.A., Ostertag S., and Chan H.M. 2011. Methylmercury and selenium speciation in different tissues of beluga whales (Delphinapterus leucas) from the Western Canadian Arctic. Environ. Toxicol. Chem., 30, 2732-2738; – Lemes M., Wang F., Stern G., Ostertag S., Chan C. 2012. Methylmercury and selenium speciation in different tissues of beluga whales (Delphinapterus leucas) from the Western Canadian Arctic. International Polar Year 2012 Conference. Montreal, April 22-27, 2012.

been demonstrated by our recent *in vitro* study (Khan and Wang 2010).

In conclusion, the finding that methylmercury in the Arctic marine animals is dominated by methylmercuric cysteinate suggests that most of the methylmercury could be potentially neurologically available to the animals. However, the direct toxicity of mercury and methylmercury seems to be alleviated by binding with selenium and by selenium-aided demethylation of methylmercury. While this may have offered the animals protection against mercury methylmercury, it could also make the animals more susceptible to oxidative damage as organoselenium is an important and essential antioxidant. Such oxidative damage is most likely to occur in the liver, kidneys and brain where a considerable amount of methylmercury demethylates. Future epidemiological studies on beluga whales need to examine symptoms of oxidative damage due to methylmercury demethylation-induced deficiency in organoselenium.

Expected Project Completion Date

This project was concluded in April of 2012.

Acknowledgments

This study was funded by the Northern Contaminants Program (Wang, Stern), ArcticNet (Wang, Stern), Natural Science and Engineering Research Council (Wang), and t he Fisheries Joint Management Committee (Stern). We thank L. Chan and S. Ostertag of the University of Northern British Columbia for collaboration on the beluga brain samples.

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The impacts of climate-induced increases in primary productivity on the cycling of mercury and methylmercury in focal freshwater Arctic ecosystems

Les répercussions de l'augmentation d'origine climatique de la productivité primaire sur le cycle du mercure et du méthylmercure dans les principaux écosystèmes d'eau douce de l'Arctique

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Abstract

Mercury is a top priority contaminant in Canadian Arctic freshwater ecosystems because concentrations of methylmercury, the toxic form of mercury, are often above human consumption guideline in freshwater fishes, such as landlocked Arctic char. We are examining key aspects of the mercury cycle which directly impact methylmercury concentrations in fish 1) the behavior of inorganic mercury after it is deposited to lakes from the atmosphere 2) the rates and mechanisms of production of methylmercury from inorganic mercury and 3) the impact of climate-induced increases in lake primary productivity on 1) and 2). To examine 1), we have analyzed numerous dated lake sediment cores from across the Canadian high and subarctic for mercury and

Résumé

Le mercure est un contaminant considéré comme hautement prioritaire dans les écosystèmes d'eau douce de l'Arctique canadien, parce que les concentrations de méthylmercure, la forme toxique du mercure, dépassent souvent les limites prescrites par les lignes directrices pour les espèces de poissons d'eau douce de consommation humaine, comme l'omble chevalier confiné aux eaux intérieures. Nous examinons les principaux aspects du cycle du mercure qui ont une incidence directe sur les concentrations de méthylmercure chez les poissons. Ces aspects sont : 1) le comportement du mercure inorganique atmosphérique tombant sous forme de dépôt dans les lacs; 2) les taux et les mécanismes de production du méthylmercure à partir du

climate-indicators, including algal-derived or S2 carbon and microfossil remains. This study represents the most geographically extensive data-set of mercury-climate dynamics in the Arctic; however we are currently expanding this data set to cover more regions of the Arctic not previously explored. To date, we found that mercury fluxes to lake sediments increased post-industrialization (post-~1850) in 9 of our 11 study lakes. Results also suggested that atmospheric mercury deposition increased since industrialization in all 11 lakes, whereas mercury inputs from the catchment increased in 9 lakes, likely due to catchment erosion. Several study lakes showed recent shifts in algal assemblages consistent with climate-induced changes. 8 lakes showed post-1850's increases in algal derived carbon or S2 fluxes, suggesting that lake primary productivity recently increased in these lakes. We also examined relationships between mercury and S2 to determine if increased primary productivity has affected the loss of mercury to lake sediments through time. In ~half the lakes, we observed no positive relationship between mercury and S2. In five of the six lakes where a positive mercury:S2 relationship was observed, algal assemblages either did not change through time or the timing of the shifts did not correspond to changes in mercury deposition. Our results suggest that, although Arctic lakes are experiencing many changes, increased lake primary productivity is not driving changes in mercury fluxes to sediments. To examine 2), we are examining the effects of increased algal production on methylmercury production in lake surface sediments using state-of-the-art mercury stable isotope tracer experiments. In July 2010 and July 2011, experiments were conducted at Meretta, Char, and Amituk lakes. In addition to amendments with stable mercury isotope $^{202}Hg(II)$ (to measure rates of methylmercury production) and $Me^{198}Hg$ (to measure rates of methylmercury loss), a subset of cores were also amended with organic carbon, sulfate, and molybdate (which stimulate and inhibit potential pathways of methylmercury production) to examine the mechanisms of methylmercury production and the impacts of increased lake primary productivity on these processes. A great deal of progress has been made on this project; however our results

mercure inorganique; 3) les répercussions de l'augmentation d'origine climatique de la productivité lacustre primaire sur 1) et 2). Pour étudier 1), nous avons analysé de nombreuses carottes de sédiments lacustres datées, provenant d'un bout à l'autre de l'Extrême Arctique et de la région subarctique au Canada afin de déterminer les concentrations de mercure et les indicateurs climatiques, y compris le carbone (C) S2 provenant des algues et des restes de microfossiles. Cette étude regroupe l'ensemble de données le plus étendu du point de vue géographique de la dynamique mercure-climat dans l'Arctique, et nous continuons à l'agrandir en y ajoutant des données sur d'autres régions de l'Arctique qui n'ont pas déjà été explorées. À ce jour, nous avons constaté que les flux de mercure vers les sédiments lacustres ont augmenté après l'industrialisation (après environ 1850) dans neuf des onze lacs étudiés. Les résultats semblent aussi indiquer que les dépôts de mercure atmosphérique ont augmenté depuis l'industrialisation dans les onze lacs, alors que les apports de mercure du bassin versant ont augmenté dans neuf lacs, probablement à cause de l'érosion du bassin versant. Plusieurs des lacs étudiés ont connu aussi des changements récents dans les assemblages d'algues, qui coïncidaient avec des changements d'origine climatique. Huit lacs ont connu des augmentations des flux de carbone S2 provenant des algues après les années 1850, ce qui donne à penser que la production lacustre primaire a augmenté récemment dans ces lacs. Nous avons aussi étudié les relations entre le mercure et le S2 afin de déterminer si la production primaire accrue a eu une incidence sur le mercure dans les sédiments lacustres au fil du temps. Dans la moitié des lacs environ, nous n'avons observé aucune relation positive entre le mercure et le S2. Dans cinq des six lacs, une relation positive a été observée entre le mercure et le S2; soit les assemblages d'algues ne changeaient pas avec le temps, soit la période des changements ne correspondait à aucune modification du dépôt de mercure. Ces résultats donnent à penser que, bien que les lacs de l'Arctique connaissent d'innombrables changements, l'augmentation de la production primaire dans les lacs n'a aucune incidence sur les flux de mercure vers les sédiments. Pour have stimulated a variety of important research questions regarding mercury-carbon-sulfur-climate dynamics which we are currently exploring.

étudier 2), nous examinons actuellement les effets d'une augmentation de la production d'algues sur la production de méthylmercure dans les sédiments de surface des lacs dans le cadre d'expériences faisant appel à des technologies de pointe de marquage avec les isotopes stables du mercure. En juillet 2010 et en juillet 2011, des expériences ont été effectuées aux lacs Meretta, Char et Amituk. En plus d'avoir utilisé les isotopes stables du mercure $^{202}Hg(II)$ (pour mesurer les taux de production de méthylmercure) et $Me^{198}Hg$ (pour mesurer le taux de perte du méthylmercure), nous avons également utilisé un sousensemble de carottes auquel nous avons ajouté du carbone organique, du sulfate et du molybdate (qui stimulent ou inhibent les voies de production possibles du méthylmercure) afin d'examiner les mécanismes de production du méthylmercure et les répercussions d'une augmentation de la production primaire des lacs sur ces processus. Beaucoup de progrès ont été réalisés dans le cadre de ce projet; cependant, les résultats ont soulevé diverses questions de recherche importantes sur la dynamique mercure-carbone-soufre-climat, que nous étudions actuellement

Key Messages

- Mercury deposition has increased in sediments since ~1850 in most lakes looked at; but it is important to note that current sediments levels are not a risk to people's health.
- Some of the increase in sediment mercury levels is likely due to deposition of mercury which has travelled in the atmosphere from Southern industrial regions.
- Several lakes showed changes in algae fossils through time which are likely due to climate-induced changes, such as shortening of the ice covered season and longer summers.
- Several lakes showed increases in certain forms of carbon, suggesting that lake production has recently increased in some lakes.

Messages clés

- Les dépôts de mercure dans les sédiments ont augmenté depuis environ 1850 dans la plupart des lacs étudiés. Il est toutefois important de noter que les concentrations actuelles ne représentent pas un risque pour la santé humaine.
- Une partie de l'augmentation des concentrations de mercure dans les sédiments est probablement due au mercure atmosphérique provenant des régions industrielles plus au sud, qui est tombé dans les lacs sous forme de dépôt.
- Plusieurs lacs présentaient des changements dans le temps pour ce qui est des fossiles et des algues, qui sont probablement induits par des changements climatiques, comme le raccourcissement de la saison des glaces et l'allongement des étés.

- Climate-induced increases in lake primary production may be stimulating production of toxic methylmercury by sulfate reducing bacteria in high Arctic lake sediments; but it is important to note that current water levels are also not a risk to people's health.

- State-of-the-art mercury stable isotope tracers experiments were carried out in several Resolute Lakes to determine rates of production of toxic methylmercury and we found that rates of methylmercury production were low in all lakes but increased in the order of Amituk < Char < Small < Meretta.

- Hg concentrations in char of these lakes increase in the opposite direction (Small < Meretta < Char < Amituk) suggesting that sediment methylmercury production does not control mercury levels in char.

- Further experiments are being carried out to examine the relationship between lake primary productivity and methylmercury production in Resolute Lakes.

- Plusieurs lacs présentaient des augmentations de certaines formes de carbone, portant à croire que la production lacustre a augmenté récemment dans certains lacs.

- Les augmentations d'origine climatique de la production lacustre primaire stimulent peutêtre la production de méthylmercure toxique par les bactéries sulfatoréductrices dans les sédiments des lacs de l'Extrême Arctique; mais il est important de noter que les concentrations actuelles dans l'eau ne présentent pas de risque pour la santé humaine.

- Nous avons effectué des expériences faisant appel à des technologies de pointe de marquage avec des isotopes stables du mercure dans plusieurs lacs de la région de la baie Resolute afin de déterminer les taux de production de méthylmercure toxique, et nous avons constaté que ces taux étaient faibles dans tous les lacs, mais qu'ils augmentaient dans l'ordre Amituk < Char < Small < Meretta.

- Les concentrations de Hg dans l'omble chevalier de ces lacs augmentaient dans l'ordre Small < Meretta < Char < Amituk, portant à croire que la production de méthylmercure dans les sédiments ne régit pas les concentrations de mercure chez l'omble chevalier.

- Nous menons actuellement d'autres expériences afin d'étudier la relation entre la productivité primaire des lacs et la production de méthylmercure dans les lacs de la région de la baie Resolute.

Objectives

Long term objectives:

1. Understand the effects of climate-driven increases in primary production on mercury (Hg) and methylmercury (MeHg) cycling in high Arctic lakes, particularly in NCP focal ecosystems.

2. Determine why MeHg concentrations in freshwater fishes are over Canadian fish consumption guidelines in some Arctic lakes, such as Amituk and Char, but not in others.

Short term objectives:

1. Test the "scavenging hypothesis", that algal derived carbon (C) drives the deposition of Hg to lake sediments, by examining Hg, S2 or algal derived C, and microfossil remains in dated sediment cores from numerous carefully selected high Arctic lakes of Nunavut, Nunatsiavut, and Nunavik.

2. Examine whether climate-induced catchment erosion is resulting in increased delivery of Hg to lake sediments through analysis of lithogenic elements in dated sediment cores.

3. Quantify rates and examine mechanisms of MeHg production in the surface sediments of a subset of our study lakes (Amituk, Char and Meretta) using state-of-the-art Hg stable isotope tracer experiments.

4. Examine the role of climate-induced increases in primary production in stimulating MeHg production in Arctic lake sediments by examining the relationship between S2 and reduced inorganic sulfur in lake sediment cores.

5. Provide this information to the Hamlet of Resolute Bay (Qausuittuq) and to the Niqiit Avatittinni Committee (Nunavut) on a timely basis.

Introduction

Mercury (Hg) is a priority contaminant in Canadian Arctic lakes. NCP supported monitoring has shown that methyl Hg (MeHg; the toxic, bioaccumulative form of Hg) concentrations in Arctic char of Amituk and Char lakes (Cornwallis Island), are above human consumption guidelines and have increased until ~2005 (*Muir et al. 2010*). Increases in fish Hg concentrations have also been observed the Mackenzie River (*Carrie et al. 2009*) and Great Slave Lake (*Evans and Muir 2009*). Research is required to understand the factors driving trends in biota so that mitigation strategies can be developed and the impacts of projected climate change can be predicted. We are thus examining key factors that affect MeHg concentrations in freshwater fish: 1) the post-depositional behavior of inorganic Hg(II) 2) the rates and mechanisms of production of MeHg from Hg(II) and 3) the impact of climate related changes on 1) and 2). This project links with numerous other NCP projects led by Derek Muir and Karen Kidd and addresses research needs described under "Pathways of Long-Range Transportation" and "Ecosystem Based Monitoring and Research: Freshwater Ecosystems" of the NCP blueprint.

It is well known that increasing atmospheric loading of Hg(II) to aquatic ecosystems can increase fish MeHg concentrations (*Harris et al. 2007*). Due to the paucity of real-time Hg deposition measurements in the Arctic, dated sediment cores have therefore been extensively used to examine Hg deposition to Arctic lakes over time. Hg fluxes have been determined in ~90 Arctic lakes, and have increased in recent decades in most systems (*Muir et al. 2009, Lindberg et al. 2007, Outridge et al. 2007, Fitzgerald et al. 2005, Bindler et al. 2001*). The reason for these increases is, however, debated. In several studies (for example, *Muir et al. 2009, Fitzgerald et al. 2005, Bindler et al. 2001*), post-industrialization increases in Hg fluxes have been attributed mainly to increased anthropogenic atmospheric Hg deposition as patterns of atmospheric circulation result in the transport of Hg emissions from southern regions, such as Asia, to the Arctic (*Durnford et al. 2010*). In other studies (*Carrie et al. 2010, Stern et al. 2009, Outridge et al. 2007*), a large portion (~70-78%) of increased post-industrialization Hg deposition has been attributed to increased algal scavenging brought about by climate-induced changes. This "scavenging hypothesis" is based upon significant positive relationships between Hg and S2, or algal-derived organic C (OC) in lake sediments, as well as upon the numerous paleolimnological studies that have demonstrated wide-spread, climate-induced changes in Arctic lakes. For example, increased algal production and sedimentation of detritus have been observed in numerous Baffin Island lakes (*Michelutti et al. 2007*) and changes in algal species composition beginning in ~1850 have been observed in lakes spanning the circumpolar Arctic (*Smol et al. 2005*). To date, sediment cores from only seven lakes have been analyzed for Hg and S2 (for example, *Carrie et al. 2010, Stern et al. 2009, Outridge et al. 2007*). Further study is clearly warranted and we are thus examining the relationships between Hg, S2, algal assemblages, and lithogenic elements in dated sediments from numerous Arctic lakes spanning both latitudinal and longitudinal gradients to examine the link between primary productivity and Hg in lake sediments and determine how to most effectively use Hg flux data obtained from dated sediment cores.

Although the quantity of Hg(II) available for methylation is an important factor driving fish MeHg concentrations, the rate of MeHg production in a system is also of great importance. Hg(II) methylation is primarily carried out by sulfate reducing bacteria in lake surface sediments (*Compeau and Bartha 1985*). Therefore, factors controlling populations of sulfate reducing bacteria, such as DOC and sulfate, can affect MeHg production rates. In temperate regions, stable Hg isotope tracer experiments have been used extensively to measure potential rates of sediment methylation and demethylation and to elucidate the mechanisms of MeHg production. We are therefore quantifying sediment methylation rates using Hg stable isotope techniques in a series of lakes, including Amituk and Char lakes. Sediments are being amended with Hg stable isotope tracers to quantify potential rates of Hg(II) methylation and MeHg demethylation, as well with sulfate and OC to examine mechanisms for MeHg production. Amendments with OC, for example, allow us to examine the impact of climate-induced increases in primary production on rates of MeHg production, which directly links to the work described above.

Activities in 2010-2011: What? Where? When? Who? How?

- We analyzed several (11) dated lake sediment cores from across the Canadian high and subarctic for concentrations of Hg, multielements, and climate-indicators, including microfossil remains and algal-derived or S2 C.

- This work resulted in publications in the journal *Environmental Science and Technology* (*Kirk et al. 2011 and Kirk et al. 2012*) and the results are shaping the work we are doing currently.

- Based on data gaps illustrated from the above work, 10 additional cores were carefully selected for analysis. We had in our possession ~20 cores collected between 2007-present, many of which have already been dated using ^{210}Pb methods. We selected six cores that have already been dated for analysis and three others that have not been dated yet.

- A new core was collected from Meretta Lake this summer (2011) by Gretchen Lescord and Jane Kirk as part of a large field campaign being coordinated for several NCP projects. Meretta Lake is an important site as long term chlorophyll a concentrations from this lake will be compared to S2 profiles to calibrate S2 as a proxy for primary productivity.

- Dated cores have been analyzed for concentrations of Hg at the Trace Mercury Analytical Laboratory at the Canada Centre for Inland Waters (CCIW), for algal assemblages by Hedy Kling (Algal Taxonomy and Ecology, Winnipeg, Manitoba), for S2 by Baseline Resolution (Shenandoah, Texas), and for multielements by he National Laboratory for Environmental Testing (NLET; CCIW).

- The three un-dated cores are currently being dated using ^{210}Pb methods by Fan Yang at our dating laboratory at CCIW.

- Plans are underway to analyze a subset of cores using visible reflectance spectroscopy (VRS) at Queen's University, as this techniques has recently been shown to successfully reconstruct lake chlorophyll a concentrations (*Michelutti et al. 2010*).

- A paper was published in *Environmental Science and Technology* in 2010 (Drevnick et al. 2010) which demonstrates that sulfate reduction and OC deposition are increasing in Arctic lakes, including Char and Amituk. These results suggest that MeHg production may also be increasing.

- Hg stable isotope tracer experiments were conducted at Meretta, Char, and Amituk lakes in July 2010 and 2011 by Paul Drevnick to examine the production of MeHg in lake surface sediments.

- Sediment samples from the Hg stable isotope tracer experiments were analyzed at the Woods Hole Oceanographic Institution Plasma Mass Spectrometry Facility (Woods Hole, Massachusetts) in collaboration with Carl Lamborg and technical staff winter 2012.

Capacity Building
For the portions of the project on MeHg production, which involve new sample collections, we hired Debbie and Brandy Iqaluk from the Hamlet of Resolute Bay in summers 2010-2011. They were trained in sediment core collection, processing (e.g. sectioning), and in state-of-the-art Hg stable isotope tracer techniques. Thus the project is helping to build expertise in scientific sampling among hunters of the community. In addition, the work on MeHg methylation is part of a M.Sc. thesis on the "effect of increased carbon flux on net Hg(II) methylation in high Arctic lakes." The student is gaining expertise on many aspects of environmental research, including highly specialized laboratory skills, such as analysis of reduced inorganic sulfur using gravimetric determination, and Hg stable isotopes using GC-ICP-MS.

Traditional Knowledge
The portions of the project that involve new sample collection (work on MeHg production and sediment core collections at Meretta Lake), rely on Traditional ecological knowledge for safe access to sampling lakes during the summer months when the ice may be unstable. In summers 2010-2011, Debbie and Brandy Iqaluk of Resolute Bay participated in the project and provided this expertise to the field team.

Communications
During the field season in July 2010, Derek Muir visited the HTA office in Resolute Bay, Nunavut and spoke with HTA Manager Nancy Amarualik to describe and update her on the project. In August 2012, principal investigators will again visit the HTA office, as well as the Wildlife office and the Hamlet Council office to discuss the project. Results have been, and will continue to be, communicated to NCP and the HTA in written reports and presentations. For example, a poster entitled "Impacts of climate-induced increases in primary productivity on Hg cycling in freshwater Arctic ecosystems" was presented at the fall 2010 NCP workshop in Whitehorse, Yukon and an updated oral presentation was made at the 2011 workshop in Victoria entitled "The impacts of climate-induced increases in primary productivity on the cycling of mercury and methylmercury in freshwater Arctic ecosystems". In addition, a small poster with numerous photos was made, then translated and submitted to the HTA in March 2011 to provide background and updates on the project. Another poster was presented at the American Geophysical Union (AGU) conference in San Francisco, CA in December, 2010 and three papers were published in *Environmental Science Technology* in 2010, 2011 and 2012 (*Drenvick et al. 2010, Kirk et al. 2011 and Kirk et. al 2012*).

Results, Discussion, and Conclusions

1) The post-depositional behavior of Hg(II) in Arctic lakes and the impact of climate-induced increases in primary productivity on this behavior: 11 dated lake sediment cores from across the Canadian high and subarctic were analyzed for concentrations of Hg and climate-indicators, including microfossil remains and algal-derived or S2 C (Figures 1 and 2). This study represents the most geographically extensive data-set of Hg-climate dynamics in the Arctic and includes more comprehensive microfossil data than previous studies of its kind as species-level diatom analysis was obtained in a subset of study lakes (*Kirk et al. 2011*).

We found that Hg fluxes increased post-industrialization (post-~1850) in 9 of our 11 study lakes (post-industrialization Hg fluxes (ΔHgF_F) = 1.5-24.2 $\mu g\ m^{-2}\ y^{-1}$; Figure 2). Correction of HgF_F for catchment contributions demonstrated that Hg deposition originating from catchment-independent factors, such as atmospheric deposition, increased since industrialization in all 11 lakes whereas Hg inputs from the catchment increased in 9 of the lakes. Several study lakes also showed post-industrial shifts in algal assemblages consistent with climate-induced changes. 8 lakes showed post-1850's increases in S2 fluxes, suggesting that lake primary productivity recently increased in the majority of our sites ($\Delta S2F_F$ = 0.1-3.7 $g\ m^{-2}\ y^{-1}$). To explore the algal scavenging hypothesis, which postulates that Hg fluxes to

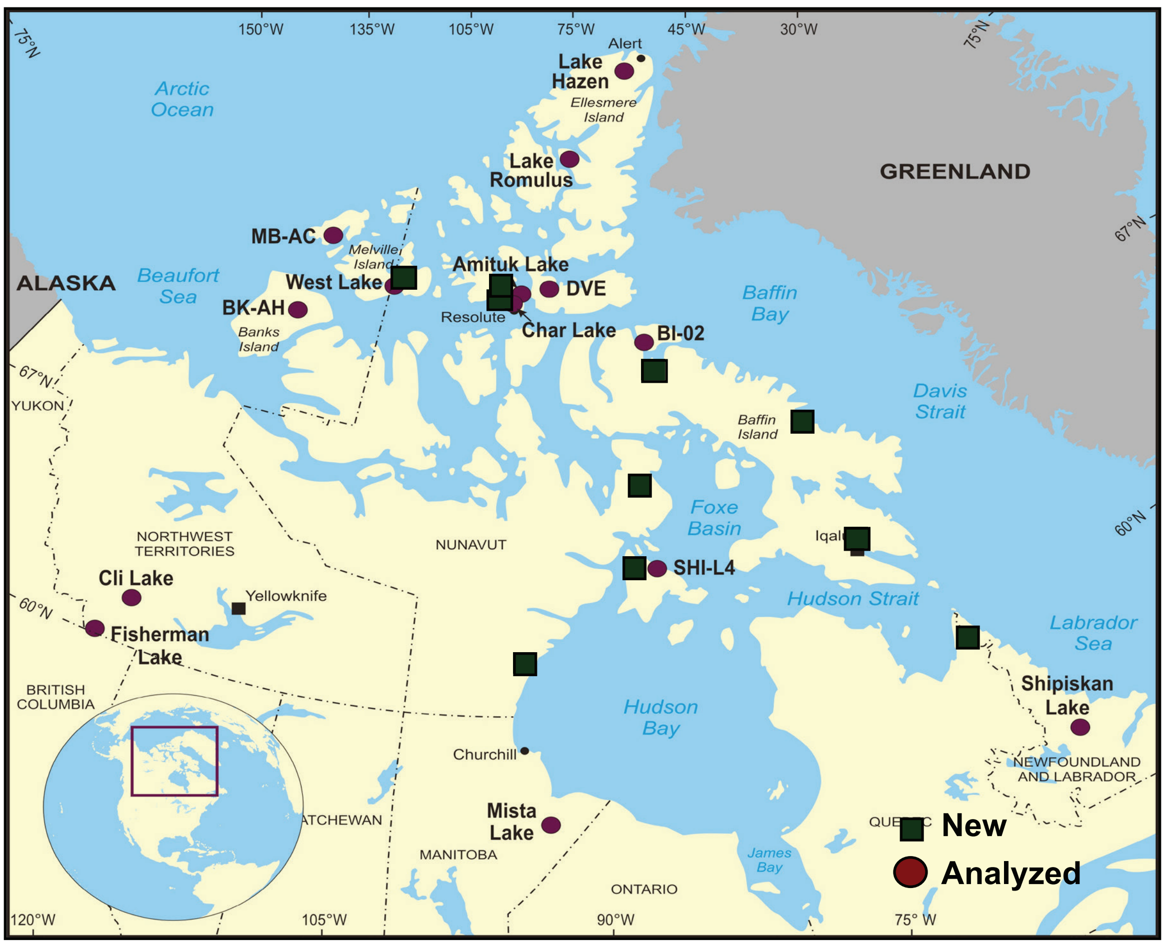

Figure 1. Location of Canadian high and subarctic lakes where sediment cores were collected then analyzed for Hg and climate-change indicators including microfossils and algal derived, or S2 C (red circles) and location of 10 new sediment cores that are currently being analyzed (green squares).

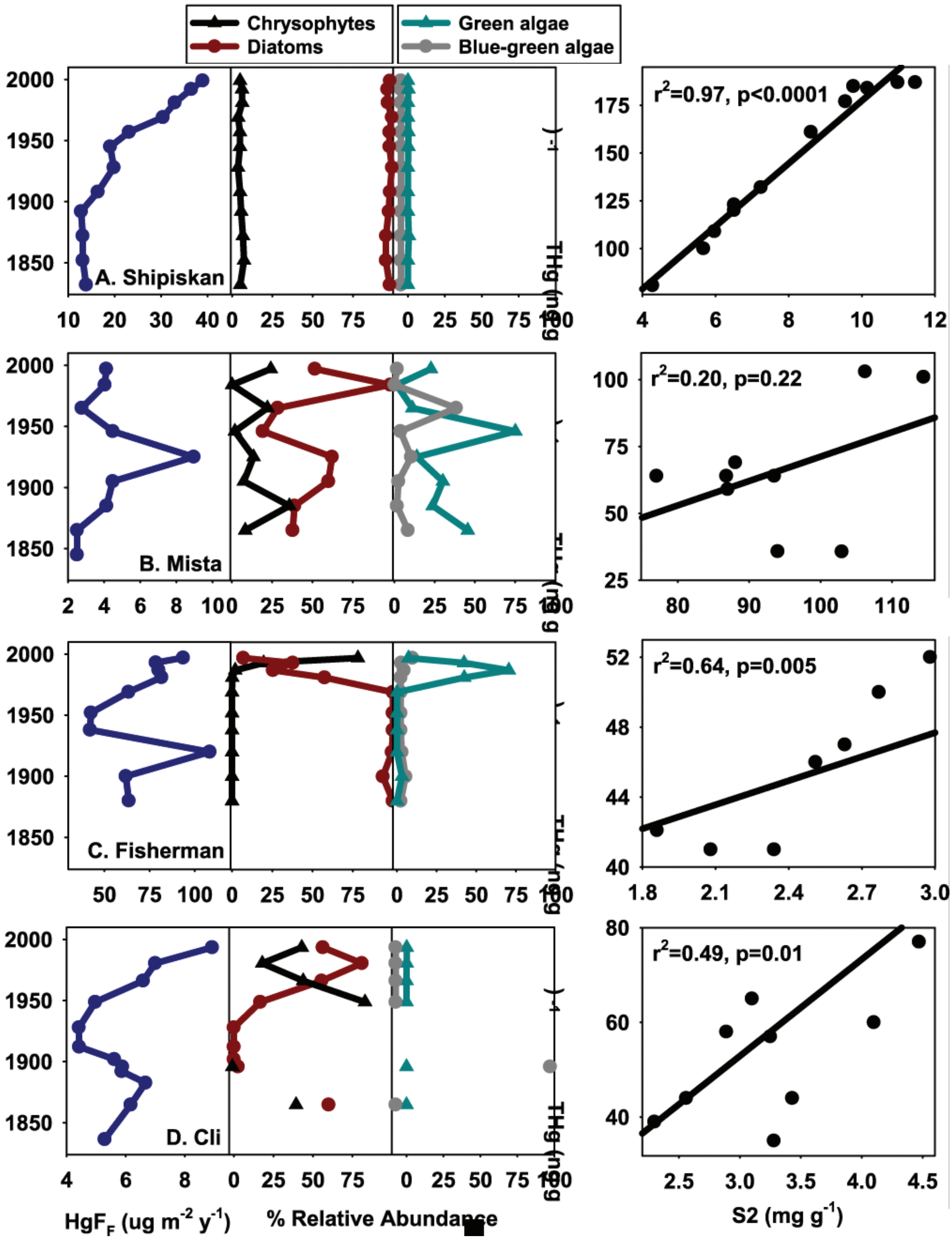

Figure 2. (part 1)

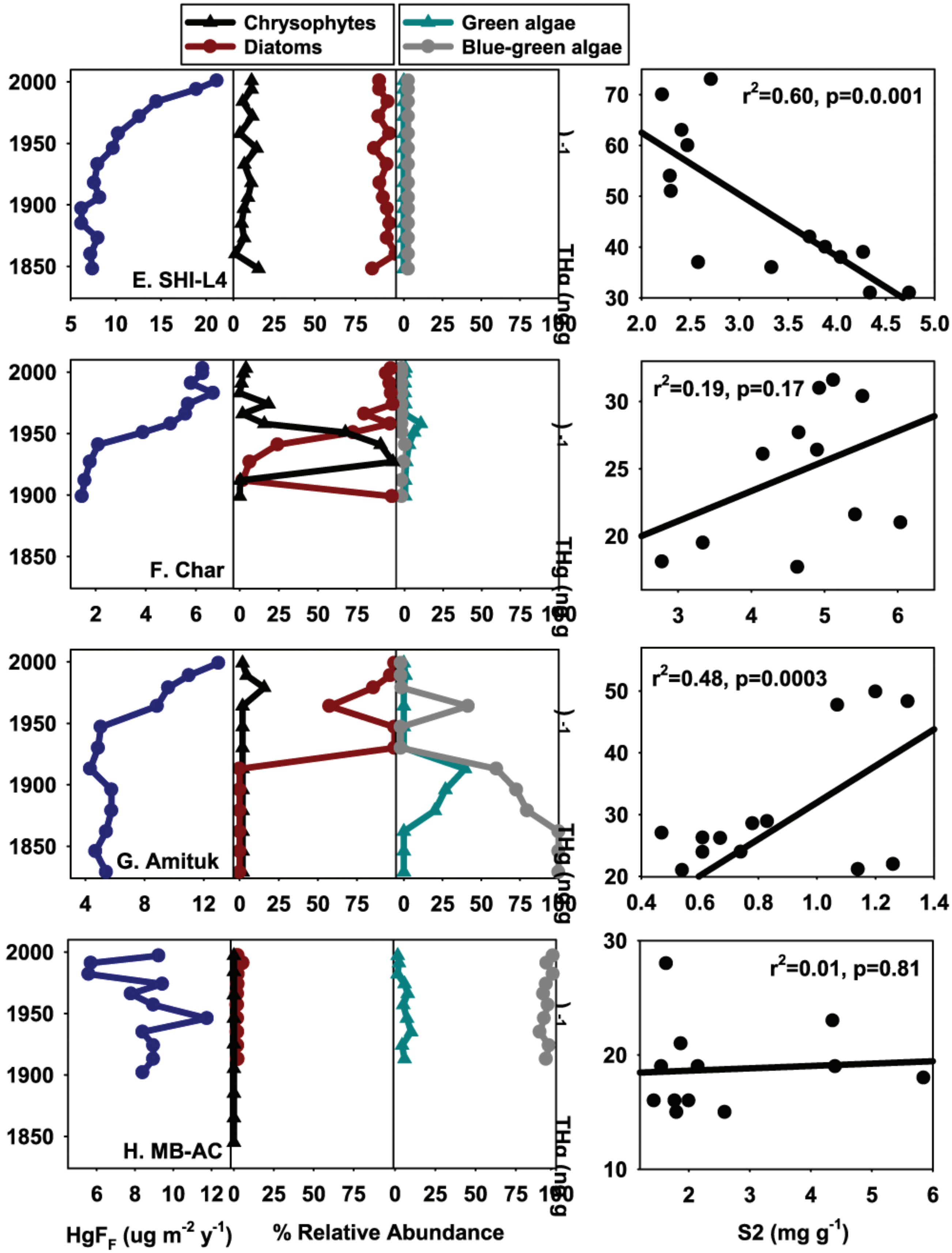

Figure 2. (part 2)

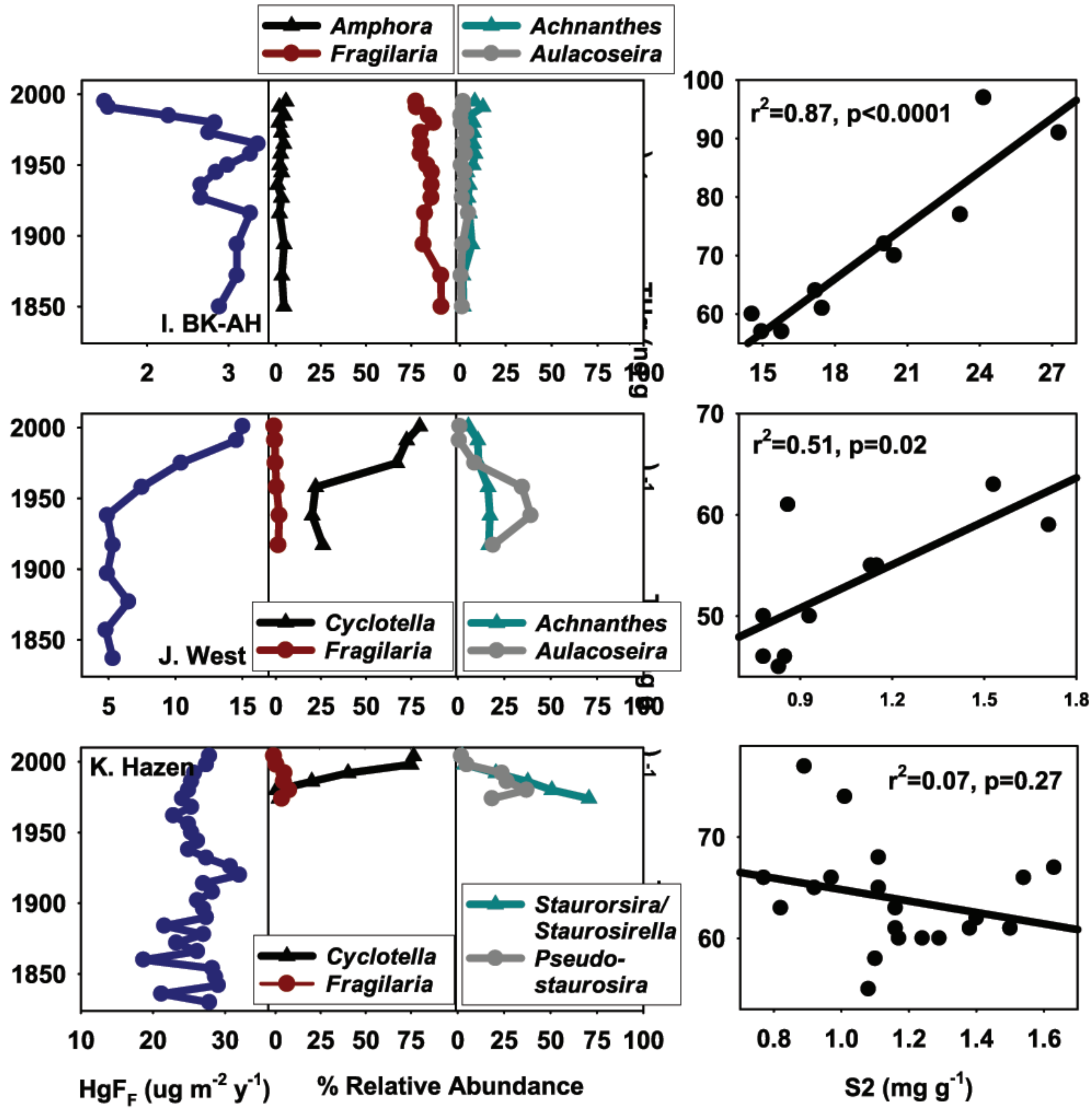

Figure 2. Focusing adjusted Hg fluxes (HgFF), relative abundance (%) of microfossils including either diatoms, chrysophytes, green algae, and blue-green algae (A-J), or predominant diatom species (I-K), and the relationship between Hg and S2 C concentration (ng g-1) in dated sediment cores from 11 Canadian Arctic lakes.

Arctic sediments are largely driven by S2 C, we examined relationships between Hg and S2 in our sediment cores. Interestingly, in four of our lakes we observed no Hg:S2 relationship, and in one lake a significant negative Hg:S2 relationship was observed. In five of the six lakes where a significant positive Hg:S2 relationship was observed, algal assemblages either did not change through time or the timing of the shifts did not correspond to changes in Hg deposition (Figure 2). In two of the study lakes where a significant Hg:S2 relationship was observed

Table 1. List of new high and subarctic sediment cores that are currently being analyzed for Hg and climate indicators. A subset are being analyzed by visible reflectance spectroscopy.

Lake	Location	Latitude (N)	Longitude (W)	Status of analysis
A5	Rankin Inlet Nunavut	61° 16.816	94° 19.291	^{210}Pb dating, Hg, algal assemblage, multielement, and Rock Eval analysis complete.
IqaluitA1	Iqaluit Nunavut	63°46.915	68°32.935	^{210}Pb dating, Hg, algal assemblage, and multielement analysis complete.
B35	Baker Lake Nunavut	64° 20.003	95° 54.167	^{210}Pb dating, Hg, algal assemblage, multielement, and Rock Eval analysis complete.
C1	Clyde River Nunavut	70° 27.784	68° 30.495	^{210}Pb dating, Hg, algal assemblage, multielement, and Rock Eval analysis complete.
North	Resolute Nunavut	74° 48.000	90° 06.000	^{210}Pb dating, Hg, algal assemblage, and multielement analysis complete.
Meretta	Resolute Nunavut	74° 42.000	94° 54.000	Core collection carried out in July 2011 and ^{210}Pb dating underway.
Lab 003	Saglek Bay Labrador	58° 25.000	63° 09.900	^{210}Pb dating underway.
BI-27	Bylot Island Nunavut	73° 08.845	80° 02.647	^{210}Pb dating, Hg, algal assemblage, multielement, and Rock Eval analysis complete.
East	Melville Island Nunavut	74° 55.000	109° 64.350	^{210}Pb dating complete, Hg analysis underway.
Fish	Boothia Peninsula Nunavut	68° 52.867	82° 57.283	^{210}Pb dating underway.

(Shipiskan and Fisherman), the ratio between S2 and the refractory fraction of C decreased from the top to the bottom of the cores indicating post-depositional degradation of S2 to RC.

Our results suggest that although Arctic lakes are experiencing a myriad of changes, including increased Hg and S2 deposition, or changing algal assemblages, increased lake primary productivity is not driving changes in Hg fluxes to sediments. Thus, although a great deal of progress has been made on this project, our results have simulated a variety of important research questions regarding Hg-OC-climate dynamics such as: Are climate-induced increases in catchment Hg inputs to Arctic lakes widespread across the Canadian Arctic? Why are Hg and S2 strongly correlated in some lakes but not in others? Is there a regional component to these differences? Is S2 well conserved in Arctic cores and is S2 a good proxy for primary productivity? We are currently exploring these questions by analyzing 10 new high and subarctic sediment cores provided to us by paleoliminologists we are collaborating with (*Kirk et al. 2011, Muir et al. 2009*) (Figure 1). Many of the cores selected were previously dated using ^{137}Cs and ^{210}Pb methods, thus funding was used to carry out Hg, S2, algal assemblage,

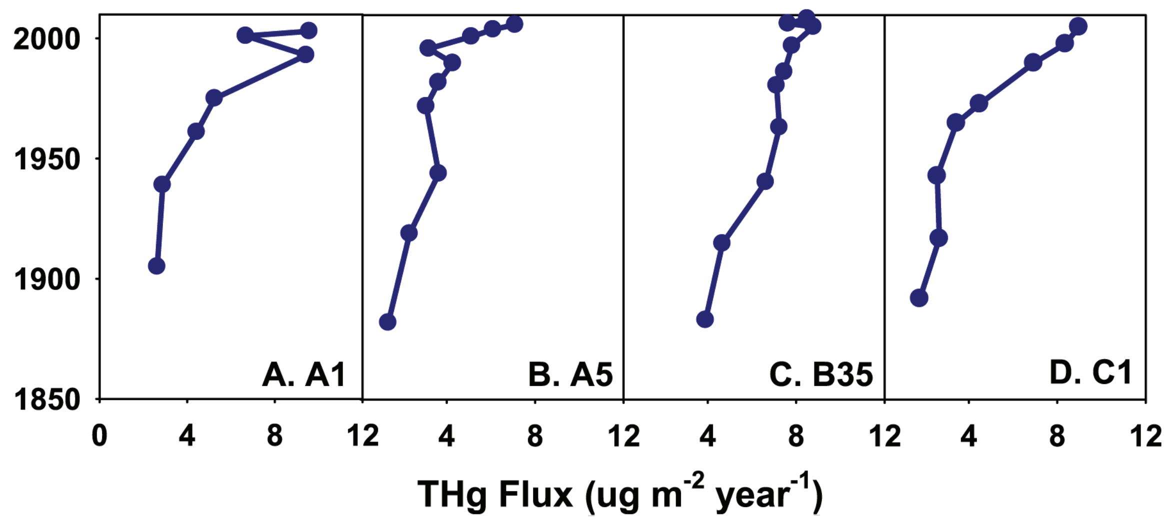

Figure 3. Hg fluxes (HgF) in new dated sediment cores from 4 Canadian Arctic lakes.

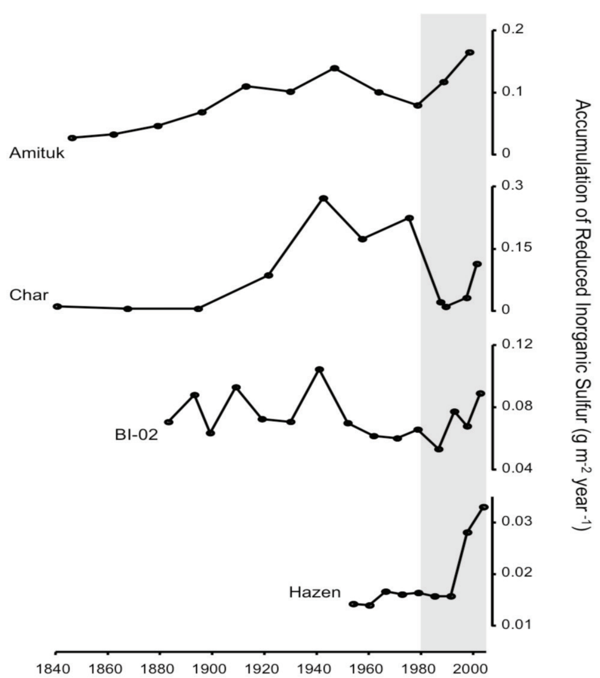

Figure 4. Fluxes of reduced inorganic sulfur (g m-2 year-1) over time measured in sediment cores collected from two NCP focal ecosystems located on Cornwallis Island (Amituk and Char lakes), BI-02, located on Bylot Island, and Lake Hazen, located on Ellesmere Island. The highlighted region illustrates the time period during which increases in reduced inorganic sulfur fluxes were observed in most of these lakes.

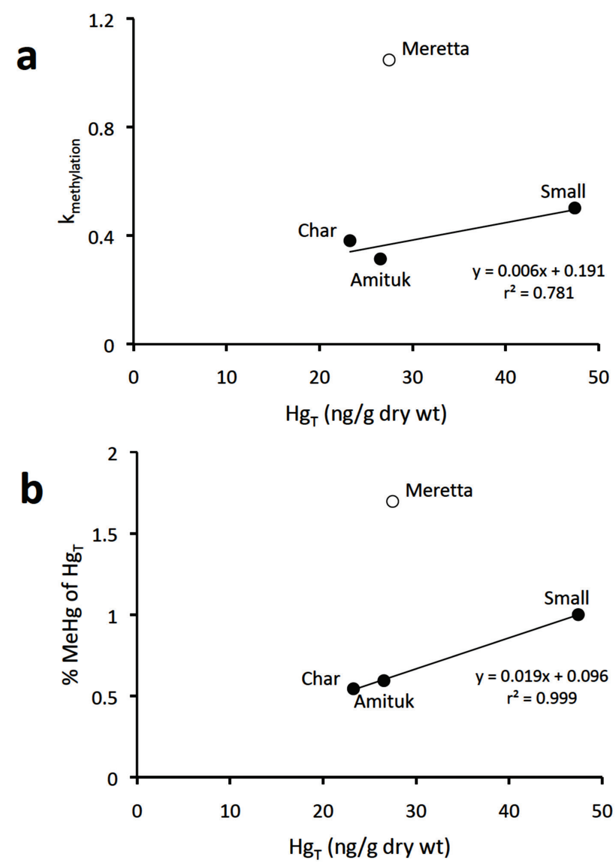

Figure 5. Relationship between ambient HgT and (a) Hg methylation rate ($k_{methylation}$) and (b) % MeHg of HgT in sediments from Amituk, Char, Meretta, and Small Lakes. The $k_{methylation}$ value for Amituk is represented by the detection limit (0.31 % per day).

Table 2. Hg methylation rates ($k_{methylation}$; percent of spike methylated per day), concentrations of ambient Hg_T and MeHg, percent MeHg or Hg_T, and total organic carbon (TOC) of sediments (0-2-cm depth) from lakes on Cornwallis Island. Concentrations of Hg_T in char from each lake are given for reference. Error terms, in parentheses, represent one standard error.

Lake	$k_{methylation}$ (% per day)	Hg_T (ng/g dw)	MeHg (ng/g dw)	% MeHg of Hg_T	TOC (%)a	Hg_T in arctic char (ng/g ww)[b]
Amituk	c	27 (2.4)	0.16 (0.03)	0.60	0.9	1.3
Char	0.38 (0.27)	23 (1.3)	0.12 (0.02)	0.55	1.7	0.46
Meretta	1.1 (0.07)	28 (5.0)	0.51 (0.15)	1.7	11	0.32
Small	0.50 (0.15)	47 (2.9)	0.45 (0.06)	1.0		0.12

a. Values for Amituk and Char are from Drevnick et al. (*2010*); value for Meretta is from Antoniades et al. *(2011)*.

b. Data are from Gantner et al. *(2010)*.

c. $k_{methylation}$ for Amituk Lake was below detection (i.e., no increase in $Me^{202}Hg$ was detected during the 8-hour incubation).

Table 3. Summary of performance indicators for 2011-2012 NCP funding year.

Performance Indicator	Number	Details / Description
Number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	2	Brady and Debbie Iqaluk of Resolute Bay.
Number of project-related meetings/workshops held in the North (April 1, 2011 – March 31, 2012)	1	HTA manager in Resolute Bay was visited for a project update.
Number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	2	1 M.Sc. student (Ben Barst) and 1 co-op (Janna Coty)
Number of citable publications (e.g., in domestic/ international journals, conference presentations, book chapters, etc)	2011: 2 2012: 1	2 publications in Environmental Sciences and Technology and 1 oral presentation at the 2011 NCP workshop.

and multielement analyses as well as other new analysis (see Table 1 for status of analysis). To complement our work at Meretta Lake on rates and mechanisms of MeHg production, a new sediment core was collected from this lake in summer 2011 and is also being analyzed.

Results from *Kirk et al. 2011 and Kirk et al. 2012* also suggest that S2 C may be subject to post-depositional degradation and indicate that S2 may not be an ideal proxy of lake primary productivity. In addition, S2 has not been "calibrated" as an indicator of changing lake primary productivity by comparing, for example, sedimentary lake S2 profiles to changes in lake-water chlorophyll a concentrations in lakes where long-term records are available. To explore these issues in more detail, we have entered into a collaboration with John Smol (Queen's University) to analyze a subset of our sediment cores for visible reflectance spectroscopy (VRS), which has recently been shown to successfully reconstruct lake chlorophyll *a* concentrations (*Michelutti et al. 2010*). Reconstructions of sediment chlorophyll a concentrations, obtained by VRS analysis, will be compared to S2 profiles to "calibrate" these methods. In addition, long-term lake chlorophyll *a* data from Meretta Lake, also obtained through collaboration with John Smol, will be compared to S2 profiles to further calibrate S2 as a proxy for primary productivity. VRS work will be carried out in winter 2011.

To date, we have carried out data analysis on 4 newly analyzed cores which are located in areas of the Arctic not previously examined in *Kirk et al. 2011* (A1 near Iqaluit, A5 near Rankin Inlet, C1 near Clyde River, and B35 near Baker Lake). Results suggest that changes in the Hg deposition from ~1850-present are very similar among all these lakes, with ΔHgF ranging from 4-8 μg m^{-2} y^{-1} (Figure 3). Consistent day, suggesting that Hg deposition in the Arctic continues to increase present day.

2) Rates and mechanisms of MeHg production and the impact of climate-induced increases in primary productivity on these processes: Newly published work by Drevnick et al. (*Drevnick et al. 2010*) suggests that climate-induced increases in lake primary productivity are stimulating MeHg production by sulfate reducing bacteria in high Arctic lakes. Algal detritus is a rich source of labile C, and therefore has the potential to stimulate populations of sulfate reducing bacteria, which are the primary producers of MeHg in surface sediments. Firstly, an increase in sedimentary accumulation of reduced inorganic sulfur was observed in high Arctic lakes, including NCP focal lakes, Amituk, Char, and Hazen, in recent years (*Drevnick et al. 2010*; Figure 4. In addition, incubations of sediment slurries from Amituk and Char lakes with acetate (labile C) resulted in significant increases in sulfide, the end product of sulfate reduction. Analyses of the different forms of sulfur and sulfur stable isotopes ($\delta^{34}S$) in sediment profiles from these lakes indicated that the sulfide that is produced during sulfate reduction is subsequently oxidized to elemental sulfur and stored in sediment. Finally, in the sediment profiles from Amituk Lake and Char Lake, OC is positively related to the %THg that is MeHg, a crude proxy of methylation rate (*Drott et al. 2008*). Taken together, these suggest that there may be potential to use sediment profiles of reduced inorganic sulfur as a historical record of sulfate reduction, and perhaps even of MeHg production in Arctic lakes. As part of this project, we are therefore now examining the effects of climate-driven increases in algal production on Hg(II) methylation using Hg stable isotope tracers experiments.

Hg stable isotope tracers experiments were conducted at Meretta, Small, Amituk, and Char lakes in July 2010 and 2011 to examine the production of MeHg in lake surface sediments. Due to our past work and links to the char monitoring programs, Small, Amituk, and Char lakes are obvious choices for these experiments. Meretta Lake is also of importance because it has a known history of eutrophication (*Schindler et al. 1974, Michelutti et al. 2002*) and will help us explore the link between primary production and MeHg production. If increased availability of OC during periods of high primary productivity stimulated Hg(II) methylation by sulfate reducing bacteria in Meretta Lake, we should observe spikes in both inorganic sulfur and S2 in sediment cores during the eutrophication period. In addition to all the parameters described above, new dated sediment cores from Amituk, Char, Small, and Meretta lakes are therefore being analyzed for reduced inorganic sulfur. In addition to amendments with stable Hg isotope $^{202}Hg(II)$ (to measure rates of Hg(II) methylation) and $Me^{198}Hg$ (to measure rates of MeHg demethylation), a subset of cores were also amended with OC (acetate), sulfate, and molybdate (which stimulate and inhibit, respectively, the sulfate reducing bacteria that produce MeHg) to examine the mechanisms of MeHg production and the impacts of increased lake primary productivity on these processes. In total, we have a control (Hg methylation and demethylation rates without effects of amendments) and seven treatments (to understand the effects of the amendments on Hg methylation and demethylation rates; treaments include: 1-molybdate, 2-sulfate, 3-acetate, 4-molybdate, sulfate, 5-molybdate, acetate, 6-sulfate, acetate, and 7-molybdate, sulfate, acetate).

Data for Hg methylation rates ($k_{methylation}$ or k_m) for "control" sediments (i.e., no amendments) from Amituk, Char, Meretta, and Small Lakes are given in Table 2. Values for k_m from all four lakes are relatively low compared to other systems, including other arctic lakes (*Hammerschmidt et al. 2006*). The k_m value from Amituk Lake was below detection for the 8-hour incubation, but a relationship between k_m and % MeHg of Hg_T for the other lakes ($r = 0.973$) indicates the k_m for Amituk is likely close to the detection limit of 0.31 % per day (because % MeHg of Hg_T can be used as a proxy for k_m (*Drott et al. 2008*)). Among lakes, k_m increases with the concentration of Hg_T (Figure 5), indicating a dependence of Hg supply on methylation. The sediments from Meretta Lake greatly deviate from this trend, however, perhaps due to increased OC (which feeds microbes that methylate Hg) in this lake that received sewage effluent for years (*Douglas and Smol 2000*). Analyses for the effects of amendments, on k_m are in progress, and the results should shed light on the effect of organic carbon on Hg methylation. Analyses for MeHg demethylation rates are also in progress.

An important note regarding the data for k_m and ambient MeHg is that as these values increase among lakes (Amituk < Char < Small < Meretta), Hg_T concentrations in char go in the opposite direction (Small < Meretta < Char < Amituk). This inverse relationship suggests that sedimentary MeHg production does not control (or at least is not first-order with) MeHg accumulation in char and that other factors, such as feeding behavior and trophic dynamics may be more important in controlling MeHg concentrations in char.

NCP Performance Indicators

(see Table 3 for summary)

Number of northerners engaged in your project: Two for both summers 2010 and 2011 (Debbie and Brandy Iqaluk).

Number of meetings/workshops you held in the North: One informal meeting took place with HTA manager in Resolute Bay, summer 2010. Another informal meeting will be conducted in summer 2012. This project relies heavily on archived samples; thus numerous meetings were conducted during collection of the sediment cores being used in this study. The following communities were consulted:

- Repulse Bay, Nunavut
- Clyde River, Nunavut
- Iqaluit, Nunavut
- Arviat, Nunavut
- Rankin Inlet, Nunavut
- Baker Lake, Nunavut
- Coral Harbour, Nunavut
- Cape Dorset, Nunavut
- Igloolik, Nunavut
- Pond Inlet, Nunavut
- Whapmagoostui-Kuujjuarapik, Nunavik
- Kangiqsujuaq, Nunavik

In addition, investigators were invited to speak to the municipality of Clyde River by the mayor Andrew Iqalujuaq and deputy mayor Nick Illauq, meetings were conducted with local hunters from several of the above communities, as well as with Hunters and Trappers Organizations (HTO) in all Nunavut communities listed above. Finally, each time John Smol is in Iqaluit, he gives talks at the museum (last one was in 2008).

Number of students (both northern and southern) involved in your NCP work: Three students are involved in this project: One master's student supervised by Paul Drevnick at the University of Quebec and two co-op students (from Guelph University and the University of Waterloo) supervised by Jane Kirk at the Canada Centre for Inland Waters.

Number of citable publications: Three papers have already been published in Environmental Science and Technology, which is a high impact factor peer reviewed journal *(Drevnick et al. 2010, Kirk et al. 2011, and Kirk et al. 2012)* and two more publications are expected. Three conference presentations have been made (SETAC North America (2009), AGU (2010), and NCP workshops 2010-2011), and several more are expected.

Expected Project Completion Date

We expect all sample and data analysis to be completed by fall 2012.

Acknowledgements

NCP has been acknowledged formally in all publications and presentations and will continue to be acknowledged.

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Characterizing contaminant-related health effects in beluga whales from the Western Canadian Arctic

Caractérisation des effets des contaminants sur la santé des bélugas dans l'ouest de l'Arctique canadien

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Abstract

Beluga whales (*Delphinapterus leucas*) in the Arctic may be vulnerable to the combined effects of contaminants and a changing climate. That said, very little is known about the factors affecting the health of the cetaceans. We have been pioneering new methods to measure the health of beluga whales in close collaboration with Inuvialuit community members from Tuktoyaktuk. After much investment in method development in previous years, we report here the completion of sample analysis. Results suggest that contaminants are affecting several health endpoints in beluga whales. Relationships between the expression several gene transcripts (each of which controls the physiology of different hormones) and the concentrations of polychlorinated biphenyls (PCBs) were observed. However, it became apparent that inter-annual differences in these health endpoints could not only be attributed to contaminants, and may in fact be due to changes in sea ice extent and the feeding

Résumé

Les bélugas (*Delphinapterus leucas*) de l'Arctique peuvent être vulnérables aux effets combinés des contaminants et du changement climatique. Cela dit, notre connaissance des facteurs influant sur la santé des cétacés est très limitée. Nous avons mis au point de nouvelles méthodes pour évaluer la santé des bélugas en étroite collaboration avec les membres des collectivités inuvialuites de Tuktoyaktuk. Après avoir consacré de nombreux efforts à l'élaboration de méthodes dans les années précédentes, nous présentons ici les résultats de l'analyse d'échantillons, qui est terminée. Les résultats semblent indiquer que les contaminants influent sur plusieurs paramètres de la santé chez les bélugas. Nous avons observé les relations entre l'expression de plusieurs transcrits de gènes (chacun d'eux contrôlant la physiologie de différentes hormones) et les concentrations de biphényles polychlorés (BPC). Cependant, nous avons constaté que les différences interannuelles de ces paramètres de santé ne pouvaient pas

behaviour of beluga whales. If these two stressors affect beluga health, reduce stock abundance, and/or diminish the condition (quality) of beluga whales, there could be consequences for traditional harvests in the future. This project represented a collaboration between the Northern Contaminants Programme (NCP - INAC) and the Department of Fisheries and Oceans Canada *(Ecosystem Research Initiative.)*

être attribuées seulement aux contaminants, mais pouvaient, en fait, être causées par une modification de l'étendue des glaces et par le comportement alimentaire des bélugas. Si ces deux facteurs de stress ont une incidence sur la santé des bélugas, réduisent l'abondance des stocks ou détériorent l'état de santé (qualité) des bélugas, cela pourrait, à l'avenir, se répercuter sur les récoltes traditionnelles. Ce projet a donné lieu à une collaboration entre le Programme de lutte contre les contaminants dans le Nord (PLCN) d'Affaires autochtones et Développement du Nord Canada (AADNC) et le ministère des Pêches et des Océans du Canada (Projet de *recherche sur l'écosystème*).

Key Messages

- While directed field sampling for our project did not take place in 2011, monitoring continued (Stern NCP, Loseto FJMC), our program completed all chemical and health-related analyses.

- Results indicate that contaminants are affecting the health of beluga whales, but that inter-annual variation in distribution and feeding ecology also affect health.

Messages Clés

- Même si l'échantillonnage ciblé sur le terrain dans le cadre de notre projet ne s'est pas déroulé en 2011, la surveillance, elle, s'est poursuivie (Stern, PLCN; Loseto, CMGP), et toutes les analyses chimiques et liées à la santé sont terminées.

- Les résultats indiquent que les contaminants influent sur la santé des bélugas, mais que la variation interannuelle de la répartition et de l'écologie alimentaire a aussi une incidence sur la santé de ces animaux.

Objectives

Our 2011-12 project focused on completing laboratory analyses and the interpretation of data in the context of the health of beluga whales. While regular annual monitoring took place at Hendrickson Island in 2011 as part of contaminant trends reporting, we did not partake in this effort as we no longer had a field programme. We worked closely with the communications/TEK program to not only communicate our findings but to bring the results into context with local observations on beluga health.

1) Re-analyze beluga age data in support of health evaluation in beluga;

2) Complete genomic, endocrine and physiologic tool measurements to characterize the health of beluga (final QA/QC of species-specific genomics toolbox and all related measurements) using 2010 samples;

3) Conduct laboratory-based in vitro toxicity experiments to evaluate effects of mercury (Hg) and other priority contaminants on beluga health (in collaboration with the Vancouver Aquarium);

4) Focus on data analysis and the preparation and submission of publications,

5) Communicate with Hunters and Trappers Committee (HTC) in Tuktoyaktuk, the Fisheries Joint Management Committee (FJMC), the Northern Contaminants Programme secretariat,and the international scientific community.

Introduction

Beluga whales are at the top of the Arctic food web, rendering them vulnerable to contamination by a variety of persistent environmental contaminants that are transported from distant sources. Previous research has demonstrated that complex environmental mixtures of persistent organic pollutants (POPs) are affecting the health of free-ranging marine mammals in more industrialized (hence, more contaminated) regions of Canada (Ross 2006; Mos *et al.* 2006; Tabuchi *et al.* 2006; Buckman *et al.* 2011). Concerns about contaminants in the Canadian Arctic emanate, in part, from studies which demonstrate possible health effects in subsistence-oriented humans, polar bears and beluga whales (Dallaire et al. 2004; White et al. 1994; Braathen *et al.* 2004). Technical and logistical challenges have generally precluded health assessments in Arctic marine mammals, but new and emerging technologies provide an opportunity to build on past efforts and shed light on an important facet of Arctic contamination (Stern et al. 2005; Lockhart *e t al.* 2005;Muir *et al.* 1999).

A complicating juxtaposition in the way of climate change may add a layer of stress to beluga whales, by altering contaminant pathways, or by reducing the condition of beluga whales (Macdonald 2005). Despite the wealth of information about pathways and fate of different classes of environmental contaminants over time and space in the Arctic little is known about adverse health effects associated with these contaminants in vulnerable species, including beluga whales.

Changes in Arctic sea ice cover, temperature profiles, food web productivity, and beluga distribution and feeding ecology may profoundly change the course of contaminant fate in the Arctic environment, as well as the condition and health of beluga. Climate change has the potential to confound our understanding of mechanistic linkages between contaminant exposure and health effects, but may also have serious implications for the health of beluga whale populations. Our programme is designed to characterize condition and nutritional status of belugas in order to generate insight into the relationship between climate, contaminants and health of beluga.

Activities 2011/2012

This year focused on the completion of laboratory analysis, interpretation of the resulting large datasets, and submission of publications to scientific journals. Primary activities included:

- Completion of all beluga ages and genetic analyses to ensure matching of individuals with jaws;
- completion of fatty acid and stable isotope analyses;
- completion of all endocrine measurements (thyroid hormones and vitamin analyses), with a newly-leveraged collaboration with Vince Palace and Gregg Tomy;
- completion of genomics analysis (qPCR) using beluga-specific primers;
- completion of collaborative study (Vancouver Aquarium) on in vitro effects of mercury (Hg) on white blood cell function using fresh blood samples collected from captive beluga;
- evaluation of PCB and PBDE transfer from mother to fetus (opportunistic study);
- data analyses and interpretation on all projects;
- drafting and submission of manuscripts for submission to scientific journals;
- community outreach efforts.

Field Program: Frank and Nellie Pokiak and their family were on site for tissue sample collections for G. Stern (DFO) and provided training for two FJMC monitors. In addition, two youth from Tuktoyaktuk participated in the program and ran several small field projects.

Results

Morphometric analysis
Beluga whales harvested and sampled from 2007 to 2010 were all adults. Females taken were without young and were on average older than the males (Table 1). However, two females with fetuses are reported on separately below.

No differences were observed in beluga length among the four years sampled. However, age did differ among years (p = 0.011), with whales in 2008 being older than those in 2007 and 2009. It appears that the adult belugas had reached their asymptotic length which resulted in a weak size and age relationship (p = 0.57).

PCB and PBDE in beluga and variation with length and age
The concentrations of total PCBs did not differ among the four year sampled (males p = 0.89; Table 2). PCB congener -153 contributed the most to total PCBs (approx. 10% of the total), followed by PCBs -138, -101, -99, -52 and -118 that contributed to almost half of the total PCB concentration. Concentrations of PBDEs were an order of magnitude lower than PCBs. The concentrations of total PBDEs did not differ among the four years sampled (males p = 0.08; Table 2). PBDE congener -47 contributed the most to the total PBDE concentration (approx. 12% of the total). PCBs and PBDEs were positively correlated, this relationship being stronger when females were excluded (Males: p < 0.0001, r = 0.7).

Both PCB and PBDE concentrations did not vary with age of beluga (PCBs r = 0.1 p = 0.4; PBDEs r = 0.03 p = 0.8) (Figure 1). PCBs did correlate with length when all years and both sexes were combined (r = 0.6, p < 0.0001). For

Table 1. Beluga whales sampled from 2007 to 2010. Mean and ranges presented for lengths (m) and estimated ages based on one growth layer group (GLG).

Year	n (F)	Length (m)		Average Age (1GLG)	
		Males	Females	Males	Females
2007	18	4.2; 3.5-4.9		25; 15-41	
2008	21 (3)	4.2; 3.7-4.8	3.6; 3.5-3.9	34; 17-56	44; 32-60
2009	12 (6)	4.2; 3.7-4.4	3.7; 3.6-3.9	29; 23-54	47; 29-59
2010	10	4.1; 3.6-5.1		24; 16-28	

Table 2. The mean and SE of the sum of PCB and PBDE concentrations (ng/g lipid) in beluga (blubber) collected from 2007 to 2010. Concentrations of PCBs and PBDEs did not differ among years (p = 0.8; 0.08).

	PCBs (ng/g lw)		PBDEs (ng/g lw)		
Year	Male	Female	Male	Female	n (F)
2007	3,618.56 ± 366.9		23.48 ± 2.3		18 (0)
2008	3,540.90 ± 357.1	208.1 ± 487.2	17.94 ± 2.3	2.06 ± 7.78	19 (1)
2009	3,630.12 ± 449.4	780.9 ± 184.1	27.36 ± 2.8	19.6 ± 2.94	12 (7)
2010	3,171.53 ± 492.3		21.21 ± 3.1		10 (0)

the year 2008, however, the length relationship was not significant (2008 $r = 0.4$, $p = 0.9$). PBDEs correlated with length when all years and both sexes were combined ($r = 0.3$, $p = 0.04$), but not for the within-year samples in 2008 and 2009 (with and without females; 2008 $r = 0.04$, $p = 0.7$; 2009 $r = 0.3$, $p = 0.3$).

The lack of PCB relationship with age was unexpected as PCBs bioaccumulate readily over time in marine mammals; this may reflect a confounding influence of feeding, with size-affiliated habitat use groups contributing to divergent PCB exposures in our beluga.

Dietary biomarker trends: Insight into feeding relationships

PCB concentrations differed among the habitat size groups (as defined in Loseto et al., 2006; 2009; $r = 0.6$; $p < 0.0001$). The largest males had average PCB concentrations of 4400 ± 250 ng/g, and the smallest males had 1800 ± 480 ng/g. However, PBDEs did not differ among habitat groups ($r = 0.3$; $p=0.1$).

Stable isotopes $\delta^{15}N$, $\delta^{13}C$ did not relate to PCBs, PBDEs, length or age of beluga whales, nor did they differ among the habitat size groups.

While PCB concentrations varied with beluga length and size habitat groups, the lack of a length trend in 2008 suggested a potential change in feeding strategy (top down) or shift in food web processes (bottom up). To investigate the diet of our individual whales, a principal components analysis (PCA) was carried out on blubber fatty acids (Figure 2).

Figure 1. ∑ PCB concentrations (ng/g lw) increased with length, but not age.

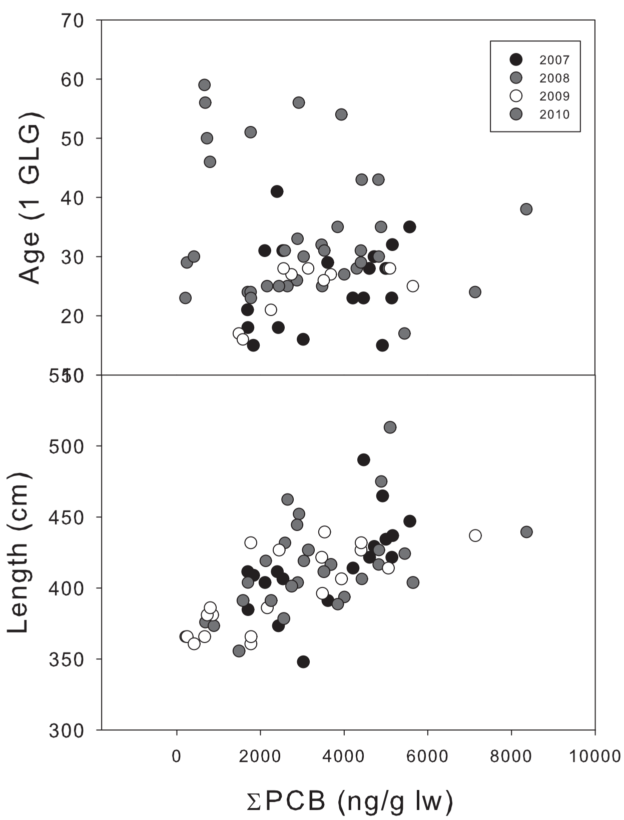
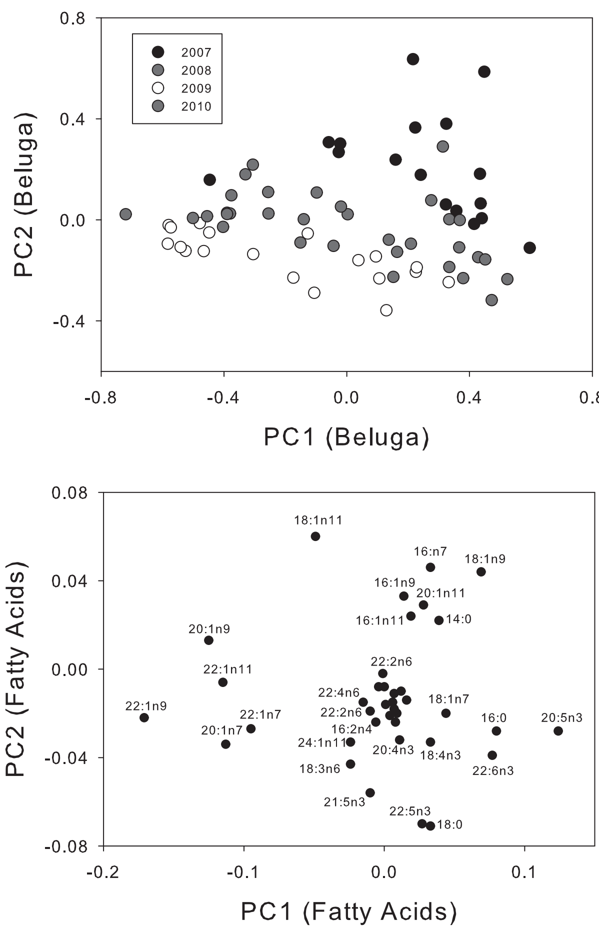


Figure 2. PCA (PC1: 53%, PC2: 16%) of 38 dietary fatty acids in beluga whale blubber samples: a) PCA scores plot of individuals by year of sampling, and b) PCA factor loadings of fatty acids contributing to dietary range.



The correlations between PC1 and PCB and PBDE concentrations (Table 3) support the notion that divergent feeding ecologies largely explained the PCB and PBDE outcomes. However diet did not relate to length in 2008 (Table 3), again suggesting that diet was not driven by size defined habitat associated foraging as observed previously (Loseto et al., 2008a, 2009).

The lack of a length-related divergence in feeding in beluga in 2008 suggests habitat use and associated diet *changed* in 2008. Given that beluga habitat is defined by sea ice and bathymetry, further investigation of habitat availability in particular of sea ice is underway. Despite apparent shifts in feeding in 2008, the overall implications to contaminant exposure appears minimal since concentrations in PCBs and PBDEs did not differ among years. However, PBDE concentrations were the lowest in 2008 (Table 2). Additionally, 2008 belugas were the most depleted in $\delta^{13}C$ ($p<0.0001$; -21.3‰), suggesting a pelagic diet over a benthic/nearshore diet.

The development and application of new genomics-based tools to assess beluga health

New genomics techniques such as quantitative polymerase chain reaction (qPCR) may offer opportunities to detect changes in targeted gene mRNA transcripts (Veldhoen et al. 2009). We developed new beluga-specific tools to investigate the impacts of PCBs and PBDEs on gene expression. Blubber, skin, liver, and muscle samples were collected from the 54 (24 from 2008, 20 from 2009, and 10 from 2010) Hendrickson Island beluga whales. Samples were preserved in RNA-Later solution and stored at -20°C until total RNA isolation.

We developed beluga whale-specific primers for 16 genes (in addition to 3 normalizer genes) based on their potential sensitivity to persistent organic pollutants, or their role in nutrition and

Table 3. Correlations of fatty acid PC1 and ∑PCB and ∑PBDE concentrations (ng/g lw) and beluga length for 2007 to 2010. Results for all years combined: PCBs r =0.52, p <0.0001; PBDEs r = 0.51, p <0.0001; Length r =0.31, p<0.0001.

	Fatty Acid PC1 vs PCBs		Fatty Acid PC1 vs PBDEs		Fatty Acid PC1 vs length	
Year	*R*	*P*	*r*	*P*	*r*	*p*
2007	0.722	0.001	0.652	0.003	0.568	0.014
2008	0.644	0.003	0.609	0.006	0.125	0.643
2009	0.719	0.001	0.655	0.008	0.476	0.046
2010	0.867	0.001	0.839	0.002	0.626	0.053

Table 4. Concentrations (wet weight) of Total mercury (THg), Methylmercury (MeHg) and Selenium (Se) in whole blood of beluga whales from Hendrickson Island (Beaufort Sea, Arctic, 2010).

	THg blood (µg/g)	THg blood (µM)	MeHg blood (µg/g)	MeHg blood (µM)	Se blood (µg/g)	Se blood (µM)
N	10	10	10	10	10	10
Mean ± SD	246 ± 105.5	1.36 ± 0.60	229.4 ± 83.9	1.20 ± 0.45	527.8 ± 105.6	7.50 ± 1.55
Range	154.9 – 450.6	0.87 – 2.53	158.4 – 395.7	0.83 – 2.07	312.8 – 695.9	4.30 – 9.80

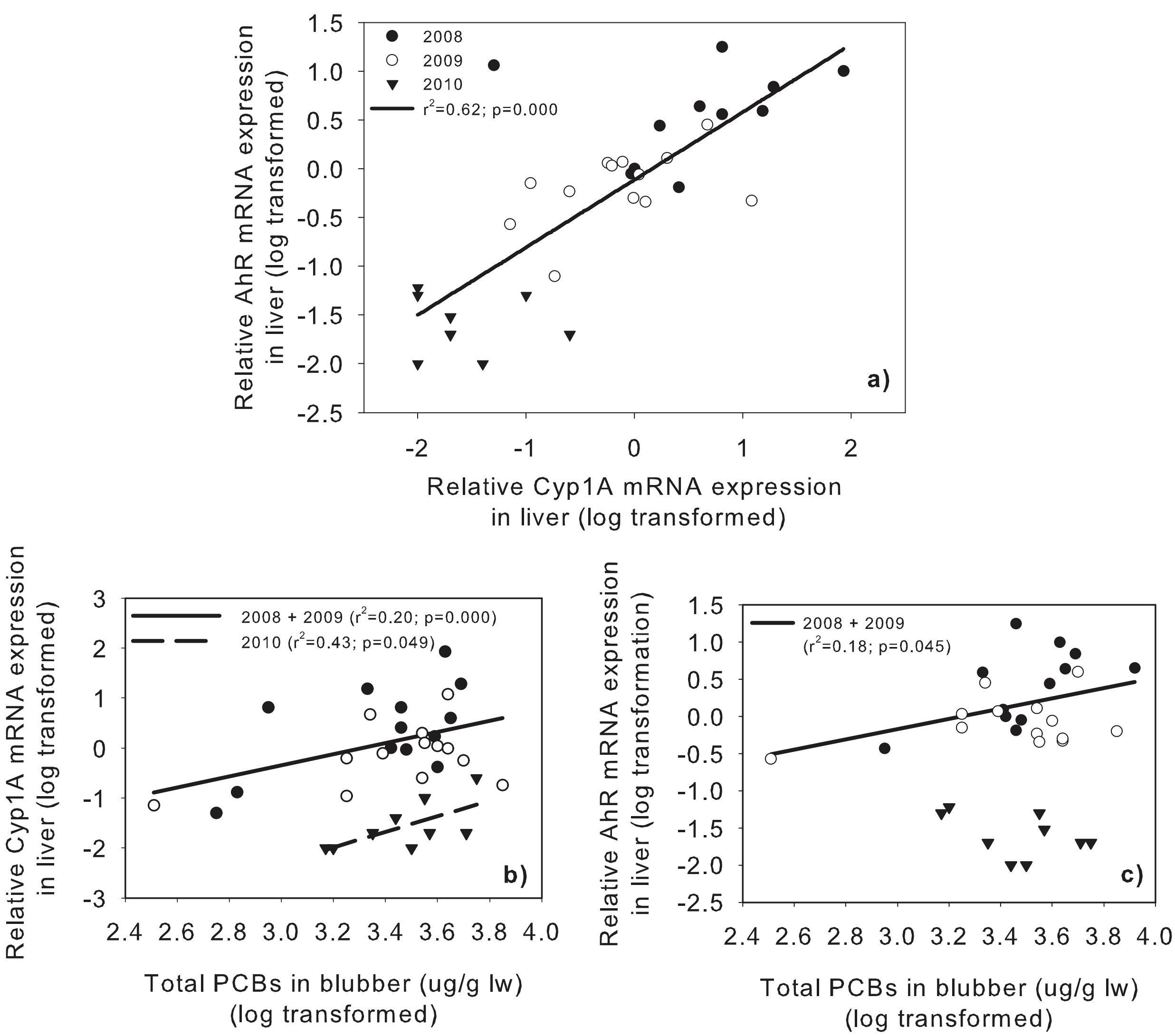
metabolism. Quantitative real-time polymerase chain reaction (qRT-PCR) was used to provide a relative quantification of results.

Normalizer genes are used to evaluate the quality of the data and provide a relative basis for the expression of addition genes. Bustin et al. (2010) recommended that normalisation should be performed against multiple housekeeping genes. In the present study, we use the geometric mean for the expression of our three housekeeping genes. We also present here the preliminary results for two important toxicology-related genes: Aryl hydrocarbon receptor (AhR) and cytochrome P450 (Cyp1A).

AhR and Cyp1A expression were quantified in liver, the main organ for metabolism of contaminants. Dioxin-like compounds such as certain PCB congeners exert their toxicity in part via the AhR, a soluble, ligand-activated transcription factor. The activation of AhR induces the transcription of multiple target genes including cytochrome P450 (Cyp 1A), a metabolizing enzyme.

The expression of AhR and Cyp1A increased significantly with age. 2010 whales had significantly lower AhR and Cyp1A expression probably reflecting their younger age, although the potential influence of feeding ecology,

Figure 3. Cyp1A and AhR mRNA expression in beluga male liver were closely interrelated (a). Each of these genes were up-regulated in whales with higher PCB levels (b and c). 2010 whales had lower Cyp1A and AhR expression likely due to their younger age.



contaminant exposure, and environmental conditions cannot be ruled out. Generally, the expression of AhR and Cyp1A increased with PCB concentrations (Figure 3), even though the relationship was not significant for AhR in the 2010 whales. This may be due to the very small sample size for that particular year.

While this is the first such report in Arctic wildlife, others have reported an increase in AhR expression with exposure to dioxin-like contaminants (Kim et al. 2005, Pitt et al. 2001). Jensen and Hahn (Jensen and Hahan 2001) also reported that the beluga AhR is a high affinity AhR suggesting that this species might be particularly sensitive to dioxin-like compounds.

Our preliminary results reveal that two important toxicology-related gene are up-regulated in Beaufort Sea beluga whales, despite their exposure to only moderate levels of PCBs. This indicates that individual whales are exposed to levels of contaminants that elicit physiological responses, although the extent to which these responses may affect this population is currently unclear.

Mercury toxicity in beluga white blood cells: limited selenium protection

As a natural element which is released through a variety of anthropogenic processes, mercury is found throughout the arctic environment, and is readily detectable in beluga whales (Table 4). While Hg is known to be toxic to mammals, little is known about its effects in beluga whales. Since dose-response studies are not practical in beluga whales, we developed a novel non-invasive strategy to evaluate the toxicity of Hg to white blood cells isolated from whole blood from live (captive) whales.

In this study, we 1) evaluated the effects of inorganic mercury (mercuric chloride, HgCl2) and organic mercury (methylmercuric chloride, MeHgCl) on the in vitro function of lymphocytes isolated from the peripheral blood of beluga whales; 2) characterized the potential protective effects of sodium selenite (Na2SeO3) on cell proliferation of HgCl2 or MeHgCl-treated beluga whale lymphocytes; and 3) compared these dose-dependent effects to measurements of blood Hg in samples collected from beluga whales in the western Canadian Arctic (Frouin *et al.*, 2012).

Lymphocyte proliferative responses were reduced following exposure to 1 µM of HgCl2 and 0.33 µM of MeHgCl (Figure 4). Decreased intracellular thiol levels were observed at 10 µM of HgCl2 and 0.33 µM of MeHgCl. Metallothionein induction was noted at 0.33 µM of MeHgCl. Concurrent exposure of Se provided a degree of protection against the highest concentrations of inorganic Hg (3.33 and 10 µM) or organic Hg (10 µM) for T-lymphocytes. Current Hg levels in free-ranging beluga whales from the Arctic fall into the range of exposures which elicited effects on lymphocytes in our study, highlighting the potential for effects on host resistance to disease in free-ranging beluga whales (Figure 5).

Table 4. Concentrations (wet weight) of Total mercury (THg), Methylmercury (MeHg) and Selenium (Se) in whole blood of beluga whales from Hendrickson Island (Beaufort Sea, Arctic, 2010).

	THg blood (µg/g)	THg blood (µM)	MeHg blood (µg/g)	MeHg blood (µM)	Se blood (µg/g)	Se blood (µM)
N	10	10	10	10	10	10
Mean ± SD	246 ± 105.5	1.36 ± 0.60	229.4 ± 83.9	1.20 ± 0.45	527.8 ± 105.6	7.50 ± 1.55
Range	154.9 – 450.6	0.87 – 2.53	158.4 – 395.7	0.83 – 2.07	312.8 – 695.9	4.30 – 9.80

Figure 4. The proliferation of T lymphocytes (bars) and their viability (lines) following different exposures to inorganic mercury (A) and organic mercury (B). Results are expressed as a (%) of the control response (unexposed cells). (*n* = 3 for inorganic mercury and *n* = 4 for organic mercury per dose group; mean ± standard error). * $p \leq 0.05$, # $p \leq 0.01$. Viability was decreased after a 48 hr-exposure to 10 µM HgCl2 or 1 µM MeHgCl. T-lymphocyte proliferation was inhibited following a 48 hr-exposure to 1 µM of HgCl2 and 0.33 µM of MeHgCl.

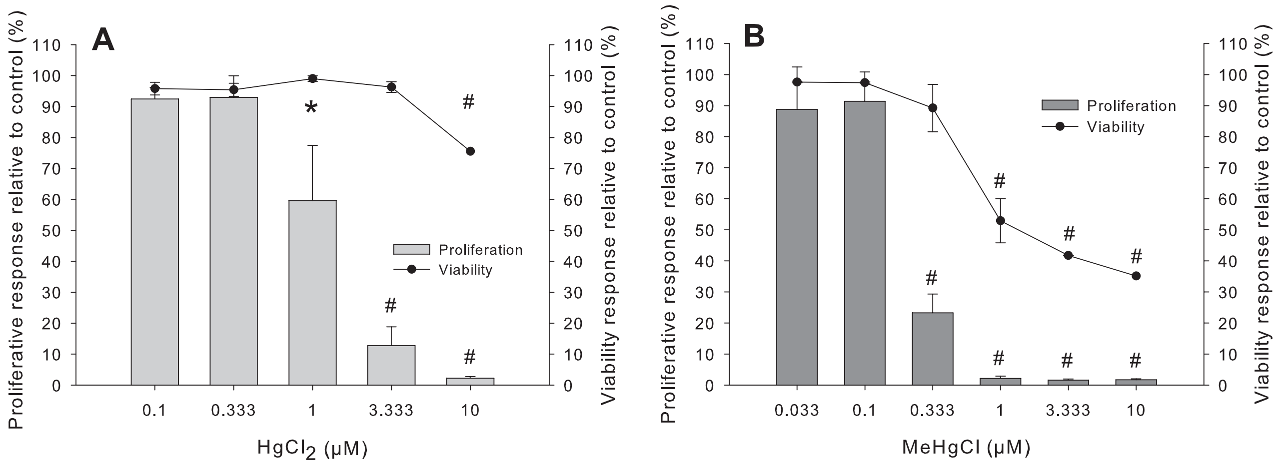
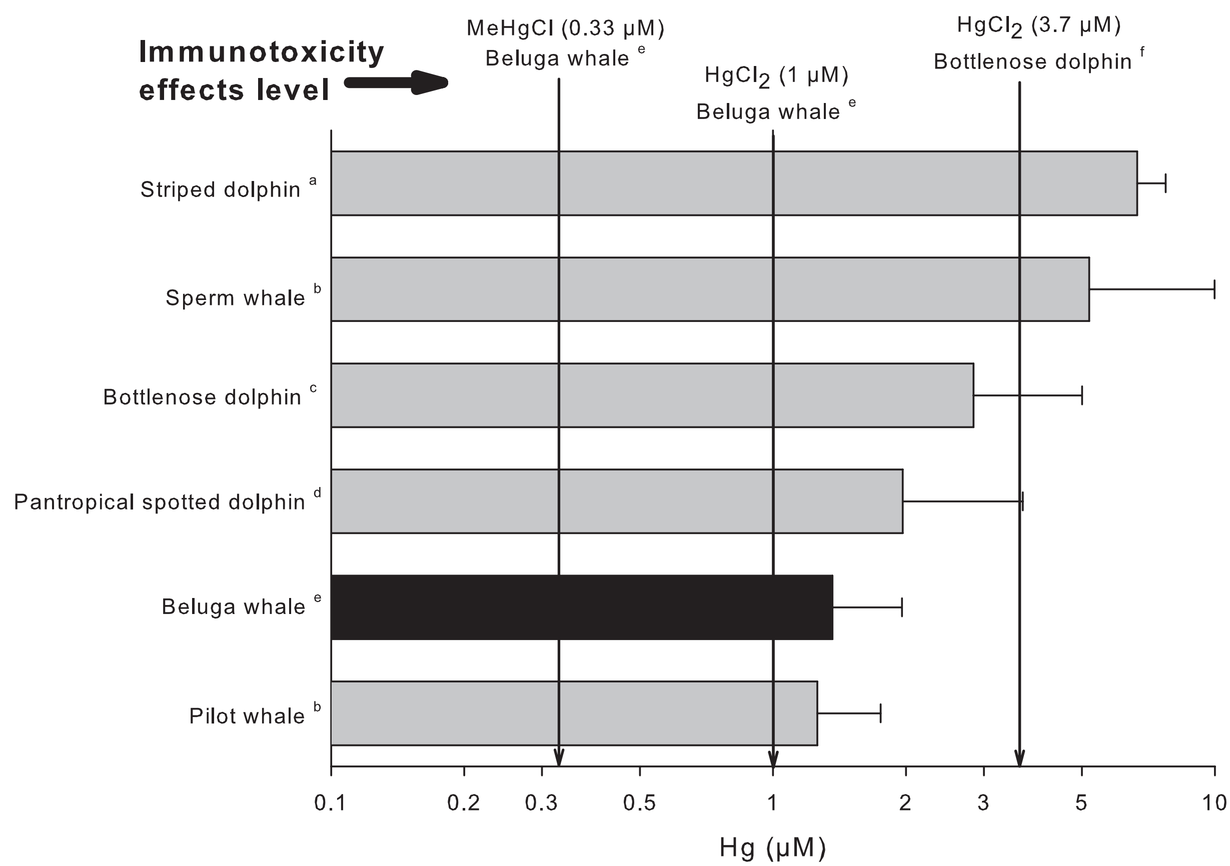


Figure 5. Hg concentrations (mean ± SD) reported in blood of cetaceans (bars) and lowest concentrations of MeHgCl or $HgCl_2$ inducing a decrease of proliferative response of T-lymphocytes (stimulated with Con A; solid lines). Data from a: Itano et al. (1984); b: Nielsen et al. (2000); c: Woshner et al. (2008); d: André et al. (1990); e: this study and f: Camara Pellisso et al. (2008).



Transplacental transfer of contaminants in beluga whales

Organic pollutants are transferred from females to their offspring throughout the reproductive process, thus exposing neonates to some of the highest concentrations of these endocrine disrupting compounds they will encounter during their lifetime. Lactational transfer of pollutants has been well described in marine mammals, but in *utero exposure* has rarely been documented because of obvious difficulties in obtaining fetal samples from healthy pregnant females.

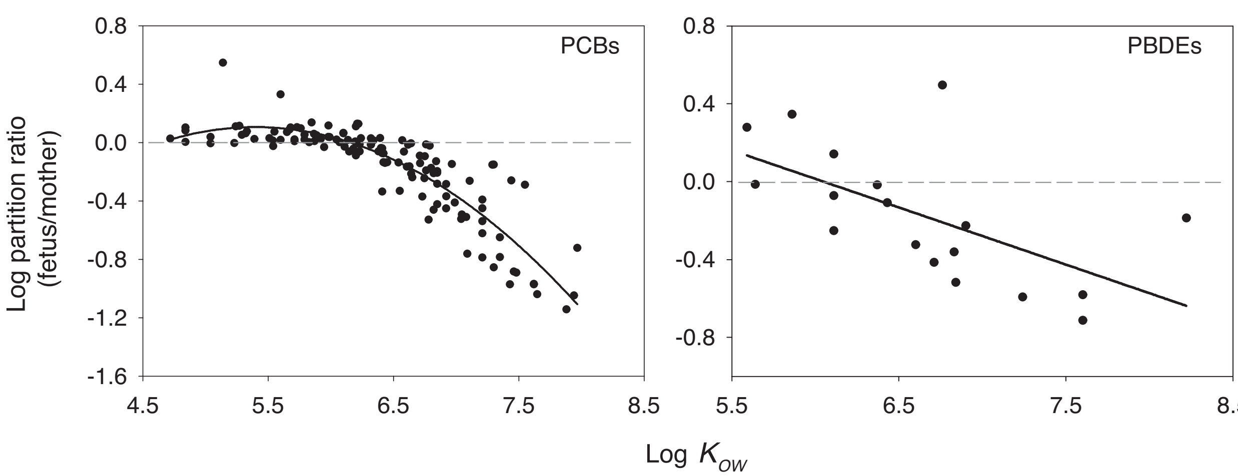
During the 2008 and 2009 traditional beluga harvests at Hendrickson Island, two individual adult females were found to be pregnant. Paired mother-fetus samples were analysed for PCBs and PBDEs (Desforges et al., 2011). We found that beluga mothers are offloading approximately 11% of their total blubber burden to their young before birth. Furthermore, this transfer was not uniform among PCB and PBDE congeners, but was highly dependent on the octanol-water partitioning coefficient (Log KOW). Congeners of both PCBs and PBDEs with values below 7 were more readily transferred across the placental barrier than heavier congeners (Figure 6). These results highlighting congener-specific placental transfer efficiencies suggest marine mammal offspring are being exposed to different contaminant profiles than their mothers.

The toxicological implications of the ready placental transfer of organic contaminants in these beluga are unclear. The risk of toxic insult to neonates is enhanced during pregnancy because exposure occurs during development when hepatic metabolic pathways appear to decrease (Juchau and Faustman-Watts 1983). Experimental studies suggests severe reproductive effects including fetal malformations and mortality, decreased litter size and lower survival rate of newborns (Kihlstrom et al. 1992, Reijnders 1986, Wells et al. 2005). More research is needed to assess the risk of chemical exposure during critical stages of fetal development.

Expected Project Completion Date

This project is complete, but a series of scientific deliverables (manuscripts for submission to journals) will continue until March 31, 2013.

Figure 6. Average partition ratios plotted against logarithmic octanol-water partition coefficients (log K_{ow}) for PCBs and PBDEs. Partition ratios were calculated as the blubber concentration in the fetus divided by that in the mother and were logarithmically transformed. The dashed line represents partition parity.



NCP Performance Indicators

Performance Indicator	Number	Details / Description
Number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	0	
Number of project-related meetings/ workshops held in the North (April 1, 2011 - March 31, 2012)	4	Meetings held in Tuktoyaktuk, Anchorage, and with the Inuvialuit Game Council (2)
Number of students (both northern and southern) involved in your NCP work (April 1, 2011 - March 31, 2012)	0	
Number of citable publications (e.g., in domestic/ international journals, conference presentations, book chapters, etc)	2	Desforges, J.P.W., Ross,P.S., and Loseto, L.L. 2012. Transplacental transfer of polychlorinated biphenyls and polybrominated diphenyl ethers in Arctic beluga whales *(Delphinapterus leucas)*. Environ.Toxicol.Chem. 31: 296-300. Frouin, H., Loseto, L., Stern, G., Haulena, M., Ross, P.S. 2012. Mercury toxicity in beluga whale lymphocytes: limited effects of selenium protection. Aquatic Toxicology 109, 185-193.

Conference and workshop presentations:
Frouin, H., Haulena, M., Loseto, L., Stern, G., Ross, P.S., 2011. Mercury and climate change: a worst-case combination for arctic beluga whales *(Delphinapterus leucas)*? 19th Biennial Conference on the Biology of Marine Mammals, Tampa, USA. 28 November-2 December.

Loseto, L.L., S. Ostertag, F. Pokiak, N. Pokiak, R. Pokiak, M. Pokiak, E. Loring, M. Andrachuk, M. Noel, G. Stern, P.S. Ross. .A community approach to collecting and sharing knowledge: Beaufort Sea Beluga Study. Oral presentation at the International Polar Year Conference, Montreal, Quebec.

Loseto, L.L., G. Stern, R. Macdonald, M. Noel, P.S. Ross. 2012. Evaluating the potential impacts of a receding ice edge on Beaufort Sea Beluga Whales. Poster presentation at the International Polar Year Conference, Montreal, Quebec.

Noel M., Loseto L.L., Helbing C., Ross P.S., 2012. PCBs and beluga health: Investigation at the molecular level. Oral presentation at the International Polar Year Conference, Oral presentation at the International Polar Year Conference, Montreal, Quebec.

Noel M., Loseto L.L., Dangerfield N., Helbing C., Veldhoen N., Ross P.S., 2011. PCBs and beluga health: What can we learn from genomics analyses? Poster presentation at the Northern Contaminant Program conference, Vicoria, British Columbia.

Ross, P.S., Brown, T., Reimer, K., Stern, G., Tomy, G., and Loseto, L.L. Towards a risk-based evaluation of persistent organic pollutants (POPs) in arctic marine mammals. 2011. Poster presented at NCP annual workshop. Victoria, BC.

Ross, P.S., M. Noel, H. Frouin, J.-P. Desforges, G. Stern, G. Tomy, R.W. Macdonald, F. Pokiak, N. Pokiak, B. Hickie, N.J. Dangerfield, and L.L. Loseto. 2011. Contaminant-related health effects in beluga whales from the western Canadian arctic: A progress report. Oral presentation to NCP annual workshop. Victoria, BC.

Outreach communications
Community workshop: March 2012. Loseto, L.L., Noel, M., Ostertag, S., Raverty S. Sharing knowledge about belugas. Community workshop in Tuktoyaktuk to present results and solicit feedback from the community. Information was also shared with elders at the elders' home and at the Mangilaluk school.

Loseto, L.L., Stern, G., Ross, P., Noel, M., Tomy, G. Beluga Health Program: Updates and future planning. Fisheries Joint Management Committee Meeting. Winnipeg MB, Jan. 19, 2012.

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Pokiak, F., Loseto, L. and team members. Beluga Health Project: team update. Inuvialuit Final Agreement Research Day, March 04 2011.

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Cadmium and Selected Metals in NWT Moose

Détection de cadmium et d'autres métaux choisis dans l'orignal, dans les Territoires du Nord-Ouest

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Abstract

Moose are an important traditional and cultural resource for northern First Nations communities, and an important traditional food that makes up a significant part of the diet for many people in northern Canada. While some work has been done on the types and levels of contaminants in moose in the Yukon, there has been limited information on contaminants in moose in the Northwest Territories. While many elements are found at relatively low levels in terrestrial ecosystems, elevated levels of some metals including cadmium have been found in the kidneys of caribou and moose in some areas. Levels remain low in the meat of those animals. A recent study of contaminant levels completed as part of a community-based moose monitoring program in the Dehcho Region of the NWT found elevated levels of cadmium in kidneys and livers, with significantly higher levels in animals harvested in the southern Mackenzie Mountains compared to the Mackenzie and Liard River

Résumé

L'orignal est une importante ressource traditionnelle et culturelle parmi les collectivités des Premières Nations dans le Nord, de même qu'un aliment traditionnel qui constitue un élément de base du régime de beaucoup de résidants du Nord du Canada. Les types et concentrations de contaminants dans l'orignal ont fait l'objet de quelques études au Yukon, mais on dispose de peu d'information sur les contaminants de l'orignal dans les Territoires du Nord-Ouest (T.N.-O.). On retrouve beaucoup d'éléments à des concentrations relativement faibles dans les écosystèmes terrestres; dans certains secteurs, par contre, des concentrations élevées de certains métaux, dont le cadmium, ont été détectées dans le rein du caribou et de l'orignal, bien que ces concentrations demeurent faibles dans leur chair. Récemment, une étude des concentrations de contaminants, menée dans le cadre d'un programme communautaire de surveillance du caribou

valleys in the same region. As a result of this preliminary study, a public health advisory was released on the consumption of moose organs in this area. Data are not available on levels of cadmium and other metals in moose in other areas of the NWT, and it is not known if similar elevated levels of cadmium and differences in mountain/valley moose occur further north in the Mackenzie Mountains. This project collected samples through existing regional hunter-based moose monitoring programs, tested for 34 different elements in moose from several regions of the NWT, examined variations in cadmium levels in mountain, valley and boreal forest moose, assessed tissue levels in moose from a human dietary exposure perspective, and looked for evidence of renal changes in moose that might be associated with the presence of elevated renal cadmium levels. Data is currently being analyzed, and an in-depth reporting will be available later in 2012.

dans la région du Deh Cho des T.N.-O., a permis de détecter des concentrations élevées de cadmium dans les reins et foies qui étaient bien plus prononcées chez les animaux du sud des monts Mackenzie que chez ceux des vallées du Mackenzie et de la rivière Liard, dans la même région. Cette étude préliminaire a mené à la publication d'un avis sanitaire sur le danger de consommer les organes de l'orignal dans ce secteur. On ne dispose d'aucune donnée sur les concentrations de cadmium et d'autres métaux dans l'orignal qu'on retrouve dans les autres secteurs des T.N.-O., et on ignore si les mêmes concentrations élevées de cadmium, et les mêmes différences entre l'orignal dans la montagne et dans les vallées, sont observées plus au nord dans les monts Mackenzie. Pour ce projet, on a recueilli des échantillons au moyen des programmes régionaux actuels de surveillance de l'orignal par les chasseurs, testé la présence de 34 éléments dans des orignaux provenant de plusieurs régions des T.N.-O., examiné les variations dans les concentrations de cadmium chez l'orignal des montagnes, des vallées et de la forêt boréale, évalué les concentrations dans la chair de cet animal du point de vue alimentaire, et recherché des indices de changement rénal, dans l'orignal, pouvant découler de la présence de fortes concentrations de cadmium dans le rein. Les données sont en cours d'analyse; un rapport approfondi sera publié plus tard en 2012.

Keys Messages

- While levels of contaminants in terrestrial ecosystems are generally low compared to marine and freshwater ecosystems, elevated levels of some metals including cadmium have been found in caribou and moose in some areas of northern Canada and Scandinavia.

- This project examined metal levels in moose from a range of locations in the Mackenzie mountains, valley and boreal forest to look at spatial patterns and geographical variation in contaminant exposure, support an updated human dietary exposure assessment, provide information for informed decision making by harvesters, and look at the significance

Messages clés

- Les concentrations de contaminants sont en général faibles dans les écosystèmes terrestres par comparaison avec celles des écosystèmes marins et d'eau douce, mais certains métaux, dont le cadmium, ont été détectés en concentrations élevées dans le caribou et l'orignal vivant dans certains secteurs du nord du Canada et de la Scandinavie.

- Le projet a analysé les concentrations de métal dans des orignaux provenant de lieux divers dans les monts Mackenzie, les vallées et la forêt boréale en vue de détecter les tendances spatiales et les variations géographiques dans l'exposition aux of these elevated levels for renal structure and function in moose.

- Samples (kidney and liver for contaminants, teeth for age) were collected from local hunters as part of regional moose monitoring programs.

- The raw data were forwarded to Health Canada by the GNWT Department of Health and Social Services for an assessment of dietary exposure in people consuming moose organs, which can be used to revisit existing public health advisory currently in place for moose in the South Mackenzie Mountains as well as moose from other areas.

- The data are currently undergoing a QA/QC review prior to analysis, interpretation and write-up. An in-depth reporting will be available later in 2012, and summary reports will be produced for distribution to all participating communities.

contaminants, d'appuyer une évaluation récente actualisée de l'exposition alimentaire humaine, de fournir aux chasseurs l'information qui leur permettra de prendre des décisions judicieuses, et d'examiner les incidences de ces concentrations élevées sur la structure et la fonction rénales de l'orignal.

- On a recueilli des échantillons (reins et foies pour les contaminants, dents pour l'âge) auprès des chasseurs locaux, dans le cadre des programmes régionaux de surveillance de l'orignal.

- Le ministère de la Santé et des Services sociaux du GTNO a transmis les données brutes à Santé Canada en vue d'évaluer l'exposition alimentaire des personnes qui consomment les organes de l'orignal, évaluation qui peut servir à modifier l'avis sanitaire actuel concernant l'orignal dans le sud des monts Mackenzie, de même que l'orignal d'autres secteurs.

- Les données font l'objet d'une analyse de la qualité et d'un contrôle de la qualité avant d'être analysées, interprétées et enregistrées. Un rapport approfondi sera disponible plus tard en 2012, et des rapports sommaires seront préparés et distribués à toutes les collectivités participantes.

Objectives

- Assess baseline levels and spatial patterns of several key metals including cadmium in moose (*Alces alces*) from geographically distinct areas of the NWT.

- Confirm differential levels of cadmium in moose from the southern Mackenzie Mountains and moose in the Mackenzie valley.

- Provide additional data to support an updated assessment of the human health significance of cadmium levels in an important traditionally harvested species.

- Examine if there are possible renal changes in moose associated with the presence of elevated tissue cadmium levels.

Introduction

Moose are an important traditional and cultural resource for northern First Nations communities and an important traditional food. In some regions including the Dehcho and South Slave, moose are one of the most frequently consumed traditional food species (Kim et al. 1998; Receveur et al. 1996). While the levels of contaminants in terrestrial ecosystems are generally low compared to the marine and freshwater ecosystems, elevated levels of some metals including cadmium have been found in caribou and moose in some areas of northern Canada and Scandinavia (Braune et al. 1999). While some work has been done in the Yukon, there has been limited information on contaminants in moose in the NWT. A recent study in the Dehcho region found elevated levels of cadmium, with significantly higher levels in moose harvested in the southern Mackenzie Mountains (SMM) compared to the Mackenzie and Liard River valleys (MLR) (Larter 2009). This data led to the release of a public health advisory for this area which recommended no consumption of moose kidneys in the SMM (Larter and Kandola 2010).

While there is some variability in levels of cadmium in barren-ground caribou across the arctic (Gamberg 2005; Elkin and Bethke 1995), there appears to be greater variability in levels of cadmium in moose based on location (Larter 2009; Larter and Kandola 2010). This project examined metal levels in moose from a range of locations in the Mackenzie mountains, valley and boreal forest to look at spatial patterns and geographical variation in contaminant exposure, support an updated human dietary exposure assessment, provide information for informed decision making by harvesters, and look at the significance of these elevated levels for renal structure and function in moose.

Cadmium concentrations in moose kidneys in some areas of the Yukon and NWT are higher than those seen in barren-ground caribou, which may be explained by differences in diet. Willows (Salix sp.) hyper-accumulate cadmium (Vandecasteele et al. 2002) and are a preferred food for moose (Risenhoover 1989). The relative contributions of local sources versus long-range (or remote) transport for cadmium levels observed are not well understood, but both likely make a contribution. Renal cadmium concentrations reported in Yukon moose were higher than levels reported from Manitoba, Quebec, Newfoundland, Norway and Sweden (Gamberg 2005; Braune et al. 1999; Froslie et al. 1986; Scanlon et al. 1988; Frank 1986; Brazil and Ferguson 1989; Crichton and Paquet 2000; O'Hara et al. 2001), and similar to levels seen in Ontario (Glooschenko et al. 1988) and New Brunswick (Redmond et al. 1988).

Gamberg (2005) and Larter (2009) have reported cadmium levels in some moose, particularly from the southeastern Yukon and southern Mackenzie Mountains, with renal concentrations within the range at which kidney dysfunction may occur in other species (Kjellstrom 1986). This study looked at the potential for cadmium associated renal effects, particularly in older moose. Reported changes associated with elevated renal cadmium include granular degeneration in proximal tubules, glomerular endothelial proliferation, vacuolar degeneration, shrunken and degenerating nuclei, and necrosis of renal proximal tubular epithelium (Stoev et al. 2003; Beiglbock et al. 2002). This study examined both metal levels and a number of these histological changes associated with cadmium exposure in paired samples.

Activities in 2011-2012

Samples (kidney and liver for contaminants, teeth for aging) were collected from local hunters as part of regional moose monitoring programs. Sample kits were provided to individual hunters, and were returned for processing by the regional biologists. As part of these monitoring programs, data collected from each animal included age, sex, reproductive status, location and habitat where harvested, as well as body condition and morphometric indices. Samples from the Mackenzie Mountains were collected by the Nahanni Butte Outfitters, South Nahanni Outfitters and Gana River Outfitters, and forwarded to the Dehcho regional biologist for processing. In an independent project, contaminant levels were also evaluated for Northern Mountain caribou, Dall's sheep and mountain goats in the same general geographical area as moose collected in the south Mackenzie Mountains.

Samples were tested for a suite of 32 elements including cadmium and mercury by the National Laboratory for Environmental Testing (NLET) in Burlington, Ontario. Analyses were conducted using inductively coupled plasma-mass spectroscopy, and cold vapour atomic absorption spectroscopy for total mercury. Blanks consisting of all lab reagents were used to check lab performance, and certified reference materials from the National Research Council of Canada were run with each batch of 20 samples. Analyses were done primarily on kidney samples, while a select number of liver and muscle samples were run to examine the relationship of levels between the two organs and muscle tissue. Muscle samples were also submitted for stable isotope analysis. An incisor tooth (I1) from each animal was forwarded for Matson's Laboratory in Milltown, Montana for aging by cementum analysis. Laboratory contaminant analyses have been completed (some stable isotope and age data still pending), and the raw data are currently being analysed and interpreted. The raw data were forwarded to Health Canada by the GNWT Department of Health and Social Services for an assessment of dietary exposure in people consuming moose organs, which can be used to revisit existing public health advisory currently in place for moose in the South Mackenzie Mountains as well as moose from other areas.

Paired frozen and formalin-fixed kidney samples were collected from as many animals as possible, and the fixed samples were submitted for histological analysis by a veterinary pathologist. Kidney portions were trimmed so that two sections from different areas of the kidney portion were prepared for histology. Tissue sections were embedded in paraffin, sectioned at 4 um and placed on glass slides, and stained with hematoxylin and eosin. Both sections of each kidney were examined by a pathologist who was blind to the age, sex, location harvested, and cadmium levels of each animal. A semi-quantitative scoring system based on Beiglbock et al. (2001) and Stoev et al. (2003) was used to evaluate histologic changes in the renal tissue. Each kidney section was assessed for the presence of the following changes: vacuolar or granular degeneration, necrosis, pyknosis and karyolysis of the proximal tubules, lymphohistiocytic inflammation, interstitial fibrosis, nephrocalcinosis, pigment deposits (intra- and extracellular), hemorrhage, cast formation, and thickened Bowman's capsule, cellular swelling, and mesangial or endothelial swelling of the glomeruli. Each of the observed changes were given a score of 0 (normal), 1 (mild change), 2 (moderate change), or 3 (severe change). The location of the inflammation, nephrocalcinosis, pigment deposits, and hemorrhage were also recorded. Other changes not included in this list were noted. The histologic assessment has been completed, and the data are currently being analyzed in combination with tissue contaminant levels.

Capacity Building

This project was done collaboratively with ongoing community-based moose monitoring programs. GNWT Environment and Natural Resources staff worked with local hunters to collect a suite of samples to provide data on a range of parameters including age, sex, morphometrics, condition, and select disease and parasite status. Training and sample kits are provided to hunters, and hunters were compensated financially for each completed sample and data kit returned. This approach builds capacity among local communities to participate in wildlife monitoring programs, and benefits from the experience and knowledge of the hunters. GNWT Environment & Natural Resources staff are also trained in handling and preparing contaminant samples, ensuring quality of samples submitted for analysis.

Communications

ENR Regional Biologists consulted with local communities and First Nations organizations in all of the participating areas prior to the beginning of the project, as well as with outfitters in the south Mackenzie Mountains. Following completion of the data analysis, interpretation, write-up and human health assessment, summary reports will be produced for distribution to all participating communities. Regional project personnel will be available to make in-person presentations to organizations upon request, and results will be presented at bi-annual regional wildlife workshops in the Dehcho (fall 2012) and South Slave (TBD) that will include representation from all communities and aboriginal organizations in the region. The project results will also be communicated with the Northwest Territories Regional Contaminants Committee (NWTRCC), both in a written report and at a regular NWTRCC meeting. Study results will be written up for publication in a peer-reviewed journal.

Traditional Knowledge

This project was done collaboratively with on-going regional community-based moose monitoring programs (Mackenzie valley and boreal forest samples). Field sampling was done by local harvesters, with traditional and local knowledge playing an important role in determining where to hunt based on moose behaviour, field harvesting and sampling of the animals, and assessing the health and condition of the animals harvested.

Results

Laboratory analysis of moose samples have been completed by NLET for 34 elements including cadmium and mercury. The data are currently undergoing a QA/QC review prior to analysis, interpretation and write-up. The histopatholgical assessment of fixed kidney samples has been completed, and will be analyzed in parallel with the contaminant data for the same animals. Some of the tooth aging and the muscle stable isotope analyses are still pending.

Discussion and Conclusions

Moose are an important traditional and cultural resource for northern First Nations communities and an important traditional food that makes up a significant part of the diet for many people in the NWT. Limited work has been done on metals and other contaminants in moose in the Northwest Territories. An initial study on contaminants in moose in the Dehcho Region found elevated levels of cadmium, with significantly higher levels in moose harvested in the southern Mackenzie Mountains (SMM) compared to the Mackenzie and Liard River valleys (MLR). The mean level of cadmium in kidneys from moose harvested in the SMM was 222.5 µg/g wet weight (ww) (range 8.9 - 624.0), and 30.9 µg/g ww (1.3 – 183.0) in livers. In

NCP Performance Indicators

Performance Indicator	Number	Details / Description
Number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	23	Hunters, guides, outfitters involved in sample & data collection
Number of project-related meetings/workshops held in the North (April 1, 2011 – March 31, 2012)	4	PKFN, LKFN, SKDB community meetings: South Slave Regional Wildlife Workshop
Number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	2	
Number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	2011:0 2012:TBD	Anticipate 1 publication and 1 conference presentation

contrast, moose harvested in the valley had mean levels of cadmium in kidneys and livers of 26.8 (range 0.2 – 222.0) and 2.7 (range 0.05 – 9.4) µg/g ww respectively (Larter and Kandola 2010). As with previous studies, tissue cadmium levels were positively correlated with moose age. Levels of cadmium in muscle (0.1 µg/g) and levels of other elements measured were similar to those reported elsewhere in the literature for free-ranging ungulates. These data led to the release of a public health advisory for this area which recommended no consumption of moose kidneys in the SMM. Additional monitoring of moose is being done to confirm these findings, assess levels in moose from other areas of the NWT, and examine the spatial pattern and geographical variation in contaminant exposure in this important terrestrial species. These results will also support human dietary exposure assessments, support informed decision making among individuals harvesting this traditional food species, and provide insight into the significance of these elevated levels for renal function in moose. Laboratory analyses for this project have been completed, and the data are currently being analyzed and interpreted, and will be written up and communicated in 2012.

Expected Project Completion Date

Data analysis, interpretation and write-up should be completed by end of 2012/2013.

Acknowledgments

Local harvesters from Jean Marie River First Nation, Salt River First Nation, Ft. Smith Métis, Deninu Kue First Nation and Ft. Resolution Métis provided samples and ongoing support for moose monitoring programs. Nahanni Butte Outfitters, South Nahanni Outfitters and Gana River Outfitters provided samples from moose harvested in the Mackenzie Mountains. Contaminant analysis was done by the National Laboratory for Environmental Testing (NLET), Ziaowa Wang coordinated the laboratory analysis, and Amy Sett did sample processing, moisture content and DMA analyses. Funding was provided by the Northern Contaminants Program and the Government of the Northwest Territories.

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Investigation of Mercury Toxicity in Landlocked Char in High Arctic Lakes

Étude de la toxicité du mercure chez l'omble chevalier confiné aux eaux intérieures dans les lacs de l'Extrême-Arctique

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Abstract

Mercury (Hg) degrades the ecosystem services that fish provide. Consumption of contaminated 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, 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 D. Muir (Environment Canada). The lakes sampled

Résumé

Le mercure (Hg) détériore les services écosystémiques fournis par les poissons. La consommation de poisson contaminé est la principale source de mercure chez les humains et les animaux sauvages et s'avère néfaste pour leur santé. De plus, le mercure cause aussi des effets toxiques chez les poissons euxmêmes. Dans le nord du Canada et particulièrement au Nunavut, les concentrations de mercure peuvent être élevées chez les poissons prédateurs, y compris chez l'omble chevalier (Salvelinus alpinus) confiné aux eaux intérieures. L'analyse des données sur l'omble chevalier dans le nord du Canada et au Groenland indique que 30 % des populations de poissons étudiés dépassent les seuils de toxicité pour le mercure. En 2011, nous avons capturé des ombles chevaliers dans des lacs d'un écosystème d'intérêt pour le PLCN, à l'île Cornwallis, afin de déterminer si

(Small, 9-mile, North, Char, Amituk) span a gradient of Hg contamination, allowing for the comparison of biological endpoints in char with low Hg concentrations to char with high Hg concentrations. Endpoints relate to 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 concentrations. Effects on the liver are more severe – at moderate Hg concentrations, injury to tissues is minor because of repair mechanisms, but at high Hg concentrations (Amituk only), repair is inhibited and there is widespread cell death and tissue inflammation. In 2012, more char will be collected from each lake for further analyses. 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 documenting Hg concentrations in fish and will provide critical knowledge concerning the status of fish health, and as stated in the latest NCP blueprint, "the health of northern Aboriginal populations is intimately linked to the health of Arctic ecosystems."

les populations sauvages subissent vraiment les effets toxiques du mercure. L'échantillonnage a été effectué en collaboration avec l'équipe du projet de surveillance de base de l'omble chevalier, dirigée par D. Muir (Environnement Canada). Les résultats obtenus pour les lacs échantillonnés (Small, Nine Mile, North, Char, Amituk) indiquent un gradient de contamination par le mercure, permettant la comparaison de paramètres biologiques entre les ombles chevaliers présentant une faible concentration de mercure et ceux présentant une forte concentration de mercure. Les paramètres sont la reproduction, l'anatomie/la physiologie du foie et l'état de santé général. Jusqu'à maintenant, les données indiquent un effet subtil possible sur la reproduction, car le nombre d'œufs par femelle parvenue à maturité (fécondité relative) est moins élevé lorsque la concentration de mercure est élevée. Les effets sur le foie sont plus graves. Lorsque la concentration de mercure est modérée, les dommages aux tissus sont mineurs à cause de mécanismes de régénération, mais, lorsque la concentration de mercure est élevée (lac Amituk seulement), la régénération est inhibée, et on observe la mort généralisée des cellules et l'inflammation des tissus. D'autres ombles chevaliers seront capturés dans chacun de ces lacs en 2012 à des fins d'analyses supplémentaires. Ces recherches devraient produire des résultats clairs sur la toxicité du mercure, et les données obtenues devraient permettre d'estimer un seuil de toxicité propre à l'omble chevalier confiné aux eaux intérieures. Nos travaux sont considérés comme nouveaux, parce qu'ils vont audelà de la documentation des concentrations de mercure chez les poissons et qu'ils fournissent des connaissances essentielles sur l'état de santé des poissons, ce qui s'avère pertinent dans le cadre du plus récent plan directeur du PLCN, où l'on mentionne que « la santé des populations autochtones du Nord est intimement liée à la santé des écosystèmes arctiques ».

Key Messages

i. We sampled landlocked arctic char from lakes (Small, 9-mile, North, Char, Amituk) near Resolute Bay, Nunavut, to determine effects of mercury on the char.

ii. Mercury concentrations in char from all of the lakes, except Small Lake, exceed values known from laboratory studies to cause effects on fish.

iii. Preliminary results indicate mercury may be affecting char via effects on reproduction and liver function.

iv. In 2012, more char will be collected from each lake for further analyses.

Messages clés

i. Nous avons effectué l'échantillonnage d'ombles chevaliers confinés aux eaux intérieures dans des lacs (Small, Nine Mile, North, Char, Amituk) près de la baie Resolute, au Nunavut, afin de déterminer les effets du mercure sur cette espèce.

ii. Les concentrations de mercure mesurées dans les ombles chevaliers de tous les lacs, sauf le lac Small, dépassent les valeurs connues entraînant des effets sur les poissons, d'après des études en laboratoire.

iii. Les résultats préliminaires indiquent que le mercure aurait une incidence sur l'omble chevalier, plus précisément sur la reproduction et la fonction hépatique de ce dernier

iv. D'autres ombles chevaliers seront capturés dans chacun de ces lacs en 2012 à des fins d'analyses supplémentaires.

Objectives

i. Study the toxic effects of Hg in landlocked char in "NCP focal ecosystem" High Arctic lakes on Cornwallis Island

ii. Estimate a threshold concentration of Hg associated with toxic effects in landlocked char

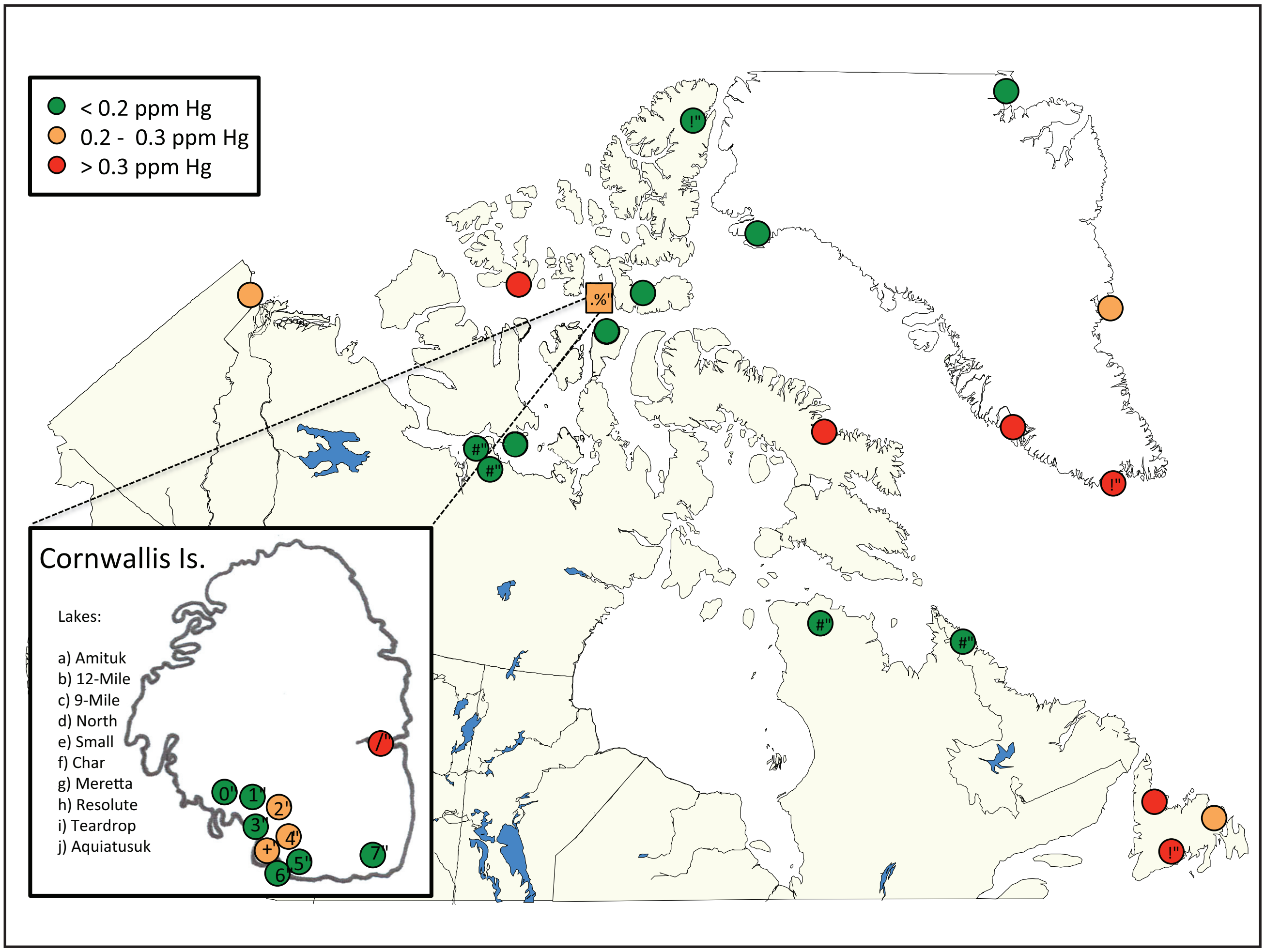
iii. Provide this information to the Hamlet of Resolute Bay (Qausuittuq) and to the Niqiit Avatittinni Committee (Nunavut) on a timely basis

Introduction

Hg is a priority contaminant for NCP because concentrations of Hg in edible muscle of predatory fish from lakes in northern Canada usually exceed the Health Canada guideline of 0.2 ppm wet wt for subsistence consumption (Lockhart et al. 2005). Anthropogenic emissions of Hg to the atmosphere, notably from burning of coal in urban centres, have led to increased atmospheric Hg deposition in even the most remote ecosystems, e.g., the Canadian High Arctic (Muir et al. 2009) and Greenland (Bindler et al. 2001). In aquatic ecosystems, microbes transform Hg into methylmercury (MeHg) which biomagnifies in food webs, resulting in high concentrations in predatory fish. Consumption of contaminated fish is the major source of MeHg in humans, and is detrimental to health (National Research Council 2000).

Arctic char are widely distributed in the northern Canada and are a main food source for Aboriginal peoples, but can contain high levels of Hg and other contaminants. Accordingly, NCP has supported extensive efforts to measure contaminants in arctic char. Anadromous (sea-run) char are relatively low in contaminants, including Hg, and are promoted as a nutritious food source by public health authorities. In contrast, landlocked char (restricted to lakes and rivers) are relatively high in contaminants, especially Hg (Swanson et al. 2011).

Figure 1. Mean Hg concentrations (whole-body, wet wt) in landlocked char populations sampled in Greenland and in eastern (Newfoundland) and northern Canada. Orange and red dots exceed toxicity thresholds estimated by Beckvar et al. (2005) and Dillon et al. (2010), respectively. Data sources are cited in the references section.



A growing body of evidence suggests that Hg concentrations regularly found in predatory fish, such as landlocked char in northern Canada, are also toxic to the fish. Recent analyses of the available data for Hg toxicity in fish indicate that effects are likely to occur at whole-body concentrations (wet wt) exceeding 0.2 ppm (Beckvar et al. 2005) or 0.3 ppm (Dillon et al. 2010, Sandheinrich and Wiener 2011) (equivalent concentrations in edible muscle are 0.33 and 0.5 ppm wet wt, respectively). According to these thresholds, 12 of 40 (or 30% of) landlocked char populations sampled in northern Canada and Greenland are at risk for Hg toxicity (Figure 1).

The research described in this report aims to study the effects of Hg in landlocked char that inhabit lakes on Cornwallis Island. The results reported below are preliminary, but are the first steps in going beyond documenting Hg concentrations to provide knowledge concerning the status of fish health. This information is important because arctic char are of untold intrinsic value to the northern ecosystems they inhabit and also because of the nutritional, cultural, socioeconomic, and recreational benefits they provide to Northerners. As stated by NCP, "the health of northern Aboriginal populations is intimately linked to the health of Arctic ecosystems."

Table 1. Summary data for fork length, mass, condition factor (CF), and concentrations of total mercury (Hg_T) in edible muscle and liver of char collected from "NCP focal ecosystem" lakes.

Lake	Year	n	Fork length	Mass	CF[a]	Hg_T (ppm wet wt) in muscle			HgT (ppm wet wt) in liver		
			(cm)	(g)		mean	SE	range	mean	SE	range
Small											
	2010	19	32.8	304	0.859	0.082	0.009	0.051-0.193	0.160	0.017	0.099-0.426
	2011	15	33.5	274	0.723	0.093	0.009	0.063-0.189	0.200	0.016	0.085-0.314
9-mile											
	2010	17	33.0	300	0.812	0.160	0.019	0.082-0.391	0.287	0.044	0.142-0.897
	2011	15	33.6	341	0.820	0.165	0.027	0.069-0.394	0.352	0.078	0.102-1.09
North											
	2010	17	34.8	424	0.911	0.275	0.072	0.105-1.38	0.546	0.144	0.162-2.69
	2011	15	38.5	499	0.853	0.327	0.042	0.155-0.699	0.723	0.076	0.293-1.36
Char[b]											
	2010	9	30.2	249	0.848	0.289	0.039	0.140-0.464	0.577	0.093	0.175-0.949
Amituk											
	2009c	13	-	-	-	1.18	0.200	0.295-2.55	2.37	0.499	0.808-6.47
	2011	12	33.5	395	0.852	0.887	0.148	0.144-2.08	2.13	0.497	0.257-6.46

[a] Condition factor = 100 x mass / fork length^3

[b] Only four char were caught in Char Lake in 2011. All were dead when retrieved from gill nets, and thus tissues were not viable for biological endpoints. None of the char were included in this study.

[c] Weather did not permit travel to Amituk Lake in 2010. However, samples of frozen tissue from collections in 2009 were available for analysis. Note that not all char collected in 2009 were measured for fork length and mass.

Activities in 2011-2012

To investigate the effects of Hg on landlocked char, we collected char in 2010 and 2011 from five "NCP focal ecosystem" lakes (Small, 9-mile, North, Char, Amituk) near Resolute Bay , NU. Collections were conducted in cooperation with the char "core" monitoring project led by Muir and a separate NCP-sponsored food web project led by Kidd and Muir. The five lakes sampled span a gradient of Hg contamination (Table 1), allowing for the comparison of biological endpoints in char with low Hg concentrations to char with high Hg concentrations. Individuals from each lake except Small exceed the toxicity threshold of Beckvar et al. (2005; 0.3 ppm wet wt in muscle), but only char from North and

Table 2. Progress and preliminary results for hypotheses designed to detect changes due to Hg in key biological systems of landlocked char.

Hypothesis	Status for samples collected in 2011 Analysis…	Preliminary result
Reproduction (suite of endpoints in relation to Hg_T concentration in edible muscle)		
H1: In females, apoptosis of ovarian follicular cells is positively related to Hg concentration.	in progress	
H2: In females and in males, plasma E2 and T levels are negatively related to Hg concentration.	in progress	
H3: In females, egg quantity and quality (size) are negatively related to Hg concentration. (Note: "Maturing" eggs only.)	completed	Egg quantity and quality increase with body size, and we thus "size corrected" the data. Relative fecundity (no. of eggs / 100g of fish) is negatively related to Hg concentration. Relative egg diameter (egg diameter / fork length) is positively related to Hg concentration.
H4: In females and in males, gonadosomatic index (GSI) is negatively related to Hg concentration.	completed	GSI is a function of (1) whether gonads are maturing and (2) body size. Hg concentration covaries with body size, but is not significantly related to GSI.
Liver anatomy and physiology (suite of endpoints in relation to Hg concentration and speciation)		
H5: Hg_T concentrations in liver will exceed Hg_T concentrations in edible muscle.	completed	Hg_T concentrations are 2-5 times greater in liver than in muscle.
H6: MeHg will comprise the majority of Hg_T in livers.	completed	MeHg comprises, on avg., 80% of Hg_T in livers.
H7: Both MeHg and inorganic Hg are primarily bound to cytosolic metal-binding proteins.	to be completed	
H8: Cytosolic levels of glutathione and metallothionein are positively related to concentrations of MeHg and inorganic Hg, respectively.	to be completed	
H9: Above threshold concentrations, MeHg and inorganic Hg "spill over" into metal-sensitive sub-cellular pools.	to be completed	
H10: Accumulation of lipofuscin is positively related to the concentration of inorganic Hg, and the two are co-localized in liver tissue.	in progress	Melanomacrophages (contain lipofuscin) increase in number with inorganic Hg; excluding Amituk data.

H11: Incidences of other liver pathologies are positively related to MeHg concentration.	in progress	Char from Amituk exhibit necrosis (cell death resulting from injury that overwhelms repair mechanisms).
H12: Lipid reserves are negatively related to Hg_T concentration.	in progress	Data are too preliminary to make conclusion.
H13: In females and in males, liver somatic index (LSI) is negatively related to Hg_T concentration.	completed	LSI is positively related to Hg_T concentration.
H14: Age and parasite infestation also are related to liver health.	in progress	Data are too preliminary to make conclusions.
General fish health		
H15: In females and in males, condition factor is negatively related to Hg concentration.	completed	Condition factor is not related to Hg concentration.

Amituk (Char Lake, as well if other years are included, e.g., Muir et al. 2005) exceed the threshold of Dillon et al. (2010; 0.5 ppm wet wt in muscle). In 2010, our investigation was preliminary and included (only) the histological examination of livers from five char from each of four lakes. We found a general trend of healthy livers, with ample fat reserves, in char with low Hg concentrations to unhealthy livers, with loss of fat reserves and tissue inflammation, in char with high Hg concentrations. For 2011, we developed a series of hypotheses (Table 2) designed to detect changes (due to Hg) in reproduction, liver anatomy and physiology, and general health of char. Each char collected in 2011 (57 total from four lakes) is being analyzed according to our hypotheses (results and interpretations presented below).

Capacity Building: The project depends on the help of local people from Resolute Bay. Since 2005, Debbie Iqaluk has worked on the char "core" monitoring project, enabling the collection of char from all targeted lakes on Cornwallis Island in a wide range of weather and ice conditions. In 2011, Debbie was hired to help collect, dissect, and assess the health of char. She previously received training in dissection and anatomical examination of fish (from Köck).

Communications: Muir has presented reports and posters to the Resolute Bay Hamlet office and the HTA for the three current char projects in the lakes of Cornwallis Island (i.e., the "core" monitoring project led by Muir, the food web project led by Kidd and Muir, and this project.

Preliminary results of this project have also been presented as posters at the 2011 NCP results workshop (Victoria BC), the 2012 Gananoque Environmental Science and Engineering Conference (Gananoque ON), and the 2012 International Polar Year conference (Montreal QC).

Traditional Knowledge Integration: Fish collection relies on the knowledge and experience of local people working on the project, as has been true for the char "core" monitoring project for a number of years. Also, traditional knowledge is used for initial assessment of fish health (e.g., Does that fish look healthy? Is that an unusual parasite burden? Is that a normal looking liver?).

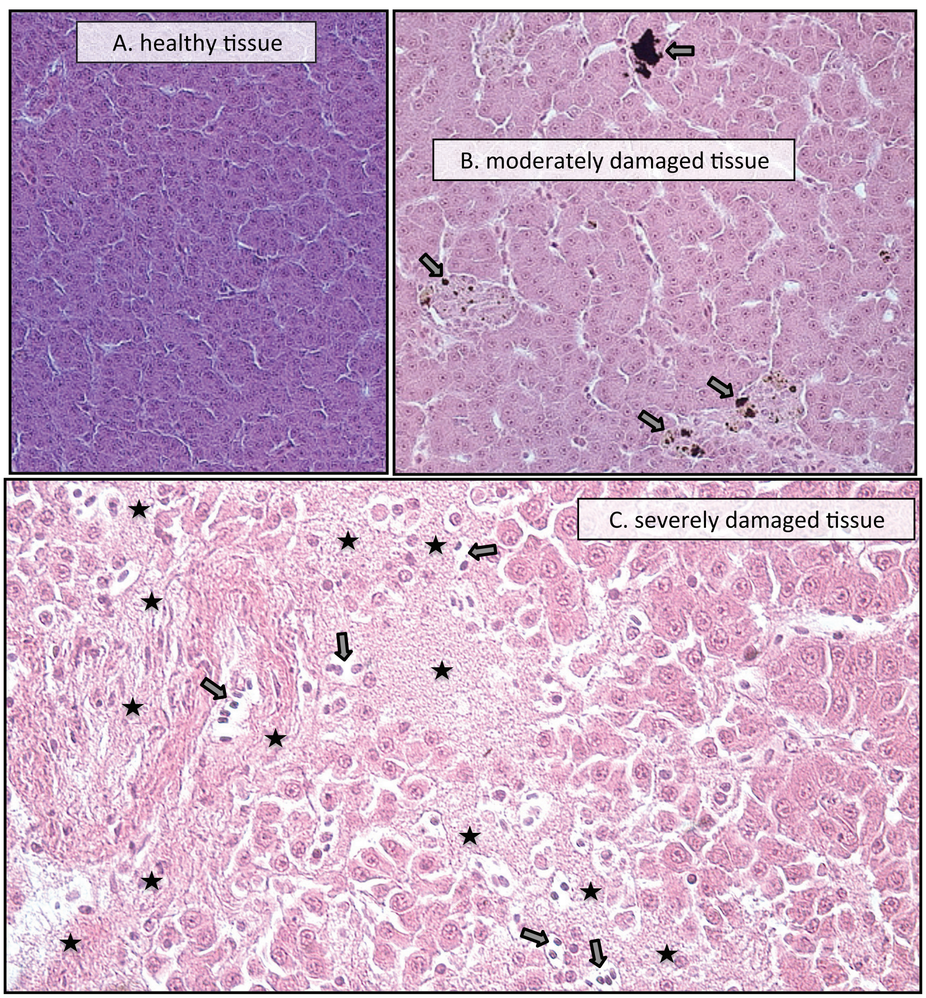
Results

Summary data for fish size, condition, and Hg content are given in Table 1, and progress and preliminary results relating to biological endpoints are given in Table 2.

Discussions and Conclusions

Data from endpoints relating to char reproduction indicate possible subtle effects of Hg. We have complete data for (H3) the quantity and quality of "maturing" eggs (females only) and for (H4) the gonadosomatic index (GSI = gonad weight / body weight x 100). Some basic knowledge about char reproduction is required to understand the results. First, not all char spawn annually, because the unproductive lakes they inhabit result in a restricted energy budget. Second, energy is allocated first for the maintenance of basic biological functions, then for growth and reproduction. Third, reproduction occurs only if energy is available to develop gonads. In Char Lake (and likely the other lakes in our study), the development of gonads in char begins in April and spawning occurs in September (MacCallum and Regier 1984). For the females (n = 30) and males (n = 27) we collected in July/August 2011, GSI was a function of (1) whether gonads were developed and (2) body size. Females had ovaries with eggs that were either undeveloped (22 females) or maturing (8 females). Males had testes that showed little development (23 males) or were fully developed (4 males).

Figure 2. H&E stained livers under light microscopy. (A) With low Hg exposure, tissues appear healthy (char from Small Lake, 0.223 ppm Hg wet wt; 200x magnification). (B) With moderate Hg exposure, melanomacrophage centres (groups of immune cells that repair damage) are evident (arrows), as well as associated inflammation (char from 9-mile Lake, 0.524 ppm Hg wet wt; 200x magnification). (C) With high Hg exposure, necrosis (disorderly cell death) and inflammation are widespread (stars), as well as Kupffer cells (a type of immune cell; arrows) (char from Amituk Lake, 3.74 ppm Hg wet wt; 400x magnification). Differences in color among (A), (B), and (C) are due to either an artifact of the staining (A stained darker than B and C) or magnification used (B vs C).



There was no relationship between whether ovaries or testes were developed (i.e., maturation index) and Hg. In regards to body size, as char grow bigger, they have proportionally bigger gonads, but also more Hg. If the "effect" of body size on GSI is removed (by ANCOVA), the results indicate that Hg is not related to GSI. For females with developed ovaries, we also found that egg number and size (diameter) increased with body size. Correcting for body size, by calculating relative fecundity (no. of eggs / 100g of body weight) and relative egg diameter (egg diameter / fork length), yields data that show possible effects of Hg. Hg concentration in muscle is negatively related to relative fecundity and positively related to relative egg diameter. Venne and Magnan (1989) predicted that, for a female char with a limited energy budget, "the first response to an additional stress would involve a decrease of the number of eggs and an increase of their diameter without affecting the gonadosomatic index." Higher probability of larval survival (because of an increase in egg size) is balanced with a reduction in the number of eggs. Our results thus indicate that Hg may be exerting effects on reproduction indirectly, i.e., energy used by the liver for Hg detoxification or tissue repair (see next paragraph) results in females altering their egg production. Completion of analyses for the other hypotheses (H1 - apoptosis; H2 - hormones) will indicate whether direct effects also occur.

Data from endpoints relating to char liver anatomy and physiology indicate severe effects of Hg. We have complete data from determinations of (H5) total Hg (Hg_T) and (H6) MeHg. Concentrations of Hg_T in liver are 2-5 times greater than in muscle – to a maximum of 6.5 ppm wet wt (or 20 times higher than the toxicity threshold of Beckvar et al. 2005). MeHg comprises 80% of Hg_T in livers. We also have preliminary data from (H10, H11) histological examinations. Livers from char collected at Small, 9-mile, and North show increasing numbers of melanomacrophage centres with Hg exposure (Figure 2). Melanomacrophage centres represent an immune response in fish, working to eliminate damaged cells that are later replaced by new cells. This repair is beneficial to tissues, but can result in deleterious reactions, such as inflammation (also shown in Figure 2). Livers from char from Amituk Lake, in contrast, show relatively few melanomacrophage centres. Instead, these livers, which have very high Hg concentrations, exhibit damage called necrosis. Necrosis is the disorderly death of cells, i.e., disease or serious injury overwhelms repair mechanisms, cell membranes rupture, and cellular debris is spread into the extracellular matrix. Debris can "attack" adjacent cells, causing a chain reaction of cell death (again, see Figure 2). Our results represent a typical dose-response relationship for toxicants (e.g., Hg) that cause necrosis (Klaassen 2001). Up to a threshold, repair restrains injury (i.e., melanomacrophages eliminate damaged cells in char from Small, 9-mile, and North). Above the threshold, repair is inhibited, allowing "unrestrained progression of injury" (i.e., necrosis in char from Amituk). Finally, we also have data for (H13) liver somatic index

NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	1	Debbie Iqaluk, Resolute Bay
number of project-related meetings/workshops held in the North (April 1, 2011 – March 31, 2012)	0	
number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	2	B. Barst, INRS-ETE, G. Lescord, Univ. New Brunswick
number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	2011: 1 2012: 2	3 conference presentations

(LSI = liver weight / body weight x 100). LSI is positively related to Hg_T concentration. Adams et al. (1990) similarly found elevated LSI in sunfish (Lepomis auritus) with high Hg_T concentrations and hypothesized that the cause was an increase in the number of liver cells (hyperplasia). To repeat from above, tissue repair includes the replacement of damaged cells with new cells. It is possible that hyperplasia is also occurring in char livers, and we will test this hypothesis (via further histological examination). We expected, however, for LSI to decrease with increasing Hg exposure, because energy used for the detoxification of Hg would drain lipid reserves in hepatocytes. Completion of analyses related to (H7, H8, H9) Hg detoxification and (H12) lipid reserves will aid in interpretation of the LSI data.

Effects on the liver may not result in a decrease in the overall condition of char. For char collected in 2010, we found a negative correlation between condition factor (100 x mass / fork length3; an indicator of "plumpness") and liver Hg_T concentration. With an additional year's data (2011), however, there is no relation between condition factor and Hg_T. Condition factor can be "insensitive to changes in body condition", though (Adams et al. 1990).

Results also indicate that data from more char are needed to increase statistical power for detecting a significant effect on a given endpoint, especially those related to reproduction. For example, relative fecundity is negatively correlated with Hg_T concentration ($r = -0.557$), but this relationship is not statistically significant ($p = 0.151$). With the small sample size of mature females ($n = 7$), our power for detecting a significant effect (at $\alpha = 0.05$) was only 23%. Doubling or tripling the sample size would increase statistical power to 41% or 50%, respectively.

To summarize, our results are preliminary but may indicate Hg is impacting the reproduction and liver function of landlocked char in lakes on Cornwallis Island. Because of low sample size and extreme variability in char biology, we have limited ability to detect a significant effect on any given endpoint. In 2012, we will collect more char from each lake to increase statistical power. Ultimately, the research will yield unambiguous results about Hg toxicity, and the data will be used to estimate a toxicity threshold specific to landlocked char.

Funding was provided by NCP (to Drevnick), NSERC Discovery (to Drevnick), and Canada Research Chairs (to Campbell). Polar Continental Shelf Program (Resolute base) provided housing, meals, laboratory space, field equipment, and flight time.

Expected Project Completion Date

We expect to complete the project by September 2013.

Acknowledgements

Funding was provided by NCP (to Drevnick), NSERC Discovery (to Drevnick), and Canada Research Chairs (to Campbell). Polar Continental Shelf Program (Resolute base) provided housing, meals, laboratory space, field equipment, and flight time.

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Production and loss of methylmercury, and its uptake in lake food webs of the High Arctic

Production, perte et absorption de méthylmercure dans les réseaux alimentaires lacustres de l'Extrême-Arctique

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Abstract

During the second year of this project, field investigations were continued on processes regulating the standing pool of methylmercury (MeHg) in lakes and wetlands on Cornwallis Island and thaw ponds on Bylot Island. Concentrations of total mercury (THg) were generally low in lake and wetland sediments on Cornwallis Island, ranging from 5.1–82.4 ng g^{-1}. Sediment concentrations of MeHg varied from 0.03–1.51 ng g^{-1} in the lakes and 0.05–4.64 ng g^{-1} in a wetland. Methylation potentials, measured using a mercury (Hg) stable isotope technique, ranged from 0.06–1.66% per day in lake sediments and from 0.19–2.33% per day in the wetland sediments. Demethylation potentials were low at all sites. Molecular analyses conducted in 2010-11 showed that a polar desert lake and wetland host a diverse microbial community

Résumé

Au cours de la deuxième année de ce projet, des travaux sur le terrain ont été poursuivis visant les processus régulant l'accumulation de méthylmercure (MeHg) dans les lacs et les milieux humides de l'île Cornwallis et les étangs thermokarstiques de l'île Bylot. Les concentrations de mercure total (THg) étaient généralement faibles dans les sédiments des lacs et des milieux humides de l'île Cornwallis, variant de 5,1 à 82,4 ng g^{-1}. Les concentrations de MeHg dans les sédiments variaient de 0,03 à 1,51 ng g^{-1} dans les lacs et de 0,05 à 4,64 ng g^{-1} dans les milieux humides. Le potentiel de méthylation, mesuré à l'aide d'une technique d'isotopes stables du mercure (Hg), variait de 0,06 à 1,66 % par jour dans les sédiments lacustres et de 0,19 à 2,33 % par jour dans les sédiments des milieux humides. Le potentiel de déméthylation était faible dans tous les

with players known to be involved in Hg transformations, namely sulphate reducers and methanogens. Incubation experiments using sediment slurries are currently ongoing to alter the biochemistry and physiology of microbes potentially involved in MeHg production and to test effects of environmental conditions on sediment Hg methylation. On Cornwallis Island, photodemethylation of MeHg was observed at similar rates in spiked and unamended samples of lake water after a five-day incubation period in the field, whereas dark controls did not vary significantly over time. Additions of glutathione and thioglycolic acid accelerated photodemethylation compared to unamended controls. A thermokarst pond on Bylot Island was covered to experimentally manipulate sunlight conditions and thus photodemethylation. A slow rise in water MeHg concentration was observed over a two-week period although photodemethylation effects were not apparent after removing the pond cover part way through the experiment. In study lakes on Cornwallis Island, benthic algae had MeHg concentrations that ranged from 0.3–9.8 ng g^{-1}. Chironomid larvae MeHg concentrations averaged 35–46 ng g^{-1} in four lakes (analyses are ongoing for two other lakes), and taxonomic and depth variation was observed within the lakes. Water depth also influenced nitrogen stable isotope ratios in chironomid larvae. Following the completion of lab analyses in 2012-13, the data collected from different project components will be integrated to further evaluate production and loss processes of MeHg in High Arctic fresh waters.

sites. Des analyses moléculaires effectuées en 2010-2011 ont montré qu'un lac et un milieu humide dans un désert polaire renferment une communauté microbienne variée, dont certains membres jouent un rôle dans les transformations du mercure, notamment les bactéries sulfatoréductrices et méthanogènes. Nous effectuons actuellement des expériences d'incubation au moyen de boues de sédiments afin de modifier les propriétés biochimiques et physiologiques des microbes qui interviennent probablement dans la production du MeHg et de vérifier les effets des conditions environnementales sur la méthylation du mercure dans les sédiments. À l'île Cornwallis, la photodéméthylation du MeHg a été observée à des taux semblables dans les échantillons dopés et les échantillons non modifiés d'eau des lacs après une période d'incubation de cinq jours sur le terrain, alors qu'aucune variation significative dans le temps n'a été observée pour les échantillons témoins conservés à l'obscurité. L'ajout de glutathion et d'acide thioglycolique accélérait la photodéméthylation, si on compare avec les échantillons témoins non modifiés. Un étang thermokarstique de l'île Bylot a été couvert afin de manipuler de façon expérimentale les conditions d'ensoleillement et, par conséquent, la photodéméthylation. La concentration de MeHg a augmenté lentement dans l'eau sur une période de deux semaines, même si les effets de la photodéméthylation n'étaient pas apparents une fois l'étang à découvert en cours d'expérience. Les concentrations de MeHg mesurées dans les algues benthiques provenant de lacs étudiés sur l'île Cornwallis variaient de 0,3 à 9,8 ng g^{-1}. Les concentrations de MeHg dans les larves de chironomes provenant de quatre lacs s'élevaient en moyenne à 3546 ng g^{-1} (des analyses sont en cours pour deux autres lacs), et une variation sur les plans taxinomique et de la profondeur a été observée dans les lacs. La profondeur de l'eau influait aussi sur les rapports des isotopes stables d'azote observés dans ces larves. Une fois les analyses en laboratoire terminées en 20122013, les données recueillies dans le cadre des différentes composantes du projet seront intégrées afin d'évaluer de façon approfondie les processus de production et de perte du MeHg dans les eaux douces de l'ExtrêmeArctique.

Key Messages

- The production of MeHg in aquatic sediments on Cornwallis Island occurs at relatively low rates in lakes and at higher rates in wetlands. Demethylation rates were low at all sites. Sediments with higher methylation rates had higher ambient MeHg concentrations.

- Freshwater sediments from Cornwallis Island host a diverse microbial community with players known to be involved in Hg transformations, such as sulphate reducers and methanogens. Microbial communities differed between wetland and lake sediments, and also with depth in the sediments.

- Methylmercury in water is broken down by photodemethylation in Resolute Bay lakes and thermokarst ponds on Bylot Island. The Resolute Bay experiments showed that, in these ecosystems, the photodemethylation rates were similar at low and high MeHg concentrations. The addition of certain chemical substances altered the rate of MeHg breakdown in water.

- Similar average MeHg concentrations were found in chironomid larvae (a main prey of Arctic char) from four lakes on Cornwallis Island, suggesting similar MeHg accumulation at the base of the food webs in these lakes. Within-lake factors (taxonomy, water depth) influenced MeHg concentrations and/or nitrogen stable isotopes in chironomid larvae.

Messages clés

- La production de MeHg dans les sédiments aquatiques de l'île Cornwallis a lieu à des taux relativement faibles dans le cas des lacs et à des taux plus élevés dans celui des milieux humides. Les taux de déméthylation étaient faibles dans tous les sites. Les sédiments caractérisés par un taux plus élevé de méthylation présentaient des concentrations plus élevées de MeHg.

- Les sédiments dulcicoles provenant de l'île Cornwallis renferment une communauté microbienne variée dont certains membres jouent un rôle dans les transformations du mercure, notamment les bactéries sulfatoréductrices et méthanogènes. Les communautés microbiennes étaient différentes selon qu'il s'agissait de sédiments provenant de milieux humides ou de lacs et aussi selon la profondeur des sédiments.

- Le méthylmercure présent dans l'eau se décompose par photodéméthylation dans les lacs de la baie Resolute et les étangs thermokarstiques de l'île Bylot. Les expériences effectuées à la baie Resolute ont montré que, dans ces écosystèmes, les taux de photodéméthylation étaient semblables, que la concentration de MeHg soit faible ou élevée. L'ajout de certaines substances chimiques modifie le taux de décomposition du MeHg dans l'eau.

- Des concentrations de MeHg moyennes semblables ont été mesurées dans les larves de chironomes (une proie principale de l'omble chevalier) provenant de quatre lacs de l'île Cornwallis, ce qui laisse supposer une accumulation de MeHg semblable à la base des réseaux trophiques dans ces lacs. Des facteurs intralacustres (taxinomie, profondeur de l'eau) ont eu une incidence sur les concentrations de MeHg et/ou les isotopes stables d'azote chez les larves de chironomes.

Objectives

The main purpose of this two-year project is to investigate sources and losses of MeHg in Arctic freshwater ecosystems and its uptake in food webs. This research is focusing on two study areas: NCP-monitored lakes at Resolute Bay (Cornwallis Island) and non-focal ecosystems at Bylot Island. Cornwallis Island is a barren polar desert with little terrestrial plant cover whereas Bylot Island is more biologically productive with extensive tundra vegetation. In the second year of this project (2011-2012), the main objectives were to:

- Measure sediment methylation and demethylation rates in lakes, wetlands, and thermokarst ponds
- Characterize the microbial community involved in methylation and demethylation
- Measure photodemethylation rates in the water column and identify the associated mechanisms;
- Measure total concentrations of MeHg in the water column
- Measure bioavailable MeHg in sediment pore water
- Investigate the bioaccumulation of MeHg at the base of food webs in lakes

Introduction

Most Hg in the environment is in an inorganic form whereas organic MeHg is the much more toxic species that biomagnifies through food webs. Processes regulating the standing pool of MeHg such as inorganic Hg methylation and MeHg degradation are therefore critical in controlling how much enters aquatic food webs. Information on these key processes is currently lacking for freshwater ecosystems in the High Arctic. Specifically, it remains unclear: 1) where MeHg is produced; 2) what groups of bacteria are methylating inorganic Hg; 3) how much MeHg is lost by sunlight-induced breakdown (photodemethylation); and 4) how these processes relate to bioaccumulation in lake food webs. Although these processes have been investigated in lakes at more southern latitudes such as in Alaska (Hammerschmidt et al. 2006) and temperate Canada (Sellers et al. 2001, Harris et al. 2007), environmental conditions in the High Arctic are severe, making it difficult to extrapolate from other studies.

MeHg production may occur within the watershed in wetlands (Loseto et al. 2004b) or thermokarst ponds (standing waters formed from permafrost thaw). These shallow standing waters typically contain abundant organic matter and may have warmer temperatures than lakes in summer, providing favourable conditions for methylation (St. Louis et al. 2005). Water draining from wetlands and ponds may then transport MeHg to lakes where it could enter the food web. Production in the sediment of lakes may also be an important source of MeHg, as observed in lakes at lower latitudes (Sellers et al. 2001). Snowmelt is another possible source of MeHg to lakes (Loseto et al. 2004a, St. Louis et al. 2005).

The production of MeHg in aquatic environments is primarily mediated by microbes, and they are also involved in MeHg degradation. The types of microbial organisms involved in these processes have not been identified in the Arctic (Barkay and Poulain 2007), but low abundance of sulfate-reducing bacteria in soil samples from Cornwallis Island put into question the importance of these microbes in the High Arctic (Loseto et al. 2004b). The role of methanogens or iron reducing bacteria remains unclear.

Arctic lakes have very transparent water, resulting in high light penetration and the potential for efficient photochemical breakdown of MeHg in the water column (Hammerschmidt and Fitzgerald 2006). Photodemethylation counter-acts MeHg production by breaking it down before it enters the food web. Estimates of photodemethylation rates and the mechanisms controlling this loss process are needed to better constrain its role in the movement of MeHg in the High Arctic.

Factors that control the uptake of MeHg at the base of lake food webs remain poorly constrained. Specifically, the role of watershed versus lake production of MeHg, and its bioavailability and photodecomposition have not been determined for High Arctic lakes. This information is important to interpret NCP monitoring of Hg in lake populations of Arctic char.

Activities in 2011-2012

This project incorporates multiple approaches, specifically rate measurements in the field of key production and loss processes, mechanistic studies of MeHg cycling (i.e., investigation of the microbial community, photodemethylation experiments), and measurements of MeHg bioaccumulation at a low trophic level in lake food webs. Rates are being measured to identify the influence of specific processes, mechanistic studies are being conducted to provide information on factors driving the processes, and a food web analysis will examine the net transfer to biota.

Resolute Bay—In August 2011, sediment cores were collected in duplicate to measure sediment methylation and demethylation rates in Char, Small, Plateau, and Amituk lakes and one wetland. Each core was assayed for Hg methylation and MeHg demethylation potential at 1, 3 and 10 cm depth by injecting isotope enriched Hg(II) (^{200}Hg) and MeHgCl (^{199}Hg). Cores were incubated for 9–10 hours in the PCSP laboratory, sliced and individually frozen slices were transported back to the lab at Trent University for analysis of ambient concentrations and Hg species transformation rates by ICP-MS.

The feasibility of using novel DGT (Diffusive Gradient in Thin film) sentinels to measure concentrations of labile (and therefore bioavailable) species of MeHg in water and pore water and estimate diffusive fluxes of MeHg from sediment to the overlying water was explored. The DGT device is comprised of an ion-exchange resin immobilized in a resin gel, which is separated from the test solution by an ion-permeable gel (diffusive gel). Concentration gradients develop across the diffusive gel and the contaminants are transported to the resin gel where they are fixed and accumulate during the deployment time. DGT devices concentrate MeHg in *situ* and yield time-averaged concentrations over the length of the deployment period. During the second field season, the DGTs were inserted in sediment cores to test for optimization in the extreme environmental conditions of High Arctic lakes. The DGTs are still awaiting measurement of MeHg concentrations.

Filtered and unfiltered water samples were collected in triplicate for MeHg analysis in the four lakes and one wetland that were sampled for sediment methylation/demethylation rates. Ambient and experimental samples of water MeHg were distilled and analyzed by CVAFS.

Three MeHg photodemethylation experiments were performed, during which water samples were incubated in the field. Two of them were conducted in Char and Resolute lakes over a period of five days, and included the following treatments:

- Filtered and unfiltered water samples kept in clear bottles (receiving visible + UVB radiation)
- Filtered and unfiltered water samples amended with 5 ng L^{-1} of MeHg kept in clear bottles (receiving visible + UVB radiation)
- Filtered and unfiltered water samples kept in clear bottles covered with light filters (receiving visible only, cut off of 50% of radiation <410 nm)
- Filtered and unfiltered water samples amended with 5 ng L^{-1} of MeHg kept in clear bottles covered with light filters (receiving visible only, cut off of 50% of radiation <410 nm)

All treatment series also included three replicates kept in the dark for the entire duration of the experiment. Bottles from each treatment were retrieved every day for analysis, in order to obtain a time series. The last experiment aimed at further exploring processes involved in photodemethylation by adding complexing agents such as thiols or scavengers of different reactive species, roughly following the approach of Zhang and Hsu-Kim (2010). All samples were filtered unless otherwise indicated, and amended with 5 ng L^{-1} of MeHg. Water samples were incubated *in situ* for 48 h in clear bottles, and the following treatments were used (final concentrations in incubation bottles are indicated): additions of (1) 10 nM of glutathione (GSH); (2) 10 nM thioglycolic acid (TA); (3) 0.01% mM n-hexane; (4) 28 g L^{-1} NaCl. Control series containing only natural water and marine water (spiked with aforementioned MeHg concentrations) were also conducted.

Chironomids, which are a dominant prey of Arctic char, were collected in all of the lakes sampled in 2010 and 2011 (Char, Meretta, Resolute, Small, Plateau, Amituk) as well as the wetland sampled in 2011. Nearshore chironomid larvae were collected with a kick net and deep-water larvae were collected with an Ekman grab. Benthic algae were collected by scraping rocks with a nylon brush and with an Ekman grab (for filamentous forms and *Nostoc* spheres). In the PCSP laboratory, chironomid and algal samples were sorted and rinsed with ultra-pure water and frozen for later analysis of MeHg by gas chromatography, atomic fluorescence spectrometry. At the G.G. Hatch Stable Isotope Laboratory (University of Ottawa), carbon and nitrogen stable isotope ratios were measured by isotope ratio mass spectrometry in chironomids and algae as well as organic matter from rock biofilms and in surface sediment.

Bylot Island—In June and July 2011, water samples were collected from three low-center polygons, three runnels and one lake for THg, MeHg and thiol analyses in water and for THg analyses in sediments. Also, the same three photodemethylation experiments described above for Resolute Bay were performed. The first two experiments were conducted in one polygon and one runnel (BYL22 and BYL24). The final experiment with thiol and radical scavenger additions was performed in BYL22. An additional experiment was conducted in BYL22, where the pond was monitored every six hours over a 14-day period for THg, MeHg, thiols and water chemistry. During days 4–8, the pond was covered with a plastic tarp, obstructing >98% of radiation between 200–700 nm. This experiment aimed to study the effects of photodemethylation on a larger scale via the manipulation of the thermokarst pond ecosystem.

At Bylot Island, methylation and demethylation rates were measured in sediment of three thermokarst ponds using the core incubation method described above for Resolute Bay.

Laboratory experiments—In August 2011, sediments were collected with an Ekman grab from Char Lake and a wetland to conduct laboratory incubations at the University of Ottawa on the sediment and alter the biochemistry and physiology of potential key microbes involved in MeHg production. This laboratory work is currently on-going. The variables tested will simulate an increase in temperature, sulphate and Fe(III) concentrations as well as carbon dioxide and hydrogen gas partial pressures, all of which can be expected as a consequence of permafrost thawing and overall increased metabolic activity in sediments. This work will contribute insights into how MeHg production will be affected in these Arctic freshwater systems as the microbial communities experience changing environmental conditions.

Capacity Building/Communications/ Traditional Knowledge

Local assistance was provided by Pilipoosie Iqaluk for the field program at Resolute Bay in August 2011. Pilipoosie participated in the collection of samples in the field and assisted with invertebrate sorting in the laboratory. Pilipoosie's participation in field programs for this project and other NCP-funded projects in recent years has resulted in important local capacity building in environmental sampling, and his experience has been a significant asset for the High Arctic field program.

The Resolute Bay HTA was consulted for permission to conduct the project activities at local lakes and wetlands. An update on the project was provided to the HTA in February 2011. During the August 2011 field program, team member J. Chételat attended an HTA meeting in Resolute with four HTA members present to discuss the project activities. Upon their request, a final report that contains the measured levels of Hg in local lakes will be provided to the HTA later in 2012 once all analytical results are available. The Nunavut Regional Contaminant Committee will be consulted prior to release of the report. In addition, metadata on the NCP project were submitted to the Polar Data Catalogue in November 2011.

Results and Discussion

A) Sediment methylation and demethylation
THg concentrations in lake sediments ranged from 12.6–82.4 ng g^{-1} and were on average 17.5, 33.8, 29.0 and 33.1 ng g^{-1} in Char, Small, Plateau and Amituk lakes, respectively. THg levels in Small Lake and Amituk Lake were lowest at 10 cm sediment depth (12.6–23.2 ng g^{-1} and 10.3–22.5 ng g^{-1}, respectively). No specific trends with depth were observed in Char and Plateau Lakes. Within-lake variations were small except for cores taken at the deepest spot of each lakes. Presumably funnelling effects lead to occasionally higher levels in the samples lakes. THg in wetland sediments was significantly lower, typically from 5.1–23.3 ng g^{-1}.

MeHg concentrations in lake sediments ranged from 0.03–1.51 ng g^{-1} and were on average 0.12, 0.20, 0.30 and 0.38 ng g^{-1} in Char, Small, Plateau and Amituk lakes, respectively. Frequently, highest concentrations were observed in the top sediment layer, with significantly lower concentrations in deeper sections of the core. MeHg concentrations in wetland sediments were equally variable, ranging from 0.05–4.64 ng g^{-1} (average 0.79 ng g^{-1}).

Rates of Hg methylation varied from 0.06–1.66% per day in lake sediments. On average 0.22, 0.16, 0.15 and 0.78% of the added inorganic Hg spike was methylated over 24 hours in Char, Small, Plateau and Amituk lakes, respectively. Wetland sediments showed the greatest variation and highest potential for methylation. Values ranged from 0.19–2.33% per day, with an average of 0.73%.

Demethylation potentials were variable. Remarkably, no decrease in the MeHg spike concentrations was frequently observed in sediments from Plateau and Amituk Lake, suggesting a low potential for demethylation in those lakes. Small Lake, on the other hand, exhibited the highest rate of MeHg degradation with on average 19% of the injected MeHg spike being demethylated over the incubation period.

Since the top sediment layer is probably most important for MeHg production and export to the overlying water, Table 1 shows characteristic data obtained in the top 1 cm slice of sediments.

Concentrations of ambient MeHg in surface sediment varied among locations. Among the lakes, the highest levels were found in Amituk Lake, with concentrations in the wetland location being still higher. Potential for MeHg

Table 1: Concentrations of THg and MeHg, and methylation and demethylation potentials in top surface sediments

	Small Lake	Char Lake	Plateau Lake	Amituk Lake	Wetland
THg (ng g^{-1})	42.9	18.9	28.6	40.1	14.9
MeHg (ng g^{-1})	0.32	0.19	0.50	0.81	1.59
M (% per hour)	0.007	0.010	0.013	0.029	0.034
D (%)	20.6	2.5	0	0	28.8

M: proportion of the inorganic Hg spike methylated per hour
D: proportion of MeHg spike demethylated during incubation

formation was also highest in the wetland location (Table 1) consistent with the observed higher level of ambient MeHg concentration in the wetland sediment, closely followed by Amituk Lake. Rates for MeHg formation in the three other study lakes were relatively low. The highest observed rates are still low compared to methylation potentials measured in southern lakes and wetlands. Highest methylation rates in surface lake sediments correlated reasonable well with standing pools of ambient MeHg (except for Char Lake). Demethylation potentials were low across the board for sediments, both in lakes and the wetland, suggesting low activity or low abundance of demethylating microbes. However, combined with the even lower rate of methylation, resulting MeHg concentrations are still lower than those typically found in southern locations.

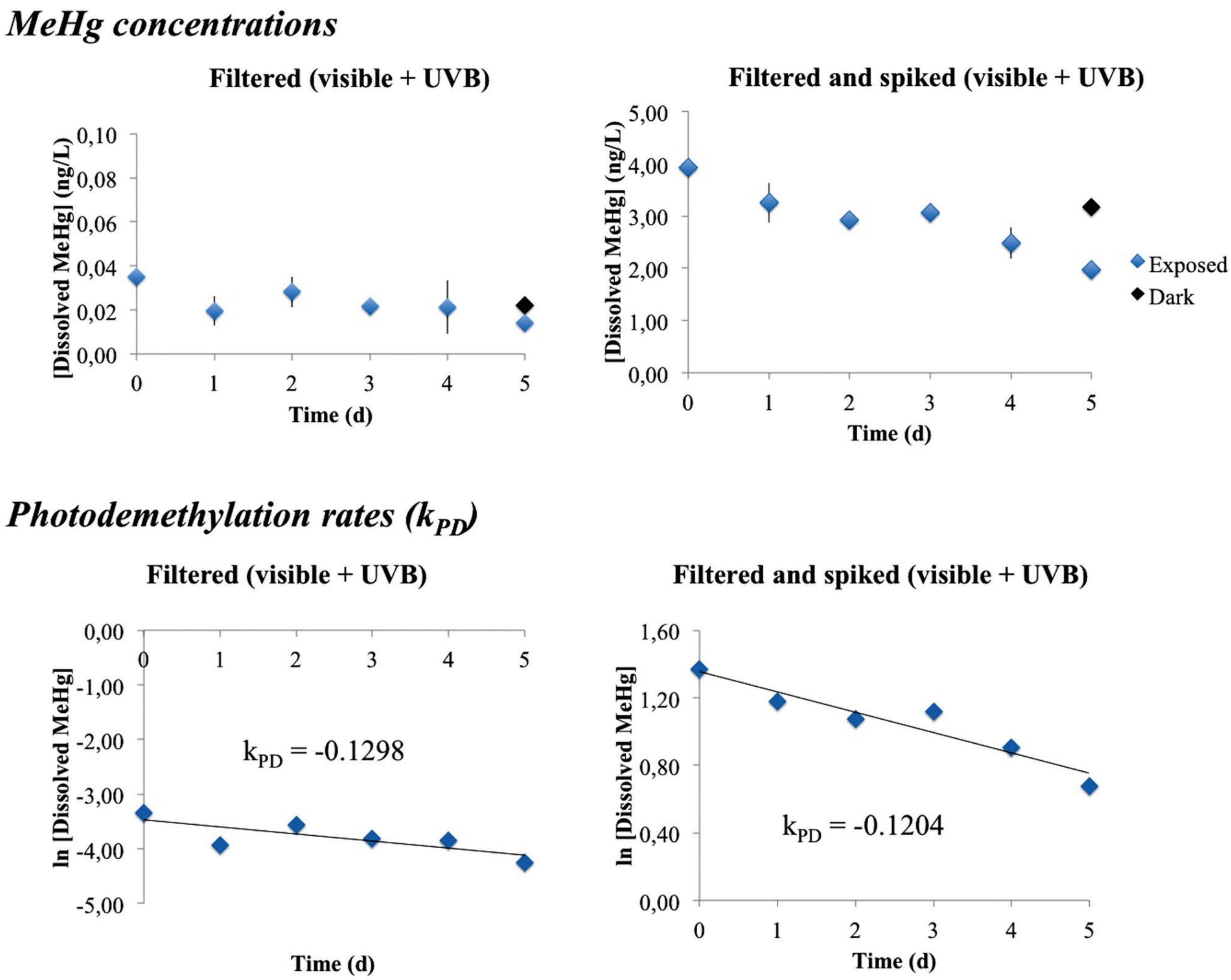
B) Sediment microbial community
Anaerobic environments are important sites for the terminal degradation of biomass and transformation of contaminants in arctic and temperate freshwater sediments. Despite rapid environmental changes in the Canadian Arctic Archipelago, there is limited knowledge of the freshwater sediment microbial activity and community structure. We sampled sediments from an Arctic wetland and an Arctic lake on Cornwallis Island. RNA was extracted at depths of 1, 3 and 10 cm and transcript copy numbers of several genes were quantified using qPCR techniques. Microbial community structure was determined from cDNA libraries of bacterial and archaeal *16SrRNA*. Because methanogenesis is a key process in carbon cycling in freshwater systems and also thought to be involved in mercury transformation, we assessed the abundance and diversity of *mcrA* transcripts, encoding for the alpha sub-unit of the methyl coenzyme-M reductase enzyme, responsible for catalyzing the production of methane. Bacterial communities in lake and wetland sediments were diverse and significantly different from each other; they structured mainly as a function of depth. Archaea were largely methanogens, *i.e.*, euryarchaeota; differences among archaeal communities were more a function of environment (wetland vs. lake). The *mcrA* transcripts were different between lake and wetland environments and both more diverse and more abundant in the wetland, suggesting higher levels of methanogenesis in this environment. The active methanogenesis, as demonstrated by *mcrA* sequences, is hydrogenotrophic, particularly in lake sediments. However, the potential for acetoclastic methanogenesis exists due to the presence of *16SrRNA* from many strictly acetoclastic methanogens.

Our results showed that these freshwater sediments host a diverse microbial community with players known to be involved in mercury transformations, such as sulphate reducers and methanogens. We are currently performing incubation experiments using sediment slurries to alter the biochemistry and physiology of the potential key players involved in MeHg production. We are using Hg stable isotopes to track changes in sediment methylation and demethylation. This work will contribute insights into how MeHg production will be affected in these Arctic freshwater systems as the microbial communities experience increased temperatures. We are also simulating an increase in sulphate and Fe(III) concentrations as well as carbon dioxide and hydrogen gas partial pressures, all of which can be expected as a consequence of permafrost thawing and overall increased metabolic activity in sediments.

C) Photodemethylation studies
We observed MeHg demethylation in Resolute Bay lakes during the incubation experiments, with significant reductions in MeHg concentration after exposure to sunlight (Figure 1). Water samples incubated in the dark over time did not differ significantly from initial MeHg concentrations at time (T) = 0. Here we present a portion of results that are currently available from the 2011 sampling campaign. In Char Lake, filtered samples exposed to visible + UVB radiation had similar rates (k_{PD}), whether they were amended with MeHg or not (Figure 1).

In the 48 h experiment, we observed varying rates of photodemethylation (k_{PD}), based on the

Figure 1. Photodemethylation measurements on water from Char Lake, Cornwallis Island. The top panels show changes in natural and spiked MeHg concentrations over a five-day incubation. The bottom panels show the photodemethylation rates for the natural and spiked water samples.

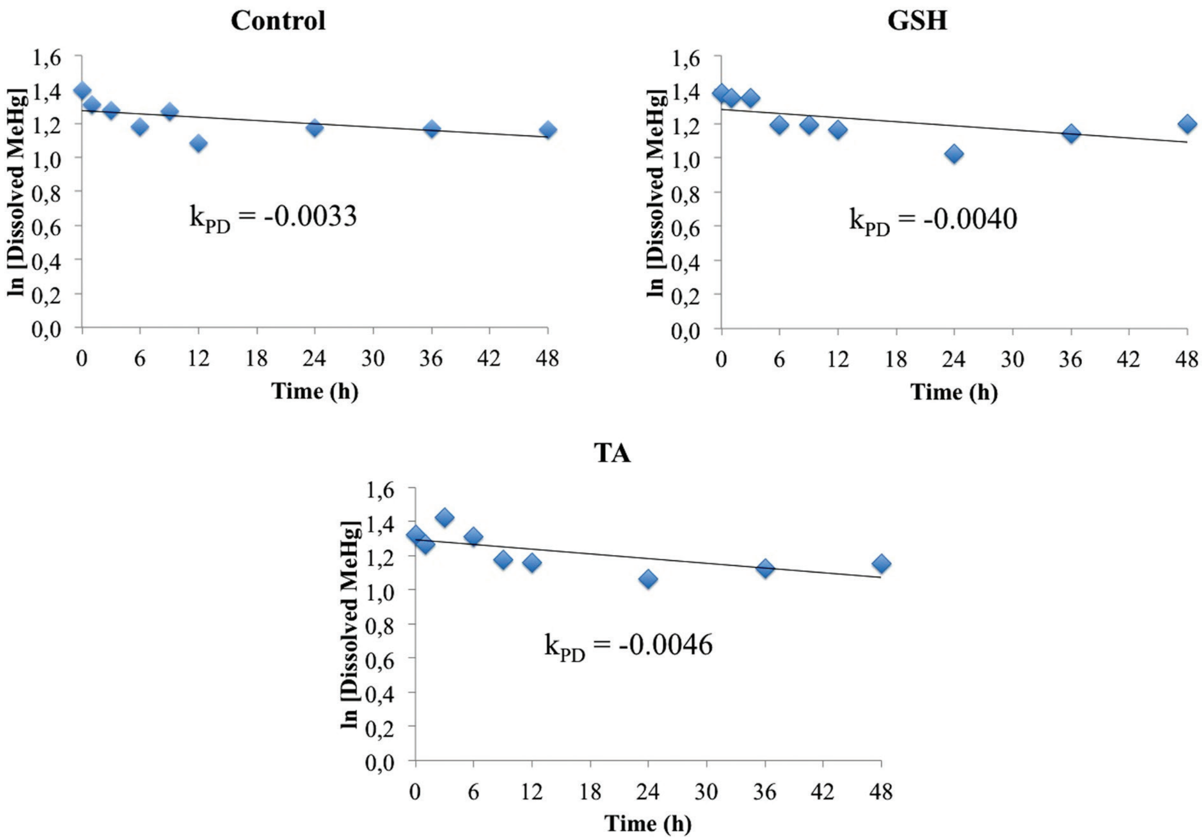


treatments applied to the samples (Figure 2). In the case of the thiols, glutathione (GSH) accelerated photodemethylation (k_{PD} = -0.0040 h^{-1}) when compared to the control series (k_{PD} = -0.0033 h^{-1}). However, the addition of thioglycolic acid (TA) showed a further increase in the photodegradation rate of MeHg (k_{PD} = -0.0046 h^{-1}). Thus, we found that naturally occuring molecules in freshwater ecosystems, like thiols, can modulate the reactions implicated in photodemethylation, affecting net degradation.

In our covered pond experiment conducted on Bylot Island in 2011, our manipulation of the ecosystem modified the chemical gradients in the water column, creating a stratification in terms of dissolved oxygen, pH and conductivity (Figure 3). Hypoxia was also induced at 30 cm, which may have heightened bacterial MeHg production.

We observed relatively stable MeHg concentrations during the monitoring period (Figure 3). Surface (0 cm) and depth (30 cm) MeHg concentrations were strongly correlated throughout the experiment (adjusted R^2=0.89). No photodemethylation was apparent after the removal of the tarp and re-exposure to solar radiation. Instead, we observed a slow rise in

Figure 2. Rates of photodemethylation in lake water samples that were amended with glutathione (GSH) or thioglycolic acid (TA), as compared to control samples. All samples were filtered and spiked with 5 ng L^{-1} of MeHg before the incubation experiments.



MeHg concentration. This increased load of MeHg may have been produced under covered conditions and sequestered in deeper sediments, only seeping into the water column once the pond was uncovered and mixed.

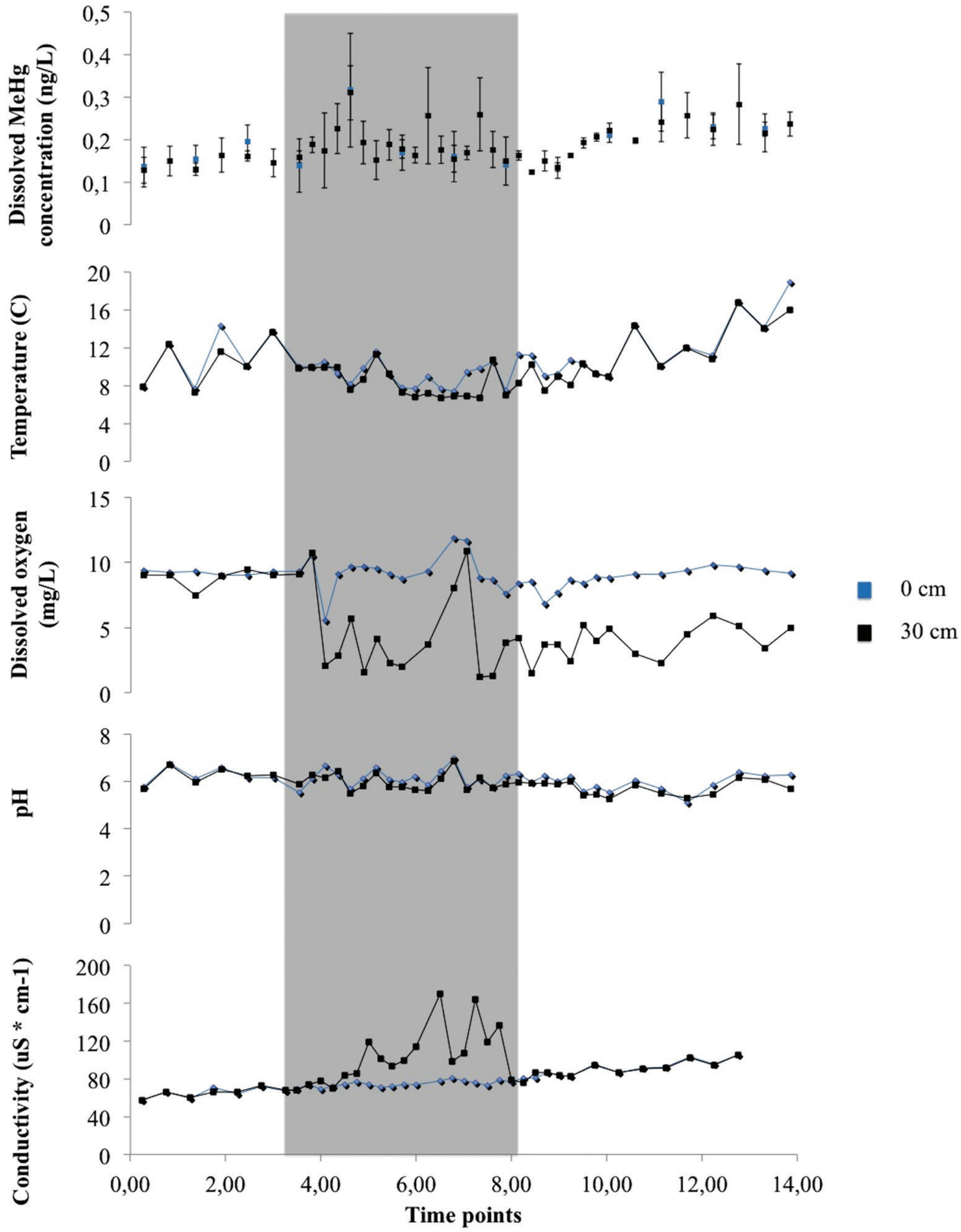
Our results show that photodemethylation does occur in lakes in Resolute Bay lakes and thermokarst ponds on Bylot Island (see also our 2010 Synopsis Report, Chételat et al. 2011). The Resolute Bay experiments showed that in these ecosystems, rates tend to be similar at low and high concentrations. They also allowed us to confirm the potentially important role of thiols in the photodegradation of MeHg in natural waters. This may be due to the complexation of MeHg to these sulphur-rich molecules, which were shown by Zhang and Hsu-Kim (2010) to promote photodemethylation.

However, the covered pond experiment yielded different results, where photodemethylation was not apparent after removal of the tarp. This underlines the importance of whole-ecosystem experiments, which include all processes occurring in the pond and avoids the potential for a bottle effect in incubation experiments. Thus, while incubation experiments offer interesting insight into the mechanisms and reactions driving photodegradation of MeHg, *in situ* experiments may provide a more realistic overview of photodemethylation.

D)Food web bioaccumulation of MeHg

Preliminary results are available for MeHg concentrations in benthic algae and chironomid larvae from Meretta, Small, Plateau and Resolute lakes. Analyses are ongoing for the remaining two lakes (Amituk, Char). The

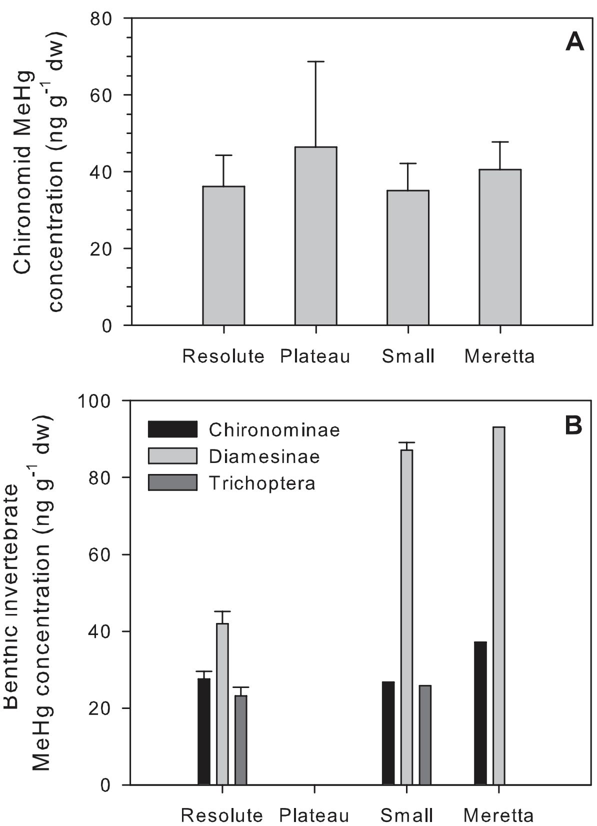
Figure 3. Water chemistry characteristics of a shallow thermokarst pond on Bylot Island that was monitored intensively for two weeks. Measurements were taken at surface (0 cm) and subsurface (30 cm) depths. The pond was covered with an opaque plastic from days 4-8 (grey horizontal bar) to block sunlight and prevent photodemethylation of MeHg in the water column.



preliminary data show that average MeHg concentrations of chironomid larvae ranged from 35–46 ng g^{-1} in four lakes and were not statistically different (Figure 4; one-way ANOVA, $p = 0.924$, $n = 17$). This finding suggests that MeHg bioaccumulation at the base of the food web is similar in the four lakes. Benthic algae (filamentous forms and *Nostoc* spheres) generally had low MeHg concentrations in the four lakes (0.3–1.9 ng g^{-1}, $n = 9$) except in Resolute Lake where deep-water filamentous algae contained 4.6–9.8 ng g^{-1} ($n = 2$).

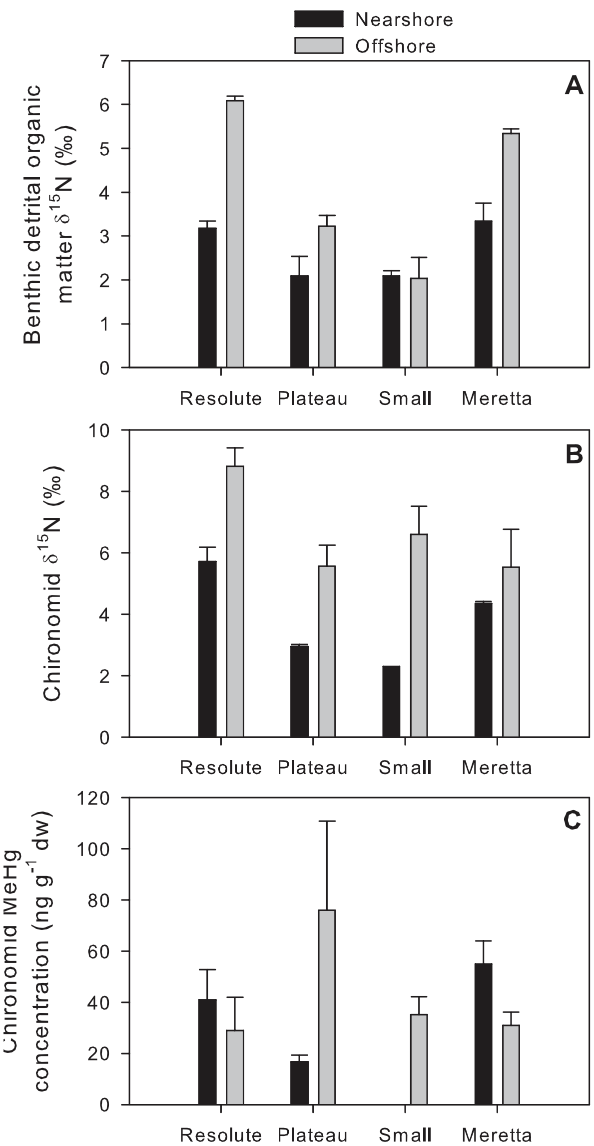
Chironomid larvae were sorted into subfamilies to investigate taxonomic influences on their MeHg concentrations. Note that these

Figure 4. Concentrations of MeHg in benthic invertebrates from four lakes on Cornwallis Island. (A) Lake-mean concentrations of MeHg in chironomid larvae (n = 3–5 samples per lake). (B) Taxonomic differences in MeHg concentrations among two subfamilies of chironomid larvae (Chironominae, Diamesinae) and one species of caddisfly larvae (Trichoptera).



identifications are preliminary and will be confirmed by an expert taxonomist. Larvae from the subfamily Chironominae had similar MeHg concentrations in Small, Resolute and Meretta lakes that ranged from 27–37 ng g^{-1} (Figure 4). Diamesinae larvae had more than double the MeHg concentrations of Chironominae in Small and Meretta lakes, but were only slightly higher in MeHg in Resolute Lake. Nitrogen stable isotope ratios ($\delta^{15}N$) of those samples indicated that Diamesinae were feeding at a higher trophic position in Small and Meretta but not in Resolute Lake. This finding is consistent with previous observations that Diamesinae sometimes contained chironomid prey in their stomachs (Chételat et al. 2010) and sometimes had higher MeHg concentrations than other taxa (Chételat et al. 2008) but not always. Caddisfly larvae (a different aquatic invertebrate from chironomids) contained similar levels of MeHg to Chironominae (Figure 4).

Figure 5. Influence of water depth (nearshore vs. offshore) on δ15N ratios in detrital organic matter (A) and chironomid larvae (B), and on MeHg concentrations in chironomid larvae (C) in four lakes on Cornwallis Island.



The influence of water depth on MeHg concentrations and $\delta^{15}N$ ratios in chironomid larvae was investigated by comparing nearshore (<1.5 m depth) to offshore samples (3–11 m

NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	1	
number of project–related meetings/workshops held in the North (April 1, 2011 – March 31, 2012)	1	Resolute Bay HTA, August 2011
number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	4	
number of citable publications (e.g., in domestic/ international journals, conference presentations, book chapters, etc)	8	A total of eight conference presentations were given in 2011-12.

depth) (Figure 5). Overall, water depth did not have a significant effect on chironomid MeHg concentrations in Meretta, Resolute and Plateau lakes (two-way ANOVA, depth $p = 0.539$, $n = 14$). However, MeHg concentrations were higher in offshore chironomids in Plateau Lake and slightly lower in offshore chironomids in Meretta Lake (Figure 5). Although further analyses are necessary, the depth variation in Meretta and Plateau lakes may be due to different taxonomic composition of nearshore and offshore chironomids. Interestingly, the $\delta^{15}N$ ratios of chironomid larvae were consistently enriched (by 1–4 ‰) in deeper waters compared to nearshore (Figure 5; two-way ANOVA, depth $p < 0.001$, $n = 19$). A comparison of $\delta^{15}N$ ratios in nearshore and offshore detrital organic matter suggests that the depth variation in chironomid $\delta^{15}N$ was due to differences in baseline signatures of diet rather than trophic position (Figure 5). One exception was Small Lake, where no depth difference was found in organic matter $\delta^{15}N$. Therefore, offshore chironomid samples in Small Lake had a higher trophic position than nearshore chironomids, likely due to the presence of Diamesinae offshore. The influence of depth on chironomid $\delta^{15}N$ ratios is relevant for investigations of food web transfer of mercury using nitrogen stable isotopes.

Conclusions

After two field programs in 2010 and 2011, considerable data have been collected on MeHg cycling in High Arctic freshwaters, specifically sediment methylation and demethylation, lake water photodemethylation, potential microbial methylators in sediment, and food web uptake and bioaccumulation of MeHg. These results show that High Arctic lakes and wetlands are active sites of MeHg production and degradation, and that environmental and ecological factors affect how much MeHg is available and biomagnified in the food web. Following the completion of laboratory analyses, results from the different project components will be integrated to further evaluate the sources and movement of MeHg in these ecosystems.

Number of Citable Publications

Girard, C., M. Amyot, and I. Laurion. 2011. Aqueous concentrations and degradation pathway of methylmercury in Arctic lakes and thaw ponds. XXI[e] symposium annuel du Groupe de recherche interuniversitaire en limnologie et en environnement aquatique (GRIL), St. Hippolyte, QC, March 3-5.

Amyot, M., C. Girard, I. Laurion, A. Poulain, M. Moingt, J. Carrie, D. Bélanger, J. Chételat. 2011. Methylmercury and thiol/mercury interactions in northern thaw ponds. 10[th] International Conference on Mercury as a Global Pollutant, Halifax, NS, July 24-29.

Amyot, M., C. Girard, I. Laurion, M. Leclerc. 2011. Photodemethylation of methylmercury in Arctic freshwater hotspots. 10th International Conference on Mercury as a Global Pollutant, Halifax, NS, July 24-29.

Chételat, J., H. Hintelmann, M. Amyot, A. Poulain, C. Girard, B. Dimock, P. Iqaluk. 2011. Production and loss of methylmercury, and its uptake in lake food webs of the High Arctic. Northern Contaminants Program 19th Annual Results Workshop, Victoria, BC, September 20-21.

Girard, C., M. Amyot. 2012. Le sort du méthylmercure dans des écosystèmes aquatiques arctiques et subarctiques., 12e Colloque du Centre d'Études Nordiques (CEN), Rimouski, QC, Febuary 10.

Amyot, A., C. Girard, I. Laurion, J. Chételat. 2012. Thaw ponds are methylmercury hotspots in Nunavut and Nunavik (Canada). IPY 2012 Conference, Montréal, QC, April 22-27.

Girard C., M. Amyot. 2012. Photodemethylation of MeHg and water chemistry of thermokarst thaw ponds: in situ observations and in vitro experiments. IPY 2012 Conference, Montréal, QC, April 22-27.

Expected Project Completion Date

Funding for this project ended on March 31, 2012. Completion of project activities (i.e. data generation, data compilation and analysis, preparation of manuscripts) is anticipated for 2012-13.

Acknowledgements

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Contaminant Bioaccumulation in Landlocked Char Food Webs in the High Arctic

Bioaccumulation de contaminants dans les réseaux trophiques de l'omble chevalier confiné aux eaux intérieures du Haut-Arctique

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Abstract

The purpose of this two year project (2010-2012) is to study how food webs influence the transfer of contaminants to the top predator, landlocked Arctic char, in the Northern Contaminants Program's (NCP) "focal ecosystem" lakes on Cornwallis Island. Mercury (Hg) and perfluorinated chemicals (PFCs) are carried into Arctic lakes during summer melt and are taken up and concentrated (biomagnified) through the food web into char. This research will examine food web accumulation of Hg, which has both natural and human sources and undergoes complex transformations in lakes, and of PFCs, which are entirely human-made, arrive solely by atmospheric deposition, and are not transformed in the environment. We are building on previous research by contrasting

Résumé

Ce projet de deux ans (2010-2012) a pour objet d'étudier comment les réseaux trophiques influent sur le transfert des contaminants vers le grand prédateur qu'est l'omble chevalier confiné aux eaux intérieures, notamment aux lacs de l'île Cornwallis, lesquels constituent un écosystème d'intérêt dans le cadre du Programme de lutte contre les contaminants dans le Nord. Le mercure (Hg) et les composés perfluorés (CPF) sont transportés vers les lacs de l'Arctique pendant la fonte estivale, puis ils sont absorbés et concentrés (bioamplifiés) chez l'omble chevalier par l'intermédiaire du réseau trophique. La présente recherche examinera l'accumulation de deux types de contaminants dans le réseau trophique : le Hg, qui a des sources tant naturelles qu'humaines

how these two persistent contaminants concentrate through lake food webs and examining factors that affect their levels in char and other organisms in High Arctic systems. The research is on lakes in the Resolute Bay area (North, Small, Meretta, Resolute, 9 Mile, and Char). Results from the 2010 and 2011 field seasons show significant differences in mean total Hg concentrations (0.08-0.29µg/g, 0.06-0.70µg/g, wet wt. respectively) in char between these lakes, and that Hg is higher in larger than smaller fish. PFCs in char also varied from one lake to another and levels were highest in fish from Meretta and Resolute Lakes. Furthermore, several invertebrate samples had higher PFC concentrations than adult fish (i.e. 1.7 ug/g vs. 0.07 +/- 0.001 ug/g PFOA for invertebrates and char, respectively, in 9 Mile Lake). The diet of the char is being assessed using carbon, sulfur and nitrogen isotopes (measures of energy flow and trophic position). Carbon isotopes show that char are feeding on littoral chironomids, as opposed to pelagic zooplankton. Analyses of PFCs in biota caught in 2011 will be completed in June 2012. Information from this study will be used to understand the lake characteristics that promote high contaminants in char and whether these persistent contaminants are transferred through High Arctic food webs at a greater rate than has been observed at lower latitudes.

et qui subit des transformations complexes dans les lacs, et les CPF, entièrement d'origine humaine, qui arrivent par dépôt atmosphérique uniquement et ne sont pas transformés dans l'environnement. En nous basant sur des études antérieures, nous comparons la concentration de ces deux types de contaminants persistants dans les réseaux trophiques lacustres et examinons les facteurs qui influent sur leurs teneurs chez l'omble chevalier et d'autres organismes des systèmes du Haut Arctique. Le projet est mené dans les lacs de la région de la baie Resolute (lacs North, Small, Meretta, Resolute, 9 Mile et Char). Les résultats des campagnes de terrain de 2010 et de 2011 montrent des différences significatives dans les concentrations moyennes de Hg total observées dans les ombles chevaliers de ces lacs d'une année à l'autre (0,08-0,9 µg/g poids humide en 2010 contre 0,06-0,70 µg/g poids humide en 2011). Ils révèlent aussi que les teneurs en Hg sont plus élevées chez les grands poissons que chez les petits poissons. Les quantités de CPF chez les ombles chevaliers variaient également d'un lac à un autre, les plus élevées étant enregistrées chez les poissons des lacs Meretta et Resolute. En outre, dans le lac 9 Mile, les concentrations de CPF étaient plus élevées dans plusieurs échantillons d'invertébrés (1,7 µg/g acide perfluorooctanoïque [APFO]) que chez les ombles chevaliers adultes (0,07 +/- 0,001 µg/g APFO). Nous évaluons actuellement le régime alimentaire de l'omble chevalier au moyen des isotopes du carbone, du soufre et de l'azote (mesures du flux d'énergie et de la position trophique). Les isotopes du carbone montrent que l'omble chevalier se nourrit de Chironomidés littoraux et non de zooplancton pélagique. Les analyses de détection des CPF dans le biote capturé en 2011 se termineront en juin 2012. Les données tirées de la présente étude serviront à comprendre les caractéristiques lacustres qui favorisent les teneurs élevées en contaminants chez l'omble chevalier et à déterminer si ces contaminants persistants sont transférés plus rapidement dans les réseaux trophiques du Haut Arctique que dans ceux des basses latitudes.

Key Messages

- Hg concentrations in adult char are similar to those reported for these lakes by Gantner et. al. in previous years. Results show that trophic position (determined by nitrogen isotope ratios or $\delta^{15}N$) is a significant predictor of Hg in all of these food webs.

- [PFC]s were 40-100 times higher in surface water from Meretta and Resolute Lakes, which are downstream of the local Resolute airport, when compared to the four atmospherically supplied lakes.

- Several PFCs were detected in char and levels were highest in fish from Meretta and Resolute Lakes. Interestingly, some PFC levels in chironomids (an invertebrate that lives in sediments) are higher than those found in adult char. This suggests PFCs do not biomagnify like other POPs in these Arctic lakes.

Messages clés

- Les concentrations de Hg chez les ombles chevaliers adultes sont semblables à celles rapportées dans ces lacs par Gantner et al. les années précédentes. Les résultats montrent que la position trophique (déterminée par les rapports des isotopes de l'azote, ou $\delta^{15}N$) est un prédicteur important du Hg dans tous ces réseaux trophiques.

- Les [CPF] étaient entre 40 et 100 fois plus abondants dans les eaux de surfaces des lacs Meretta et Resolute, lesquels se trouvent en aval de l'aéroport local de Resolute, que dans les quatre autres lacs, où les contaminants se déposent par voie atmosphérique.

- Plusieurs CPF ont été détectés chez l'omble chevalier, et les teneurs étaient les plus élevées chez les poissons des lacs Meretta et Resolute. Fait intéressant, certaines concentrations de CPF dans les Chironomidés (invertébrés qui vivent dans les sédiments) étaient plus élevées que celles observées dans les ombles chevaliers adultes. Ce constat donne à penser que les CPF ne se bioamplifient pas, contrairement à d'autres POP présents dans ces lacs arctiques.

Objectives

- Study and contrast the transfer of perfluorinated chemicals and mercury (mainly the organic form methylmercury, MeHg) through food webs to landlocked Arctic char *(Salvelinus alpinus)* in High Arctic lakes.

- Investigate chemical, physical and biological factors influencing contaminant levels in landlocked char by sampling lakes with a range of catchment/lake area ratios, nutrient concentrations, and organic carbon inputs (i.e. through permafrost melting), and by assessing the diet of char with stable nitrogen, sulfur and carbon isotope and gut content analyses.

- Provide this information to the Hamlet of Resolute Bay (Qausuittuq) and to the Niqiit Avatittinni Committee (Nunavut) on a timely basis.

Introduction

Contaminant levels in fish can fluctuate from one lake to another, even within the same region. This study explores the differences in contaminant concentrations between neighbouring lakes around Resolute Bay, Nunavut (NU), focusing on the accumulation of two particularly problematic contaminants, mercury (Hg) and perfluorinated chemicals (PFCs). Despite the many contaminant studies done on Arctic systems, we are still unsure whether or how physical and chemical differences between lakes affect the transfer of contaminants through food webs. Features such as catchment area, water chemistry, and food web characteristics may account for localized variability in contaminant levels. This study will compare the Hg and PFC concentrations in the food webs from six lakes, each with differing physical and chemical characteristics.

Both PFCs and Hg are carried to the Arctic through long range atmospheric transport and deposited around lakes in annual snowfall. This snowmelt is thought to be one of the main sources for certain contaminants to enter lakes. Each summer this snow melts, transporting the contaminants into lakes where they are accumulated by the biota (Gantner et. al. 2009a; Loseto et. al. 2004; Stock et. al. 2007). Snow runoff and melt waters are the main source of Hg in small High Arctic lakes (Semkin et. al. 2005). Once taken up by organisms at the bottom of a food web, these contaminants accumulate and concentrate through the trophic levels, resulting in relatively high levels in top predators (Dewailly et. al. 1993; Martin et. al. 2003; Wyn et. al. 2009).

Arctic char are the top predator and often the only fish species in High Arctic lakes and therefore represent an important indicator species for Northern contamination (Gantner et. al. 2009a). Due to the biomagnification of contaminants to top predators, Arctic char have been found with relatively high levels of Hg (Gantner et. al. 2009a; 2009b; 2010). The same pattern is expected for PFCs, though less is known about their levels in landlocked char. Given that char are an important part of Arctic food chains and are eaten by Inuit, contaminant levels in these fish are of particular concern.

Similar to predatory fish in southern systems (Houde et. al. 2008), contaminant levels in char at high latitudes can vary by 2-3 times between neighbouring lakes. One possible reason for this variability is the differing physical characteristics and food web dynamics between lakes. Studies have shown that features such as catchment area, water chemistry, food web structure, and lake area can play a role in the transfer and biomagnification of contaminants (Wyn et. al. 2009; Gantner et. al. 2010; Gantner et. al. 2009b).

Although Hg is a naturally occurring element, human activities release Hg into the atmosphere, contributing to its widespread environmental contamination (NRC 2000; Gantner et. al. 2009b; Health Canada, 2007; 2009). Concentrations of Hg in many Arctic predatory fish, including Arctic char, often exceed the governmental recommendation, which is currently set at 0.5 ppm for total Hg (Gantner et. al. 2009b; Health Canada, 2007; 2009).

Overall, far less is known about the behaviour of PFCs in aquatic systems when compared to Hg. Two lakes near Resolute Bay have been found with similar if not higher PFC levels in water than the Great Lakes, approximately 10 ng/L (Stock et. al. 2007). PFCs have been detected at elevated levels in fish from these lakes (Muir et al. 2010 NCP Synopsis report) and at much lower levels in other lakes. While there have been previous studies of PFCs in Arctic marine food webs (Tomy et. al. 2004; 2009), to our knowledge, this is the first study looking at the biomagnification of PFCs through Arctic freshwater food webs supporting landlocked char.

This report describes the sampling and results from the field seasons in 2010 and 2011. During both trips, water, sediments, invertebrates and fish were collected from 6 lakes near Resolute Bay. This research is part of an MSc student thesis (G. Lescord) at the University of New Brunswick Saint John that is anticipated to be completed by December 2012.

Activities in 2010-2012

Sample Collection: Six lakes on Cornwallis Island were sampled over 7 weeks (from early July to mid-August) in 2010 and 2011 for char, lower-trophic-level organisms (zooplankton and chironomids), water and sediments to assess concentrations of Hg and PFAs as well as food web structure in these systems. Field work was done under the guidance and with the assistance of three members of the local community

(Debbie Iqaluk, Brandy Iqaluk, and Pilipoosie Iqaluk). A key difference between the 2010 and 2011 sampling and previous work (Gantner et al. 2009a, 2009b) is the more detailed sampling of water and food web organisms beginning at the initial ice melt and continuing through the ice out period in this recent study. Using clean techniques, water samples for THg/MeHg were collected weekly in 2010 and bi-weekly in 2011 in order to measure temporal changes. Separate water samples were also collected 2 to 3 times/lake for PFC analyses. All chironomids (adults and larval) were separated into general predator (Tanypodinae) and herbivore (Orthocladiinae and Chironomidae) sub-families before analysis. Adult chironomids were collected as they emerged through the ice. Benthic invertebrates were collected by benthic sweep nets and Eckman grabs. Zooplankton were sampled with a Wisconsin net pulled through the water column. In addition, representative samples of terrestrial vegetation and periphyton were collected from each lake to characterize the stable isotope signature of the primary producers potentially supporting the lakes' biota. Surface sediment cores were collected using a Uwitech gravity corer for sulfur isotope analysis. At the end of the season, adult fish were collected with gill nets and angling. Juvenile fish were also collected by electrofishing along the shore. Fish were kept cool in the field and then processed back in the lab for length, weight, and ageing structures. Gut contents and muscle tissues were removed and frozen for diet and contaminant analyses. In total, approximately 125 fish/year were collected and between 4 and 20/lake/year were analyzed for Hg and PFCs (Tables 1 and 2).

Chemical Analysis: *Mercury:* Total Hg was determined on whole tissues using a DMA (Milestone Instruments, Shelton, CT) at the UNB (EPA method 7473). MeHg in water and sediments were determined at Environment Canada, Burlington. MeHg analyses of biota were done at Acadia University (in collaboration with Nelson O'Driscoll). Analyses of all samples for MeHg used EPA Method 1630 and involved distillation (water) or methanol-potassium hydroxide digestion (sediment and organisms), aqueous phase ethylation, GC separation, and CVAFS detection using a Brooks Rand MERX automated MeHg analyzer. *Water and sediment quality:* Water chemistry analyses were conducted by the National Laboratory for Environmental Testing (NLET) following standard protocols outlined by Environment Canada (1994). *Perfluoroalkyl compounds:* Samples were analyzed for a full range of PFCs, including C6 to C15 perfluorocarboxylates (PFCA) and C6 to C12 perfluoroalkanesulfonates (PFOS) at Environment Canada (Burlington, ON). The extraction procedure involves the addition of mass-labeled internal standards (13C-labeled PFCA and PFOS) and an ion-pairing agent and extraction with acetonitrile (Müller et. al. 2011). The PFCs in sample extracts were determined by high-performance liquid chromatography with negative electrospray tandem mass spectrometry (HPLC-MS/MS). *Stable Isotope Analysis:* Freeze-dried and homogenized tissues of individual fish and pooled invertebrates were analyzed for stable carbon and nitrogen isotope ratios at the UNB (SINLab) and for sulfur isotopes at the Universities of Waterloo (water) and Arizona (sediment and biota) using a continuous-flow isotope-ratio mass spectrometer.

Quality assurance: Certified reference materials (NRC DORM-2 and TORT-1 for Hg; NIST serum SRM 1957 for PFCs) and working lab standards (stable isotopes) were run with each batch of 12 contaminant samples to ensure accuracy of results. Sample duplicates (10% of samples) and blanks were also run with each batch of samples to test for precision and background contamination, respectively. The laboratories took part in interlab studies through NCP and among the different groups involved in the collaborative projects (INRS, Environment Canada, UNB, Acadia). More specifically, the Environment Canada lab participated successfully in an interlab calibration study of PFAs in NIST reference materials (Keller, Calafat et al. 2010).

Statistical Analysis: Preliminary statistics were run on all available data generated from the both field seasons and are presented here. In order to understand the factors that best predict fish contaminant concentrations, hierarchical multiple regressions were run for each contaminant using a wide range of potential factors. Preliminary statistics (i.e. Kruskal Wallis) and graphing were done to estimate the order of factors, and all models were compared using Akaike Information Criterion (AIC). Normality was tested for all factors and log transformations were made when required. Similar hierarchical multiple regressions were also run on THg and MeHg concentrations in water, testing various water chemistry parameters as potential predictors.

Capacity Building and Training: The project depended heavily on the help of local people in the Hamlet of Resolute. Since 2005 Debbie Iqaluk has worked on the arctic char "core monitoring" project and enabled us to collect fish from all our targeted lakes on Cornwallis and Melville Islands in a wide range of weather and ice conditions. This year Debbie, her daughter Brandy (Iqaluk), and son Pilipoosie (Iqaluk) assisted with field collections and preparations. Gretchen Lescord (M.Sc. student) received extensive training and experience in netting and processing fishing, invertebrate collections and identification, sample processing and lab analyses for Hg, PFAs, and stable isotopes, food web modeling, data analysis, scientific presentations and manuscript writing.

Traditional Knowledge: Timing of collections and number of samples collected relied heavily on the knowledge and experience of local people working on the project. This was particularly the case when the lakes were ice covered, which is frequently the case in early through late July. The traditional method of getting onto the ice (sometimes by boat or by wading from shore) and sampling proved very successful, although a bit dangerous.

Communications: Graduate student Gretchen Lescord was based in Resolute (at the PCSP base) from early July until mid August 2010 and 2011 and was in the nearby village of Resolute frequently. She many informal discussions about this work in the community during the field season. Up-to-date results from this study have also been presented at conferences in 2011 and 2012, including:

Muir, D.C.G., Kock, G., Wang, X., Iqaluk, D., Williamson, M., Lescord, G., Kidd, K.A., Sverko, E., Barresi, E. Temporal trends of legacy and new persistent organic pollutants in landlocked char in High Arctic lakes in Canada. Poster presented at Annual SETAC World meeting in Germany, May 2012.

Lescord, G.L., K. Kidd, A. De Silva, D.C.G. Muir, C. Spencer, M. Williamson. Concentrations and biomagnification of perfluorinated compounds (PFCs) through lake food webs on Cornwallis Island, Nunavut in the Canadian High Arctic. Platform presented at the International Polar Year conference, Montreal, April 2012.

Lescord, G.L., K. Kidd, D.C.G. Muir, J. Kirk, X. Wang, G. Lawson, N. O'Driscoll. Factors affecting Hg biomagnification through lake food webs on Cornwallis Island, Nunavut (NU) in the Canadian High Arctic. Platform presented at the International Polar Year conference, Montreal, April 2012.

Lescord, G.L., K. Kidd, D.C.G. Muir, J. Kirk, N. O'Driscoll. Factors affecting Hg biomagnification through lake food webs in the Canadian High Arctic. Poster presented at the 32nd Annual SETAC North America Meeting, Boston MA, November 2011.

Lescord, G.L., K. A. Kidd, D.C.G Muir, A. De Silva, M. Williamson, and C. Spencer. Concentrations and biomagnification of perfluorinated compounds (PFCs) through lake food webs in the Canadian High Arctic. Platform presentation at the 32nd Annual SETAC North America Meeting, Boston MA, November 2011.

Lescord, G.L., K. Kidd, D.C.G. Muir, J. Kirk, N. O'Driscoll. Factors affecting Hg biomagnification through lake food webs in the Canadian High Arctic. Poster presented at the 10th International Conference on Mercury as a Global Pollutant, Halifax NS, July 2011.

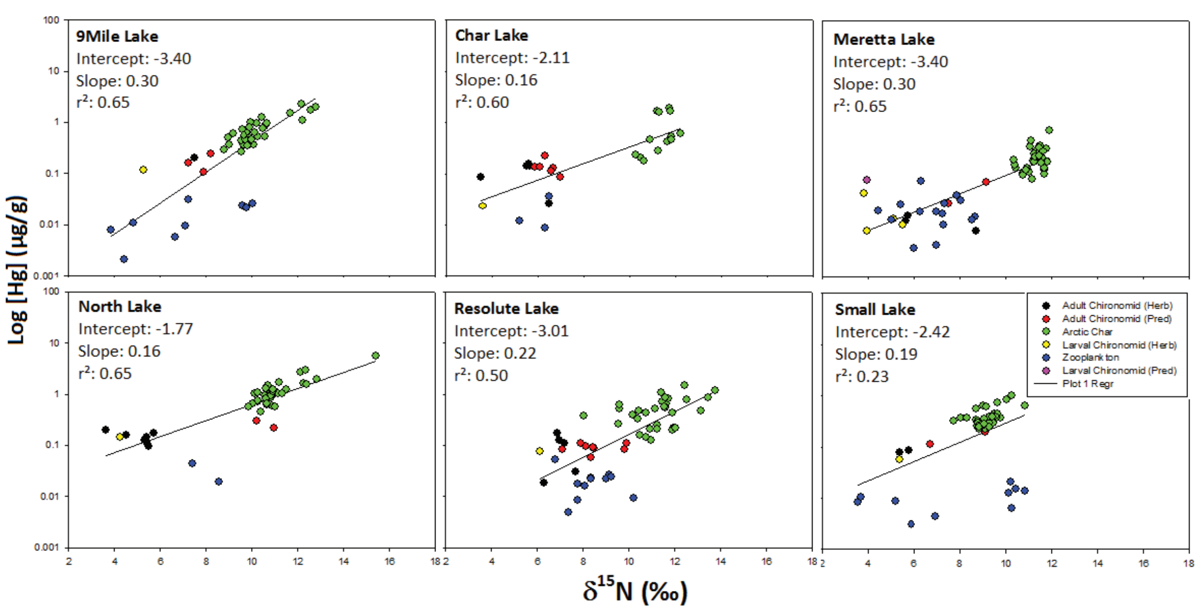
There was a community consultation with the local Hunters and Trappers Association in May 2011. As soon as the final data for this project are available, a report will be prepared in non-technical language by Kidd and Muir and sent to the HTA, Wildlife Office, and Regional Contaminants Committee. The anticipated date of this report is August 2012. A report was not submitted earlier this year because some analyses are ongoing and we want to be able to provide the full story to these groups.

Table 1. Select water chemistry data (n=6-10/lake/year, surface and deep waters) for 2010 and 2011, and sulfate isotope signatures (n=1 for surface sample) from the Cornwallis Island lakes sampled in 2010. (DOC = dissolved organic carbon)

Lake	Year	%MeHg*		pH		Conductivity (µS/cm)		Chlorophyll a (µg/L)		DOC (mg/L)		δ34S (‰)
		Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg
Small	2010	3.52	0.70	8.12	0.07	298.1	78.5	0.75	0.26	2.08	0.39	-8.49
	2011	nd	nd	8.01	0.03	294.2	10.1	2.60	0.28	1.77	0.12	-10.96
North	2010	2.47	1.13	7.95	0.05	158.3	48.9	1.10	0.40	0.90	0.23	-11.17
	2011	nd	nd	7.84	0.06	185.8	9.7	4.0	0.88	0.75	0.12	-9.11
Meretta	2010	9.51	5.14	7.93	0.05	244.9	78.4	0.56	0.20	1.89	0.37	-2.19
	2011	nd	nd	7.85	0.04	266.0	33.4	2.63	0.46	1.7	0.23	-3.28
9 Mile	2010	3.54	3.91	8.09	0.03	196.5	11.5	0.30	0.22	1.25	0.08	-7.08
	2011	nd	nd	7.94	0.05	239.5	87.4	2.73	0.83	1.0	0.08	-9.87
Char	2010	3.50	1.34	8.14	0.03	267.1	25.5	0.05	0.08	0.59	0.06	-6.26
	2011	nd	nd	8.04	0.03	281.8	8.5	3.90	1.91	0.45	0.05	-6.21
Resolute	2010	4.68	1.24	8.12	0.02	356.1	16.3	0.68	0.25	1.04	0.07	-4.82
	2011	nd	nd	8.04	0.03	395.3	11.5	2.55	0.53	0.93	0.05	-5.78

*%MeHg = MeHg]/ [THg]*100 for water data

Figure 1. Mercury concentrations (µg/g dry weight and $\delta^{15}N$ (‰) values for char, chironomids, and zooplankton collected in 2010 and 2011 from each lake around Resolute Bay. Mercury was measured as Total Hg for char and as methyl Hg for chironomids and zooplanktons.



Results and Discussion

Mercury and nutrients in water: [MeHg] were significantly different across lakes in 2010 (p=0.002) and 2011 (p=0.009, Table 2). Meretta Lake had the highest [MeHg] in both 2010 (0.062 ng/L) and 2011 (0.044 ng/L). In 2010, Meretta Lake also had a

Table 2. Average and range of THg (char) and methyl Hg (chironomids and zooplankton for samples collected from all 6 lakes near Resolute Bay in 2010 and 2011 [Hg] wer compared across lakes and within taxa usnig Kruskal Wallis tests

Sample	Overall Mean [Hg] (μg/g)*	Range [Hg] (μg/g)*	Different between lakes?
2010			
Arctic Char	0.8 ±0.15	0.05-1.38	p<0.001
Chironomids (Predatory)	0.20 ±0.08	0.11-0.30	
Chironomids (Hebivorous)	0.09 ±0.09	0.03-0.20	
Chironomids (Larval)	0.10 ±0.05	0.07-.014	
Zooplankton (500μm)	0.07 ±0.05	0.01-0.13	
Water ** (Surface)	0.029 ±0.021	<0.003-0.82	p=0.009
2011			
Arctic Char	0.19 ±0.13	0.06-0.70	p<0.001
Chironomids (Predatory)	0.13 ±0.05	0.58-0.22	
Chironomids (Hebivorous)	0.12 ±0.05	0.02-0.21	
Chironomids (Larval)	0.11 ±0.15	0.02-0.33	
Zooplankton (500μm)	0.01 ±0.01	0.01-0.05	
Water ** (Surface)	0.21 ±0.014	<0.003-0.057	p=0.009

*THg (wet wt.) for Arctic Char, MeHg (dry wt.) for invertebrates
**Concentrations reported in ng/L

NCP Performance Indicators

Number of Northerners engaged in your project:	3/year
Number of meeting/workshops held in the North:	2
Number of students involved in the work:	1
Number of citable publications:	None to date

Table 3. Select fish characteristics for all adult car caught from the Cornwallis Island lakes in 2010 and 2011 and analyzed for total mercury (THg)

Lake	Year		Total Length (cm)		Weight (g)		Conditon (g/cm^3)		Age (years)		$\delta^{15}N$ (%)		THg (µg/g ww)	
		n	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
Small	2010	19	35.3	3.0	303.6	63.2	0.7	0.1	10.9	2.2	9.29	0.48	0.08	0.04
	2011	15	35.8	2.6	274.0	59.5	0.59	0.08	nd	nd	8.94	0.60	0.09	0.04
North	2010	17	37.2	4.7	424.3	311.1	0.7	0.1	13.0	4.8	11.05	1.28	0.28	0.30
	2011	15	41.3	3.7	498.7	154.1	0.69	0.07	nd	nd	11.14	0.83	0.33	0.16
Meretta	2010	19	40.7	4.4	610.8	237.8	0.9	0.1	4.9	1.3	11.52	0.24	0.20	0.06
	2011	10	38.3	3.8	487.0	131.9	0.84	0.04	nd	nd	10.80	0.30	0.14	0.03
9 Mile	2010	17	35.6	3.1	300.0	111.4	0.6	0.1	13.6	3.8	10.38	0.88	0.16	0.08
	2011	15	36.3	5.3	341.3	207.8	0.65	0.08	nd	nd	10.09	1.16	0.17	0.20
Char	2010	9	32.4	3.4	248.6	112.1	0.7	0.1	9.2	1.1	11.23	0.69	0.29	0.12
	2011	4	35.2	3.6	345.0	90.0	0.78	0.07	nd	nd	11.50	0.29	0.40	0.06
Resolute	2010	8	44.1	4.0	689.6	183.2	0.8	0.1	13.5	2.0	11.52	0.80	0.19	0.10
	2011	20	44.4	4.4	584.5	218.1	0.8	0.06	nd	nd	11.3	1.17	0.17	0.07

nd = No Data available, analysis is ongoing

Table 4. Average MeHg concentrations (µg/g dw) for adult chironomides (herbivores and predators), larval chironomids and zooplankton from the Cornwallis Island lakes in 2011 and 2010

		Chironomids (Herb)			Chironomids (Pred)			Chironomids (Larval)			Zooplankton		
Lake	Year	n	Avg	SD	n	Avg	SD	n	Avg	SD	n	Avg	SD
Small	2010	0			1	0.17		0		10.9	2	0.01	0.00
	2011	1	0.08		1	0.11		1	0.06		4	0.01	0.00
North	2010	1	0.18		2	0.24	0.04	1	0.13		2	0.03	0.02
	2011	3	0.15	0.01	0			0			2	0.03	0.02
Meretta	2010	1	0.06		1	0.27		1	0.06		5	0.06	0.03
	2011	2	0.08	0.01	1	0.14		2	0.11	0.04	12	0.19	0.13
9 Mile	2010	0			2	0.16	0.06	0			4	0.01	0.00
	2011	1	0.20		1	0.16		1	0.12		7	0.02	0.01
Char	2010	0			2	0.09	0.02	1	0.13		1	0.01	
	2011	1	0.15		2	0.16	0.03	1	0.02		3	0.03	0.02
Resolute	2010	4	0.05	0.02	2	0.09	0.01	1	0.07		5	0.02	0.01
	2011	3	0.08	0.03	2	0.07		1	0.08		6	0.02	0.02

Table 5. Average concentrations of representative PFCs in surface waters of the six lakes

Lake	Year	n	PFOA (C8)	PFOS	4:2 FTS	PFECHS
North	2010	3	0.89	0.03	0.00	0.06
	2011	2	0.31	0.03	0.00	0.06
Small	2010	3	0.75	0.08	0.00	0.15
	2011	2	0.38	0.11	0.01	0.10
Char	2010	3	0.76	0.05	0.00	0.09
	2011	2	0.40	0.06	0.01	0.10
9Mile	2010	3	0.68	0.02	0.00	0.14
	2011	2	0.70	0.03	0.00	0.06
Meretta	2010	3	18	43	0.24	3.5
	2011	2	16	37	31	5.5
Resolute	2010	3	11	29	0.19	2.9
	2011	3	7	21	0.21	2.1

significantly higher percent MeHg (Kruskal-Wallis p=0.014), suggesting a higher rate of Hg methylation in this lake (see Table 3, 2011 data is ongoing). Interestingly, Char Lake had the lowest [MeHg] in 2010 (0.009 ng/L) and 2011 (0.009 ng/L), while having the lowest chlorophyll a concentrations in 2010 (0.05µg/L) and the highest in 2011 (3.90 µg/L). Overall, chlorophyll a concentrations in surface water samples were up to 3.5 to 6 times higher across lakes in 2011 compared to 2010 (Table 1). Other water chemistry parameters (pH, conductivity, DOC, and $\delta^{34}S$) were similar between years (Table 1).

Mercury in biota: Table 3 summarizes the average characteristics of fish caught in 2010 and 2011 from each of the six lakes. In 2010 and 2011, the highest and lowest mean [THg] in char were measured in Small Lake and Char Lake, respectively. In general, [Hg] were higher in organisms feeding at a higher trophic level ($\delta^{15}N$) within each lake (see Table 4). Interestingly, [THg] in char were significantly different across lakes in 2010 (p>0.01) and 2011 (p>0.01), but no other differences in [Hg] were detected in lower trophic level biota (adult chironomids, larval chironomids, and zooplankton) in either 2010 or 2011 (Table 2).

To determine the best predictors of Hg levels in char, a hierarchical multiple regression was run, using the categorical variables lake and sex of the fish, and the continuous variables fish fork length and age. All factors, including THg, were log transformed. The best fit model predicting Hg concentrations in char across lakes included lake, trophic position ($\delta^{15}N$) and fork length ($R^2 = 0.66$; ANOVA $p<0.001$). As was found in other studies, there were significant relationships between log-Hg and $\delta^{15}N$ through the food webs of all 6 lakes (Figure 1, $p<0.001$, $r^2=0.23$ to 0.65) and the slopes of these lines were similar to what has been found in other studies (e.g. Gantner et al. 2010). Currently, baseline (periphyton) nitrogen isotope values are being analyzed for each lake. Once available, $\delta^{15}N$ values of invertebrates and fish will be corrected and biomagnification rates (regression slopes) will be compared across lakes and with various physical characteristics.

PFCs in water: Table 5 shows the mean concentrations of various PFCs in surface water samples from 2010 and 2011. Water from Meretta and Resolute Lakes, the two lakes located downstream of the Resolute airport, have 40-100 times higher concentrations of the various PFCs compared to the four atmospherically supplied lakes. Concentrations of PFOS are similar to those found in Stock et al. (2007), averaging 1.2-69 ng/L. Interestingly, newly produced fluorotelomer sulfonates (FTS) compounds, relatively new PFCs produced to replace PFOS/PFOA in various products, were detected in all six lakes. Concentrations of various FTS compounds are similar and sometimes exceeding levels found in municipal Spain (mean 0.56 ng/L; Ericson et al. 2009).

PFCs in biota: Figure 2 shows the mean concentrations of various PFCs in char caught in 2010. Similar to water, char from Meretta and Resolute Lakes are up to 100 times higher in PFCs compared to the atmospherically supplied lakes. The dominant PFCs in char were PFOS and several lower chain PFCAs. Concentrations

Figure 2. Mean concentrations of PFCs (ng/g wet weight) in char caught in 2010 from lakes around Resolute Bay, NU

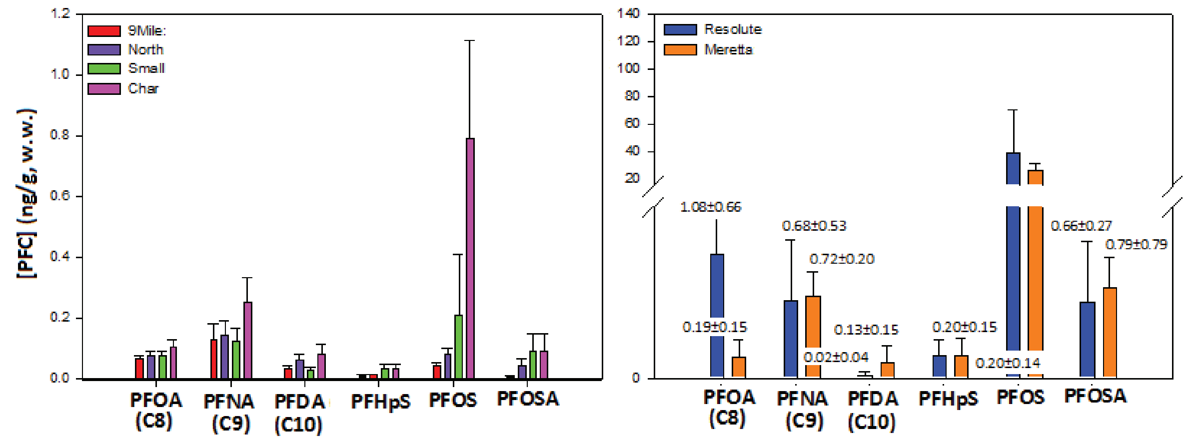
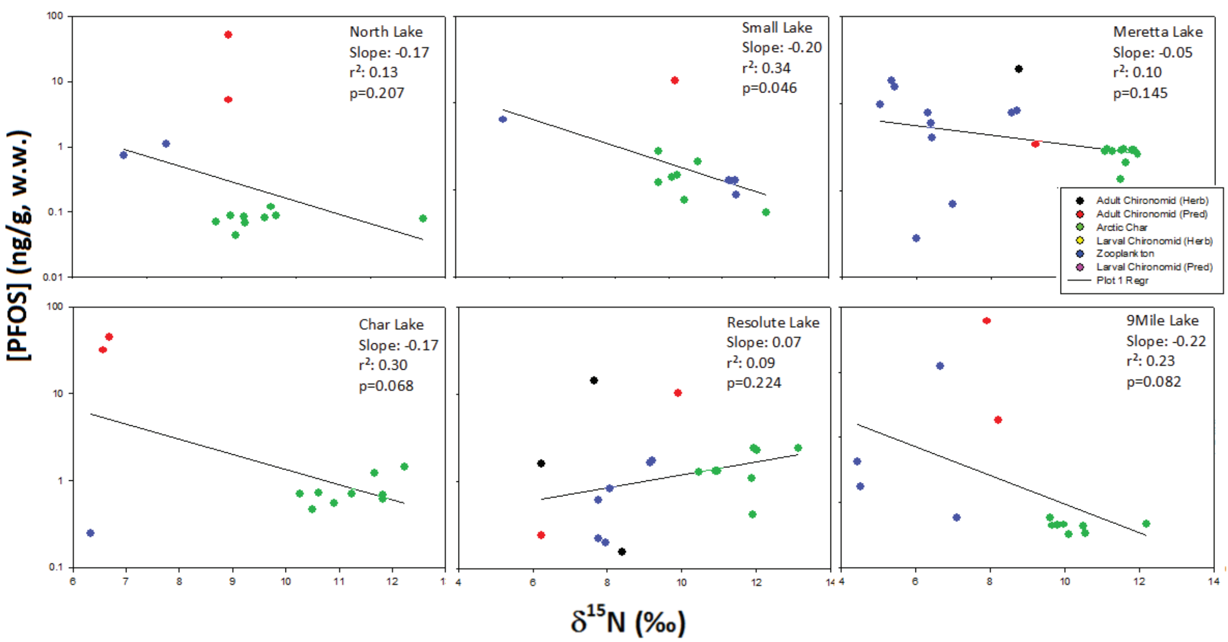


Figure 3. PFOS concentrations (ng/g wet weight) and δ15N (‰) values of char and invertebrates collected in 2010 from the six lakes around Resolute Bay, NU.



of PFOS in char were slightly lower (0.03-121.8 ng/g) than those found in various Great Lakes fish (4.8-121ng/g; Houde et al. 2011). Similar to Hg, exploratory hierarchical multiple regressions were run to test which factors best predict 2010 PFC levels in fish. Out of the factors tested (fish age, sex, fork length, and lake), only lake was slightly and sometimes significantly related to various PFCs (R^2 =0.231 for PFNA, 0.164 for PFDA, 0.348 for PFOA).

As in other studies (Martin et al 2004; Houde et al 2008), benthic invertebrates (chironomids) often had the highest PFC concentrations within a food web (see Figure 3). Of the six lakes, only Small Lake showed a significant relationship between log [PFOS] and trophic position ($\delta^{15}N$) of biota (Figure 3, 2010 only as 2011 analyses are ongoing). However, no lake showed a positive slope, implying no biomagnification of PFOS through these food webs. Similar trends were also seen in PFOA (r^2: 0.01 to 07951, slopes: -0.13 to -0.57).

Isotopes: Bi-plots of $\delta^{15}N$ versus $\delta^{13}C$ for char and invertebrates (Figure 4) show that char occupy the highest trophic level in each of the 6 lakes. $\delta^{13}C$ signatures of char match those of chironomids (-22.86, and -24.4 ‰, respectively), suggesting the fish feed on these benthic invertebrates. Although other studies have used $\delta^{34}S$ to successfully separate organisms feeding on open-water energy from those feeding on sediment-derived energy (e.g. Croisetière et al.

Figure 4. Food web plots for lakes sampled in 2010 near Resolute Bay using stable isotopes; $\delta^{15}N$ indicates trophic position and $\delta^{13}C$ indicates energy source.

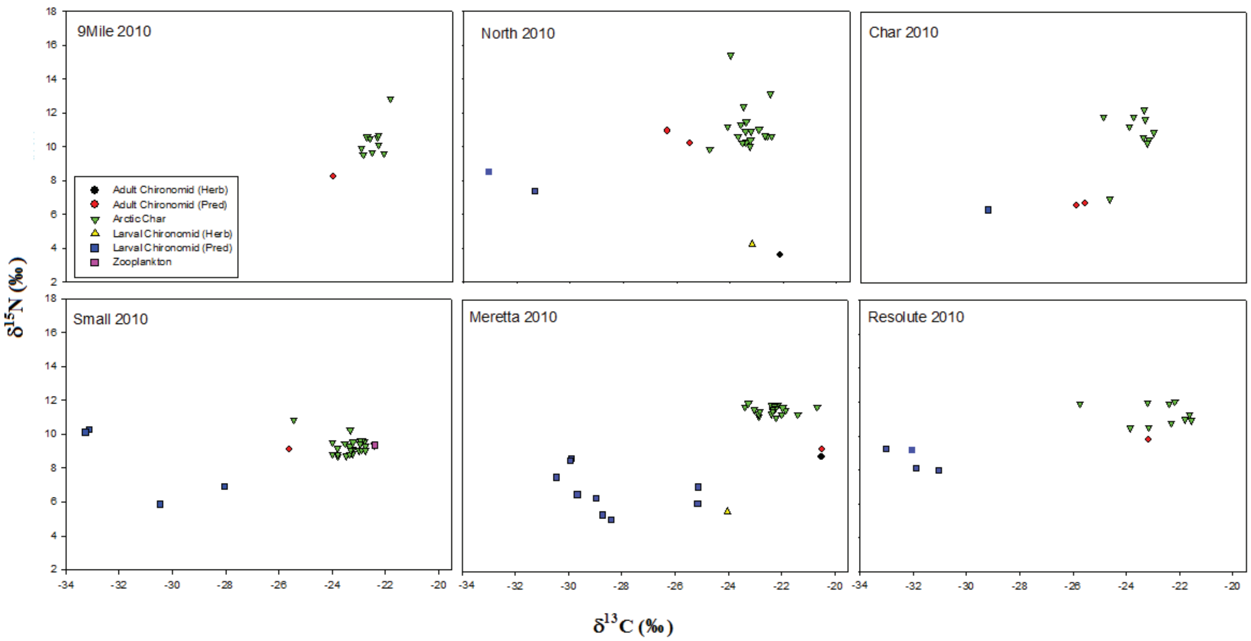
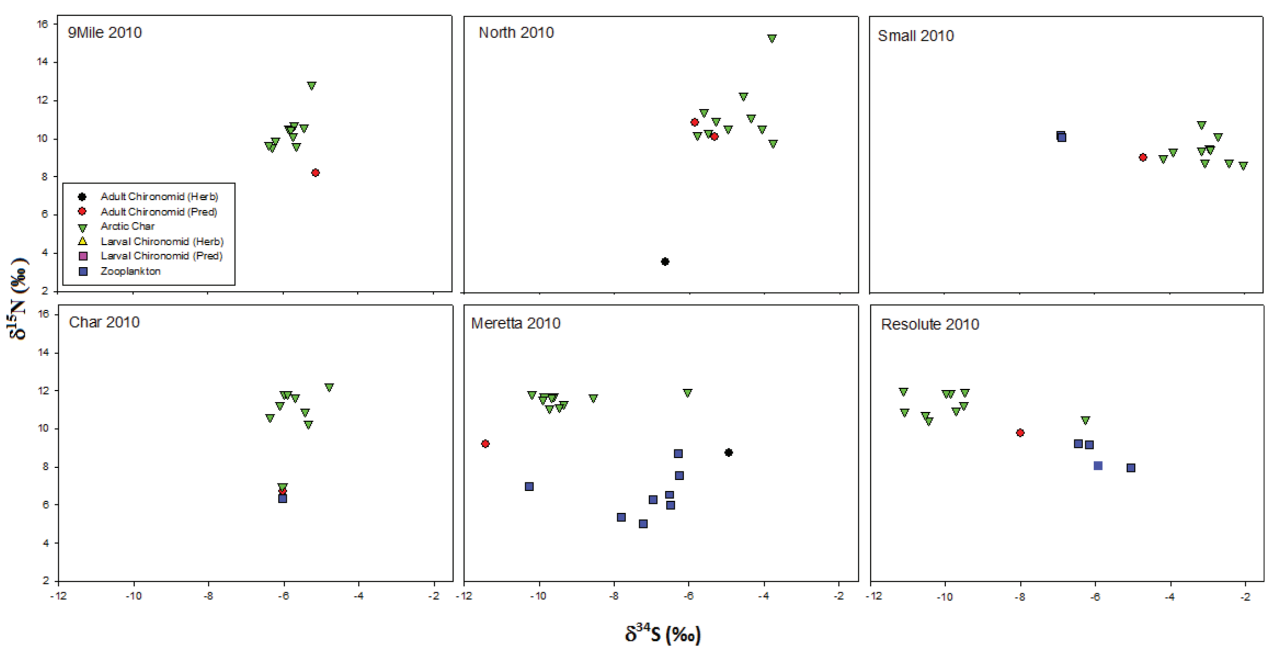


Figure 5. Food web plots for lakes sampled in 2010 near Resolute Bay using stable isotopes; $\delta^{15}N$ indicates trophic position and $\delta^{13}C$ indicates energy source.



2008), $\delta^{34}S$ data for the 6 lakes near Resolute Bay did not improve our understanding of energy flow in these systems (Figure 5). However, some $\delta^{34}S$ are not yet available for the sediments from these lakes and these data may help interpret the results for the biota.

Ongoing analyses: Fish and invertebrates sampled in 2011 are currently being analyzed for PFCs. Analyses of 2011 terrestrial vegetation, periphyton scrapings, and juvenile fish for carbon and nitrogen isotope signatures are also ongoing. These data will be available in July and August of this year and the full results will be presented at the NCP workshop later this year. Once complete, more detailed modeling of the biological, chemical and physical characteristics that predict contaminant concentrations in Arctic char will be explored. These updated models will help us understand how Hg and PFCs are transferred through these food webs to char and whether their accumulation is higher or similar to what has been observed in other studies.

Conclusions

This study has added to our understanding of Hg concentrations in High Arctic lakes by generating information on how Hg concentrations in lake water vary over the open water season, and by assessing the levels of PFCs in abiotic and biotic compartments of these lakes. As found in other studies, concentrations of Hg in food web organisms vary from one lake to another and are higher in fish than invertebrates. In contrast, concentrations of some PFCs were similar in fish and adult chironomids (or lower in fish than invertebrates), suggesting that PFCs are not concentrated (biomagnified) through food webs.

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Anticipating the Effect of Climate Change on Contaminant Exposure in the Arctic

Anticiper les effets du changement climatique sur l'exposition aux contaminants dans l'Arctique

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Abstract

The potential influence of global climate change (GCC) on the fate, transport, bioavailability and bioaccumulation of organic contaminants is rapidly becoming an area of interest for scientists engaged in environmental chemistry and toxicology research. The Arctic region is of particular concern due to changes to the cryosphere that are already occurring (e.g. reduction in sea-ice cover and volume, melting of permafrost and glaciers), the fact that climate change models project the greatest warming to occur in this region in the future and finally that human inhabitants of this region harvesting local food resources (e.g. seals) have an elevated exposure to many contaminants of concern (i.e. persistent organic pollutants, POPs). GCC could potentially influence exposure to organic contaminants via direct (e.g. altered distribution of chemicals in the environment) and indirect (e.g. increased primary productivity = altered organic carbon cycling = altered fate in aqueous environments) pathways. For human beings, lifestyle changes (e.g. dietary transition) facilitated by changes in the environment could also be highly influential in

Résumé

L'influence potentielle du changement climatique mondial (CCM) sur le devenir, le transport, la biodisponibilité et la bioaccumulation des contaminants organiques devient rapidement un domaine d'intérêt pour les chercheurs qui étudient la chimie et la toxicologie environnementales. La région de l'Arctique est particulièrement préoccupante parce que : la cryosphère subit déjà des changements (réduction de la couverture et du volume de la glace de mer, fonte du pergélisol et des glaciers, etc.); les modèles de changement climatique projettent que le réchauffement sera le plus marqué dans cette région; les humains qui habitent la région et qui y prélèvent des ressources alimentaires locales (p. ex. les phoques) sont fortement exposés à de nombreux contaminants préoccupants (polluants organiques persistants, ou POP). Le CCM pourrait influer sur l'exposition aux contaminants organiques par voie directe (p. ex. distribution modifiée des substances chimiques dans l'environnement) et indirecte (p. ex. productivité primaire accrue = cycle du carbone organique altéré = devenir

the long-term. The purpose of this investigation was (i) to explore the potential influence of changes to the physical environment (e.g. temperature, precipitation rate, sea-ice cover) on the long-range transport and accumulation of neutral organic compounds in the Arctic, and (ii) to quantify the potential influence of intergenerational dietary transitions on human exposure to organic contaminants in the Arctic environment using PCB-153 as a case study. Overall, the results suggest that dietary transitions may have a larger effect on the future exposure of Northerners to POPs than changes in the physical environment occurring as a result of GCC.

modifié dans les milieux aquatiques). Pour les humains, les changements de mode de vie (p. ex. dans les habitudes alimentaires) causés par les changements dans l'environnement pourraient aussi avoir des répercussions importantes à long terme. La présente étude vise : i) à explorer l'influence potentielle des changements au milieu physique (température, taux de précipitation, couverture de la glace de mer, etc.) sur le transport à grande distance et l'accumulation des composés organiques neutres dans l'Arctique; ii) à quantifier l'influence potentielle de l'évolution des habitudes alimentaires d'une génération à l'autre sur l'exposition humaine aux contaminants organiques dans l'environnement arctique au moyen du PCB-153 en guise d'étude de cas. Globalement, les résultats indiquent que l'évolution des habitudes alimentaires exerce des effets plus importants sur l'exposition future des populations du Nord aux POP que les changements dans le milieu physique causés par le CCM.

Keys Messages

- The impact of climate-related changes in the physical environment (temperature, precipitation, sea ice cover, atmospheric transport) on exposure relevant concentrations in Arctic sea water are predicted to be remarkably small for all types of persistent organic pollutants (POPs), generally being of a factor of less than two.

- In contrast, changes in the structure of the human food chain could have much more dramatic consequences: Specifically, the dietary transition from traditional food items (including those originating from marine mammals high in the food chain) to imported food that is occurring in many Arctic communities (and that may be accelerated by a changing climate), has the potential to result in much larger changes in human exposure to POPs.

- A similarly large effect might be expected to occur if the food chain structure is not changing as a result of dietary choices humans make, but as a result of changes

Messages clés

- L'impact des changements climatiques dans le milieu physique (température, précipitation, couverture de la glace de mer, transport atmosphérique) sur l'exposition à des concentrations pertinentes dans l'eau de mer de l'Arctique devrait être remarquablement faible, et ce, pour tous les types de polluants organiques persistants (POP), c'est-à-dire à un facteur généralement inférieur à deux.

- En revanche, les changements dans la structure de la chaîne alimentaire humaine pourraient avoir des conséquences bien plus dramatiques. Plus précisément, l'évolution des habitudes alimentaires, de la nourriture traditionnelle (dont celle issue des mammifères marins des niveaux trophiques supérieurs) à la nourriture importée, qui est en cours dans de nombreuses collectivités de l'Arctique et qui peut être accélérée par un climat changeant a le potentiel d'entraîner des changements beaucoup plus importants dans l'exposition des humains aux POP.

in the trophic relationships in the marine food chain, e.g. if seals change their diet to fish feeding at a different trophic level. The latter type of change is, however exceedingly difficult to anticipate and thus quantify.

- In order to predict future exposure of Northerners to POPs the following factors need to be considered (in decreasing order of importance): (1) changes in the extent and location of global emissions of POPs, (2) changes in the dietary composition of Northern populations, (3) changes in Arctic and global climate.

- Un effet d'aussi grande ampleur pourrait se produire si la structure de la chaîne alimentaire ne change pas en raison des choix alimentaires que font les humains, mais plutôt en raison des changements dans les relations trophiques au sein du réseau trophique marin (p. ex. si les phoques modifient leur alimentation en mangeant des poissons qui se nourrissent à un autre niveau trophique). Ce genre de changement est toutefois extrêmement difficile à anticiper et donc à quantifier.

- Pour prévoir l'exposition future des habitants du Nord aux POP, les facteurs suivants doivent être considérés (en ordre décroissant d'importance) : 1) changements dans l'étendue et l'emplacement des émissions mondiales de POP; 2) changements dans la composition de l'alimentation des populations du Nord; 3) changements dans le climat de l'Arctique et dans le climat mondial.

Objectives

Long-term:

- To identify and describe mechanisms by which a changing climate may affect the exposure of Arctic populations to organic contaminants and mercury, including changes in chemical use and emissions, in the delivery of contaminants to the Arctic ecosystem, in their processing within the Arctic physical environment and in the human food chain.
- To estimate the likely magnitude of changing contaminant exposure in the Arctic in response to different scenarios representing global climate change.
- To assess to what extent a changing climate may confound contaminant time trends obtained by analyzing residue levels in marine organisms from the Arctic.

Short-term:

- To assess how the global transport of persistent organic pollutants of different partitioning and degradation characteristics and their accumulation in the Arctic is expected to change as a results of a changing global climate
- To quantify the potential changes in the exposure of Northerners to organic contaminants that could arise from the transition from a traditional to a southern diet, whereby this transition may be accelerated by Arctic climate change.

Introduction

It is well-established that despite being located far from most major emission sources of organic contaminants, wildlife and humans inhabiting the Arctic environment exhibit much higher body burdens of environmental contaminants of concern than might otherwise be anticipated (Dewailly et al. 1993). Human subpopulations harvesting extensively from the marine environment are particularly susceptible to exposure to many of these contaminants, collectively known as POPs, especially those which tend to consume fatty tissues (e.g. blubber, skin) as part of the traditional diet (Undeman et al. 2010).

More recently, a focus on the potential implications of GCC for ecological and human exposure to organic contaminants has emerged in the scientific literature (e.g. Armitage et al. 2011). This issue is highly relevant for the Arctic environment because of the extent of warming projected to occur in this region and the vulnerability of the cryosphere to such changes. Modelling studies focused on the potential implications of GCC on chemical fate on a global-scale (MacLeod et al. 2005, Lamon et al. 2009) indicate that the influence of temperature, precipitation and atmospheric/oceanic circulation patterns may have only a modest influence on the occurrence of POPs in the Arctic. Additional simulations incorporating a wider range of GCC scenarios and chemical property combinations are required to more completely investigate this aspect of GCC however.

An additional factor to consider with respect to human exposure to organic contaminants is that people living in the Arctic have experienced increasing access to and consumption of imported food items over the past several decades, a trend that is likely to continue in the future (Kuhnlein et al. 2004, Deutch et al. 2007). This dietary transition has implications for both historic and future exposure to organic contaminants. For example, dietary shifts within and between generations may contribute to the variability in human tissue residues often observed. With respect to GCC, the extent to which subpopulations shift away from the consumption of locally-harvested food represents the extent to which these people become decoupled from any potential changes in exposure to POPs related to the dramatic environmental changes already occurring and those projected to occur in the future. As discussed recently (Undeman et al. 2010, Armitage et al. 2011), the dietary transition may overwhelm any other potential effects of GCC on human exposure in this region, especially if it involves a substantial reduction in the consumption of marine mammals (e.g. ringed seal).

Activities in 2011-2012

The focus of the activities in 2011/12 was on two major modeling studies. The first involved calculations of global fate and Arctic accumulation under conditions of future GCC, the second looked at the potential impact of dietary transitions on the time trends in Inuit contaminant exposure.

Global Fate and Arctic Accumulation Under Conditions of GCC. The effect of GCC on the global transport and accumulation of persistent organic pollutants in the Arctic was studied with the help of the global transport and distribution model Globo-POP (Wania and Mackay 1995). Prior to this application of the model, it had to be modified to include a dynamic description of the global cryosphere, namely the polar sea ice cover and the seasonal snow cover of high latitude regions. Once the adapted model had been tested, the approach was as follows:

- **Environmental Parameterisation:** Chemical fate calculations were performed for two environmental parameterisations, first using the default values implemented in the model, which reflect late 20th century condition (designated as “DEF”), and then using values based on late 21st century projections (designated as “GCC”) from the Intergovernmental Panel on Climate Change (IPCC 2007). The major parameters to be changed include temperature, precipitation, run-off, snow cover and length of the spring snow melt period. Furthermore, the ice cover and the concentration of particulate organic carbon in the Arctic Ocean were adjusted.

- **Chemical Properties:** Chemical fate calculations were performed for a set of hypothetical chemicals, with partitioning properties ranging widely (air-water partition coefficient log K_{AW} = -5 to 3, octanol-air partition coefficient log K_{OA} = 4 to 15; octanol-water partition coefficient log K_{OW} = log K_{OA} + log K_{AW}). All hypothetical chemicals are assumed to degrade in surface compartments with a half-life of 6.3 years and to have a reaction rate constant with OH radicals in the atmosphere of $1.6 \bullet 10^{-13}$ cm3 $molecules^{-1}$ s^{-1}. Model results, most notably ratios of calculated concentrations obtained for the two different environmental parameterisations, can therefore be displayed graphically as a function of log K_{OA} and log K_{AW} (i.e. the "chemical partitioning space").

- **Emission Scenario:** To reflect the dynamic nature of the emissions of most chemicals as well as to account for the long time it takes highly persistent chemicals to establish steady state, emission were assumed to be first steady for 20 years and then ceased entirely afterwards. Model results for year 20 i.e. the end of the emission period) and year 40 (i.e. after 20 years of environmental depuration) were being evaluated.

These calculations therefore went beyond previous efforts of this nature (MacLeod et al. 2005, Lamon et al. 2009) in several important regards: They are much more comprehensive than studies that focus on one or a select few substances and they no longer make the often unreasonable assumption that steady-state conditions prevail. Furthermore, they explicitly consider the effect of GCC on the cryosphere, which may greatly amplify effects of temperature changes on contaminant fate (Macdonald et al. 2005).

Impact of Dietary Transitions on the Time Trends in Human Contaminant Exposure in the Arctic. An integrated approach combining chemical fate and bioaccumulation modeling was used to assess the potential implications of intergenerational dietary transitions on human exposure to organic contaminants in the Arctic (Quinn et al., submitted). First the Globo-POP model (Wania and Mackay 1995) was used in combination with estimates of time variant global emissions (Breivik et al. 2007) to calculate time trends of PCB-153 concentrations in the physical environment (i.e. air, water, and soil) of the Arctic as well as the regions from which food stuffs may be imported to the Arctic (i.e. temperate and boreal zone of the Northern hemisphere). These concentrations were then used as input to Arctic and temperate versions of the food chain bioaccumulation model ACC-human (Czub and McLachlan 2004) to calculate time trends of PCB-153 concentrations in both traditional country foods (esp. fish and seal) and in food imported to the North (dairy, meat, fish). Finally, the human sub-model from ACC-human was used to calculate age-dependent PCB-153 concentrations in Inuit cohorts (subsequent generations of people born every ten years) that eat diets that differ in their relative contribution of traditional and imported food items. Five possible diets were considered, ranging from 100 % traditional to 100 % imported. The calculated cohort concentration trends could then be "sampled" at different times to obtain concentration time trends as they would be obtained from typical human biomonitoring studies.

Results

Global Fate and Arctic Accumulation Under Conditions of GCC. Primarily two ratios were used to illustrate the results of the global fate and Arctic accumulation simulations with Globo-POP. The ratio RY=20 compares the model output (mostly concentrations in the air and surface ocean compartment of the North Polar zone) for the two environmental parameterizations at the end of simulation year 20:

$$R_{Y=20} = C_{GCC,20}/C_{DEF,20}$$

If RY=20 is smaller (larger) than 1, the concentrations are lower (higher) under the global climate change scenario than the default scenario. The ratio RY=40 compares the rate of depuration after an additional 20 years of no emission:

$$R_{Y=40} = (C_{GCC,40}/C_{GCC,20}) \ / \ (C_{DEF,40}/C_{DEF,20})$$

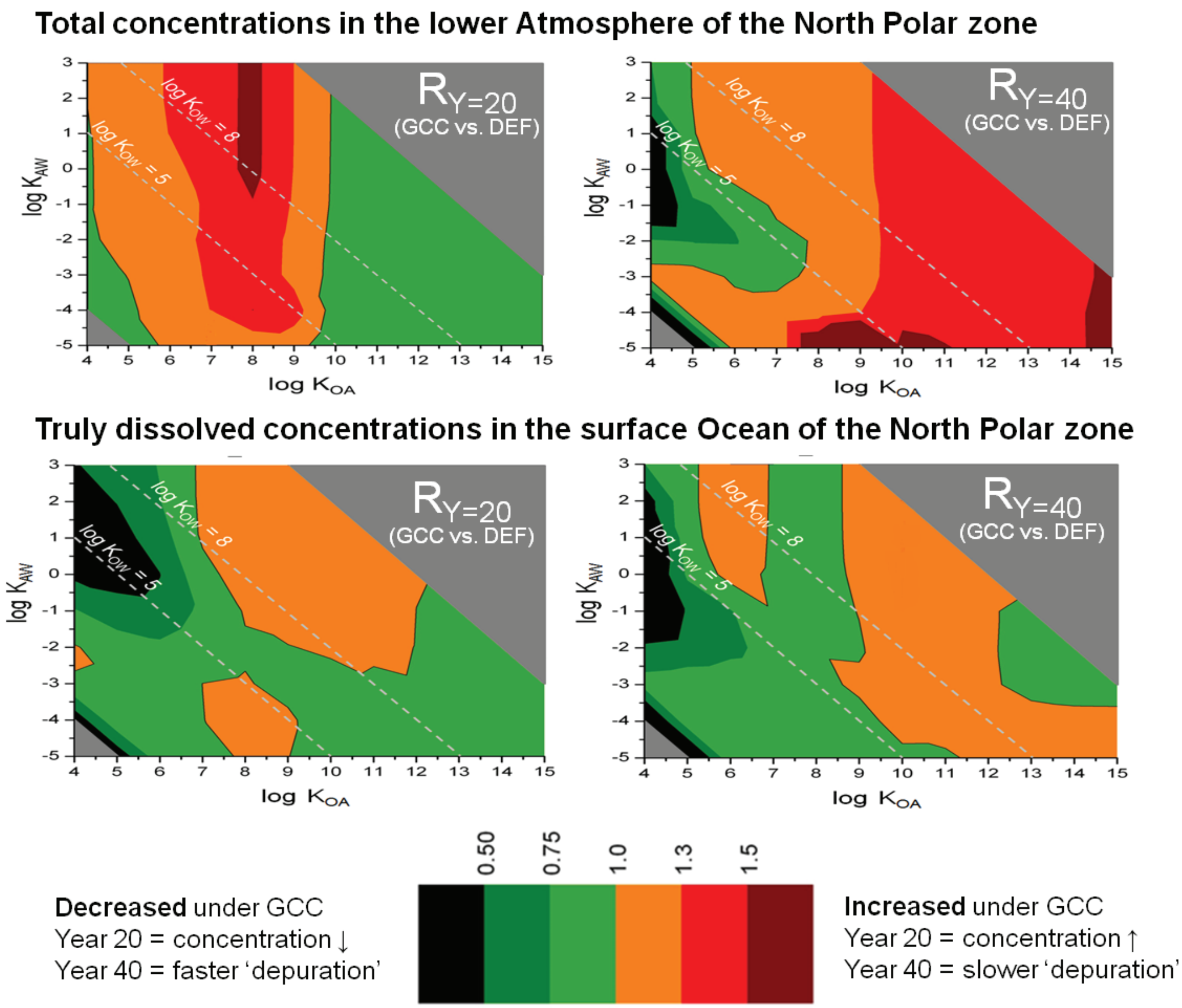
If $R_{Y=40}$ is smaller (larger) than 1, the rate of depuration is faster (slower) under the global climate change scenario than the default scenario.

Figure 1 shows the two ratios for the total air concentration and the truly dissolved sea water concentration of the North Polar zone as a function of the chemical partitioning space defined by log K_{OA} and log K_{AW}. A number of observations can be made based on these plots.

The effect of GCC:

- on the concentrations in the Arctic is likely to be quite limited, as suggested by ratios $R_{Y=20}$ and $R_{Y=40}$ that are generally quite small (generally much smaller than 2). These

Figure 1. Simulated change in the concentration of hypothetical chemicals in the lower atmosphere and in the surface ocean of the North Polar zone as predicted to occur by a global fate and transport model as a result of a changed global climate. Displayed are concentration ratios RY=20 and RY=40 (defined in detail in the text) as a function of the chemical partitioning space defined by the log KOA and log KAW of the hypothetical chemicals. Green (red) colours indicate that environmental levels of contaminants are lower (higher) or are dropping faster (slower) under future climate conditions than under current climatic conditions.

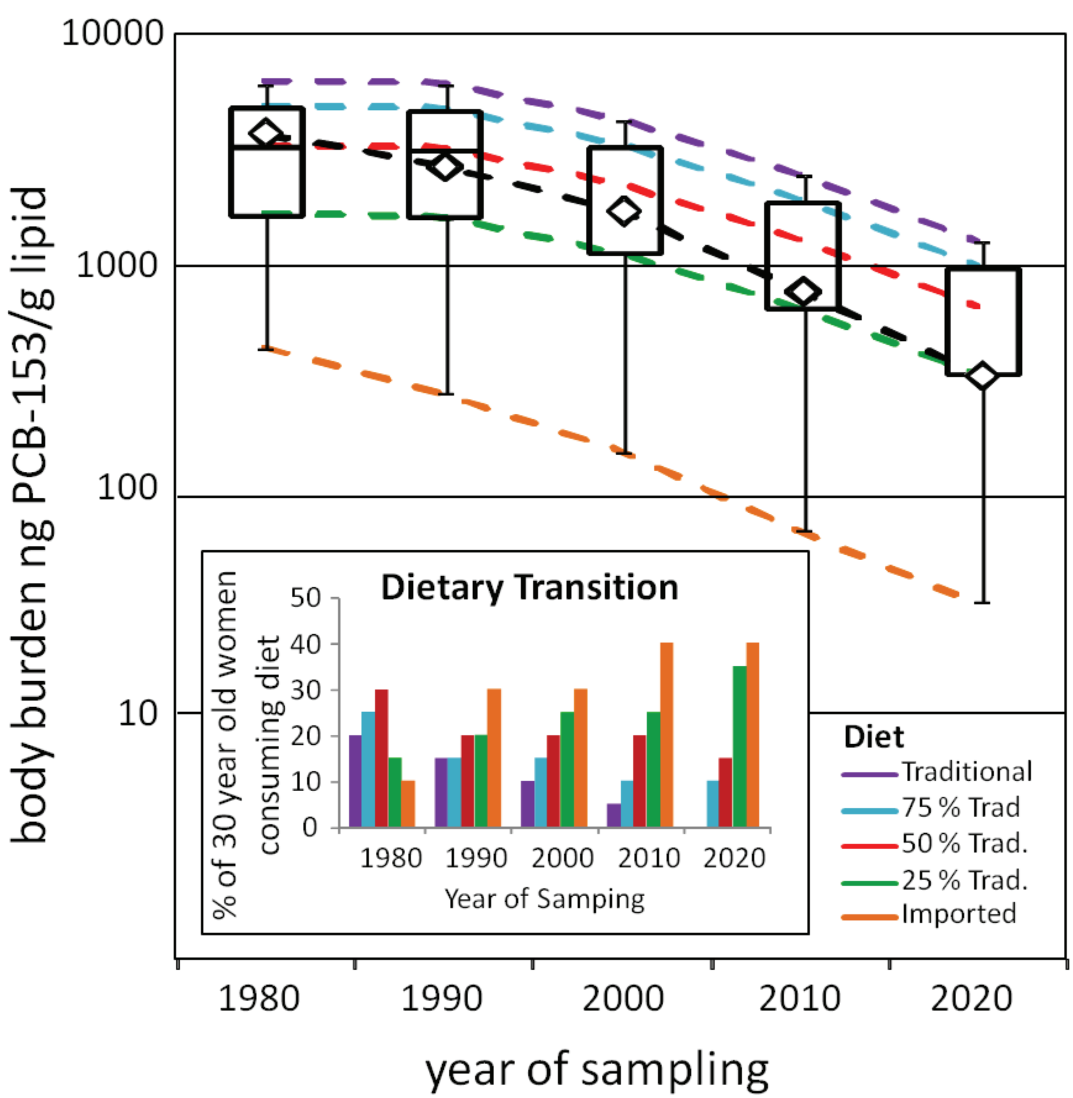


results reflect the fact that the GCC scenarios often result in shifts in fate and transport behavior that frequently act in opposition (i.e. compensatory behavior) (Armitage et al. 2011)

- is dependent on a chemical's partitioning properties (i.e. comparing different sections within one partitioning space plot). For example, while air concentrations of less volatile contaminants (log $K_{OA} > 10$, e.g. PBDEs) are predicted to be lower under GCC, those of contaminants with intermediate volatility ($6 < \log K_{OA} < 9$, e.g. HCHs, HCB) are expected to increase.

- is predicted to depend on the emission history (i.e. comparing partitioning space plots for $R_{Y=20}$ and $R_{Y=40}$). For example, during times of ongoing primary emissions ($R_{Y=20}$), concentrations of low volatility compounds (e.g. PBDEs) in Arctic air and water are expected to be lower under GCC. However, the rates of depuration of these

Figure 2. The distribution of PCB-153 body burdens of a population of 30-year old Inuit women from 1980-2020 (black box and whiskers) according to a gradually shifting dietary distribution (insert) as calculated with a combination of global transport and fate and human food chain bioaccumulation models. The body burdens for a population of 30 year old Inuit women who all consume the same diet are overlaid for comparison (broken coloured lines).



same compounds from Arctic air and water during times when secondary sources dominate ($R_{Y=40}$) are expected to be slower under GCC.

- The effect of climate change is not always the same for air and ocean (i.e. comparing partitioning space plots for air and water). For example, whereas air concentrations of HCB and lighter PCBs are expected to be higher under GCC, the concentrations in sea water for those same compounds are predicted to be lower.

Results of simulations (not shown) that also involved a change in the particulate organic carbon concentration in the Arctic Ocean, as may be expected to occur as a result of increased marine primary productivity in a warmer Arctic, may be important for a number of POPs. By influencing the truly dissolved (i.e. bioavailable) fraction in the water column, the POC concentration may decrease water concentration of hydrophobic substances during times of primary emission, but also decease the rate of depuration of many of those same chemicals after emissions have ceased.

Impact of Dietary Transitions on the Time Trends in Human Contaminant Exposure in the Arctic. Without dietary changes in time, the model predicted that the PCB-153 body burden of a 30 year old Inuit woman in 2020 would be a factor of 5-15 times lower than in 1980. This decline in body burden is a direct result of decreased emissions. Assuming a rapid dietary transition (lasting 40 years) starting in 1960, the body burden of the 30 year old female cohort declined by 2.3 and 2.9 orders of magnitude over the same 40 year period (1980-2020) assuming consumption of food imported from the Northern Temperate and Boreal zone, respectively. In other words, the dietary transition could cause up to an additional 150-fold reduction over a forty year time period, in addition to the 5-fold reduction due to emissions.

If the dietary transition was assumed to be more gradual (starting 1960, lasting 70 years), then the body burden declines over time could be less obvious: the dietary transitions are only predicted to yield body burden declines for 30 year old females of 1 order of magnitude from 1980 to 2020 or up to a 2-fold decrease in addition to that expected from emissions alone. This is much less than the 150 fold reduction predicted for the rapid dietary transition for the same population over the same time period and highlights the importance of understanding both the timing and rate of dietary transitions to the accurate interpretation of biomonitoring studies.

In the above results, the assumption is that every person in a specific age group consumes the exact same diet. In reality, each cohort will be composed of individuals with a wide range of diets and it is the distribution of these diets which shifts increasingly towards more imported food items over time. Figure 2 illustrate the changing body burden of 30 year old Inuit women over time assuming mixed dietary consumption distributions. According to this more realistic dietary transition, the average body burdens for the 30 year old female cohort in 2020 are predicted to be 12 times lower than those in 1980 for either imported food sources, i.e. the dietary transition could cause an additional two-fold decrease. Figure 2 also demonstrates that there is likely to be more variability within an age group than between age groups unless a very fast dietary transition is occurring and therefore the distribution of dietary habits is likely to be an important source of variability seen in measured body burdens.

Discussion and Conclusions

These results highlight possible sources of the large degree of variability that is observed in human biomonitoring data from the Arctic. In particular, the geographical source of the imported diet, timing of the dietary transition, rate of the transition, and the dietary distribution over time are all paramount for estimating the contribution that dietary transitions make to the decline in human body burdens. In general, changing dietary

NCP Performance Indicators

Performance Indicator	Number
number of Northerners engaged in the project (April 1, 2011-March 31, 2012)	0
number of project-related meetings/workshops held in the North (April 1, 2011-March 31, 2012)	0
number of students (both northern and southern) involved in your NCP work (April 1, 2011-March 31, 2012)	1 southern

number of citable publications		
in peer-reviewed international journals	2011: 1	Armitage, et al. 2011. *J Environ Monit 13*: 1532-1546.
	2012: 2	Gouin, T., J.M. Armitage, I.T. Cousins, D.C.G. Muir, C.A. Ng, L. Reid, and S. Tao. Assessing the influence of global climate change on chemical fate and bioaccumulation: The role of multimedia models. *Environ Toxicol Chem*: accepted with major revisions. Quinn, et al. submitted
conference presentations	2011: 1	Armitage, J.M., T.N. Brown, T. Meyer, S.-D. Choi, and F. Wania. A quantitative comparison of long-range transport potential and contaminant delivery to the Arctic ecosystem under current and future global climate scenarios using a global-scale fate and transport model. Poster presentation at the NCP Results Workshop, Victoria, BC, September 20-21, 2011.
	2012: 2	Armitage, J.M., and F. Wania. Assessing the potential influence of global climate change on the long-range transport and accumulation of organic contaminants in the Arctic environment in relation to physical-chemical properties. Poster presentation at the 6th SETAC World Congress, Berlin, May 20-24, 2012. Wania, F., C.L. Quinn, and J.M. Armitage. Modelling the impact of dietary transitions on human exposure to bioaccumulating organic contaminants. Platform presentation at the 6th SETAC World Congress, Berlin, May 20-24, 2012.

trends contribute to declining body burdens in the Arctic for PCBs, although the relative influence of declining global PCB emissions and dietary changes is highly sensitive to the specific characteristics of the dietary transition for a given population. The calculations presented here serve to emphasize potential sources of uncertainty associated with analyzing biomonitoring studies for populations undergoing a dietary transition such that future studies can attempt to address these issues.

This study highlights the complex array of factors determining human exposure to organic contaminants in the environment. While many aspects can be addressed through the application of chemical fate and bioaccumulation models, substantial uncertainties and data gaps remain which limit the opportunities to use such tools more broadly. With respect to the interpretation of cross-sectional body burden age trends, the long-term PCB-153 simulations illustrate the key roles of emission history and dietary composition in determining absolute exposure levels over time and potential variability within and between different subpopulations. For chemicals which are more susceptible to biotransformation, uncertainties related to estimating metabolic rate constants in humans and the various organisms in the human food chain present an additional challenge to model parameterization as these parameter values can be highly influential (McLachlan et al. 2011).

The long-term simulations conducted here were made possible by the existence of the detailed historic and projected emission inventory for PCB-153 (Breivik et al. 2007). Similar calculations could be repeated for other PCB congeners as well as other POPs for which historic emission inventories are available. These simulations could provide additional insight into spatial and temporal trends evident in the available biomonitoring data and provide guidance for future sampling campaigns. The lack of emission estimates for current-use pesticides and other contaminants of emerging concern limit the scope of modeling studies to hypothetical scenario assessment. These activities can still be quite valuable, particularly in the context of hypothesis development and field study design. Some commonalities can be expected to apply to all organic contaminants, namely the importance of assumptions regarding the temporal evolution of emission rate over time, the importance of partitioning properties and biotransformation in determining bioaccumulation potential and the influence of diet in determining absolute levels and variability in human exposure levels. As demonstrated here, modeling approaches are well suited to assessing such considerations in a holistic and transparent manner.

Communications. In addition to the conference presentation listed above, project results were also presented at two seminars at universities:

- Armitage, J.M. et al. 2012. Illustrating the role of chemical fate models in assessing the potential influence of global climate change on exposure to organic contaminants. Seminar presentation at the Department of Chemistry, University of Toronto, Toronto, Canada, January 16, 2012.
- Wania, F., C.L. Quinn, and J.M. Armitage. 2012. Modellierung des Schadstoffverhaltens in der Umwelt und der menschlichen Nahrungskette: Nahrungswandel und Schadstoffbelastung in der Arktis. Seminar presentation at the Institute for Environmental Systems Research, University Osnabrück, Germany, May 25, 2012

Expected Project Completion Date

We expect the project to be completed during fiscal year 2012/13.

Acknowledgments

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Occurrence and Levels of POPs in the Connected System of Air-Water Phytoplankton-Zooplankton from the Canadian Archipelago

Occurrence et concentrations de POP dans le système air-eau-phytoplancton-zooplancton de l'archipel canadien

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Abstract

Air, water, phytoplankton and zooplankton samples were collected on board the CCGS Amundsen in October 2011 as part of ArcticNet between Kugluktuk, NT and Quebec City, QC via Baffin Bay, see Figure 1. The samples were analysed for legacy organochlorine pesticides (OCPs), current use pesticides (CUPs), per and polyfluoroalkyl substances (PFAS) and organophosphate flame retardants and plasticizers (OPs). The purpose of collecting air and water samples in the Canadian Archipelago was i) to continue the time trends of OCPs and CUPs, ii) to confirm the presence of PFAS observed in recent years and iii) establish baseline concentrations of OPs. The phytoplankton and zooplankton samples investigation will allow quantification of the above compounds in the lower food web and

Résumé

Des échantillons d'air, d'eau, de phytoplancton et de zooplancton ont été prélevés à bord du NGCC Amundsen en octobre 2011 dans le cadre d'un projet ArcticNet entre Kugluktuk (Nunavut) et la Ville de Québec (Québec) dans la baie de Baffin (voir la figure 1). Les échantillons ont été analysés en vue d'y détecter des pesticides organochlorés (POC) hérités du passé, des pesticides en usage (PU), des substances perfluoroalkylées et polyfluoroalkylées (SPFA) et des produits ignifuges et des plastifiants organophosphatés (PO). Le prélèvement d'échantillons d'air et d'eau dans l'archipel canadien visait : i) à continuer d'établir les tendances temporelles des POC et des PU; ii) à confirmer la présence de SPFA ces dernières années; iii) à établir les concentrations ambiantes des PO. L'étude des échantillons de phytoplancton

observe how these compounds move from the abiotic to biotic environment.

Four OPs, tri-phenyl phosphate (TPP); tris-(2-chloro ethyl) phosphate (TCEP), tris-(2-chloro propyl) phosphate (TCPP) and tris-(1,2-dichloro propyl) phosphate (TDCPP) were identified in air samples for the first time in Canadian arctic air and levels are very high compared to levels of Σ-PBDEs and other brominated flame retardants at Alert (Xiao et al., 2012). Due to these findings, archive samples from Alert and previous ArcticNet cruises were also analysed for OPs, thus establishing baseline concentrations in Canadian arctic air in which future trends can be compared.

Our results show, that legacy OCPs, namely hexachlorocyclohexanes (HCHs) and components of technical chlordane continue to decline in arctic air and there are indications that levels of some PFAS compounds are also declining in response to regulations. Additionally, several CUPs in air had lower concentrations in 2011 than previously measured. Endosulfan-I has steadily declined from the early 1990s to 2011, this maybe a result of restrictions on endosulfan use in Europe and North America.

Water column profiles were taken for PFAS compounds but no apparent concentration differences with depth were found, suggesting the upper 50-100m of archipelago water is well mixed for these compounds. Higher concentrations of perfluorocarboxylates (PFCAs) compared with polyfluoroalkyl sulfonates (PFSAs) were observed in water. For the PFSAs, lower chain length compounds were dominant.

In phytoplankton was perfluorooctane sulfonate (PFOS) was the only PFAS found, detected in 100% of the samples, where OCPs and CUPs were below detection limits in all phytoplankton samples.

et de zooplancton, quant à elle, permettra de quantifier les composés ci dessus dans les niveaux trophiques inférieurs et d’observer comment ces composés se déplacent d’un milieu abiotique à un milieu biotique.

Quatre PO, soit le phosphate de triphényle (PTP), le phosphate de tris (2 chloroéthyle) (PTCE), le phosphate de tris-(2-chloropropyle) (PTCP) et le phosphate de tris-(1,2-dichloropropyle) (PTDCP), ont été identifiés dans des échantillons d’air pour la première fois dans l’Arctique canadien, et leurs concentrations sont très élevées quand on les compare à celles des Σ-PBDE et d’autres produits ignifuges bromés à Alert (Xiao et al., 2012). À la lumière de ces constats, des échantillons archivés pris à Alert et dans le cadre de campagnes ArcticNet précédentes ont également été analysés aux fins de détection de PO; on a ainsi pu établir les concentrations ambiantes dans l’air de l’Arctique canadien auxquelles les tendances futures peuvent être comparées.

Nos résultats montrent que les POC hérités du passé, notamment les hexachlorocyclohexanes (HCH), et les composantes du chlordane technique continuent de décliner dans l’air de l’Arctique et que les concentrations de certaines SPFA sont aussi à la baisse grâce à la réglementation. En outre, plusieurs PU présentaient des teneurs atmosphériques qui étaient inférieures en 2011 à celles mesurées auparavant. Les teneurs en endosulfan-I ont baissé de manière soutenue entre le début des années 1990 et 2011, résultat qui découle peut-être des restrictions visant l’utilisation de l’endosulfan en Europe et en Amérique du Nord.

Les profils des SPFA ont été pris dans la colonne d’eau, mais aucune différence de concentration apparente en fonction de la profondeur n’a été trouvée, ce qui donne à penser que la plage supérieure de 50-100 m de l’eau de l’archipel présente un bon mélange de ces substances. Dans l’eau, les concentrations de perfluorocarboxylates (PFCA) étaient plus élevées que celles des polyfluoroalkylsulfonates (PFAS). Pour ces derniers, les composés à courte chaîne étaient plus nombreux.

Dans le phytoplancton, le sulfonate de perfluorooctane (SPFO) était la seule SPFA trouvée; il a été détecté dans 100 % des échantillons. Les POC et les PU se trouvaient en deçà des limites de détection dans tous les échantillons.

Keys messages

- For the first time organophosphate flame retardants and plasticizers have been identified in Canadian arctic air. Along with archived ArcticNet 2010 and samples from Alert 2008/09, baseline concentrations in air have been determined from which future trends can be gauged.
- Temporal trends indicate that OCPs and most CUPs are declining in arctic air.
- PFAS in arctic air between 2004-2011 suggest they are also declining, but further sampling is needed to confirm this.
- The upper 50-100m of the water column in the Canadian Archipelago is well mixed for PFAS compounds, showing no change in concentrations with depth.
- Phytoplankton samples had detectable amounts of PFOS but no other target compounds.

Messages clés

- Pour la première fois, des produits ignifuges et des plastifiants organophosphatés ont été détectés dans l'air de l'Arctique canadien. D'après des échantillons archivés lors de la campagne ArcticNet 2010 ainsi que des échantillons prélevés à Alert en 2008-2009, des concentrations atmosphériques ambiantes ont été déterminées; les tendances futures pourront donc y être comparées.
- Les tendances temporelles indiquent que les concentrations de POC et de la plupart des PU sont à la baisse dans l'air arctique.
- Les teneurs en SPFA observées dans l'air de l'Arctique entre 2004 et 2011 semblent aussi à la baisse, mais d'autres échantillonnages sont nécessaires pour le confirmer.
- La plage supérieure 50-100 m de la colonne d'eau dans l'archipel canadien présente un bon mélange de SPFA, les concentrations ne changeant pas en fonction de la profondeur.
- Les échantillons de phytoplancton affichaient des quantités détectables de SPFO, mais aucun autre composé ciblé n'a été trouvé.

Objectives

- To collect a set of baseline seawater concentration data for legacy persistent organic pollutants (POPs) and new chemicals in the Arctic against which future trends, sources and sinks in the ocean may be evaluated;
- To collect accompanying air, phytoplankton and zooplankton concentration data in a way that will assist transport and environmental fate modeling of arctic contaminants;
- To develop a better understanding of the air-water-food web exchange dynamics and framework for assessing climate change impact on arctic contamination; and

- To apply the ocean contaminant data to the design of a practical monitoring strategy for Canadian arctic waters.

Introduction

Contaminants are transported to the Arctic by air and ocean currents. Air in the arctic is a relatively well-mixed system but arctic oceanography is very complex thus levels of contaminants in arctic water vary, this is demonstrated with hexachlorocylochexanes (HCHs) in surface waters in the Canadian archipelago (Bidleman et al. 2007) and the Beaufort Sea (Pućko et al., 2012). Arctic monitoring programs have observed declines in organochlorine pesticides (OCPs) over the past two decades in air and biota (Hung et al., 2010; Riget et al. 2010), but there has never been a coordinated arctic water monitoring program. Water is a secondary medium for the Stockholm Convention's Global Monitoring Plan for Persistent Organic Pollutants (POPs). Additionally, source transport and distribution of current use pesticides (CUPs) in the arctic is more limited than that of OCPs in air and water.

Stain-repellent-related per and polyfluoroalkyl substances (PFAS) have gained global attention for their bioaccumulative, persistent, long range transport potential and toxicity, particularly perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). Recently, PFOS and its salts were added to Annex B of the Stockholm Convention on POPs. Accordingly, industries have changed from producing the more persistent PFAS (including perfluoroalkyl carboxylates (PFCAs) and polyfluoroalkyl sulfonates (PFSAs)) towards more volatile substances, including fluorotelomer alcohols (FTOHs), fluorotelomer acrylates (FTAs)) and shorter chained perfluoroalkyl substances. With the addition of potentially more water soluble compounds to the Stockholm Convention, such as PFAS, it is essential to determine whether air or ocean currents are more efficient carriers of these pollutants to the arctic aquatic system and lower foodweb. Correlation analyses revealed that polyfluoroalkyl substances have similar sources and/or transport mechanisms but with exceptions.

Organophosphate flame retardants and plasticizers (OPs) are potentially toxic compounds that are high production volume chemicals and the Chemical Management Plan risk assessment has identified several of these compounds as high priority compounds. Since the banned of the penta- and octa-mixtures of polybrominated diphenyl ethers (PBDEs), the production of OPs has increased and this growth is expected to continue. In this study, we have determined baseline concentrations of OPs in air against which future trends can be gauged. Such information is vital in determining whether a new chemical is a candidate for national and international regulations.

The intent of this project was to better understand whether air or ocean currents are more important in delivering specific contaminants to the Arctic, what happens to them once they are there and how they enter the aquatic foodweb. To achieve this, we coordinated air-water-phytoplankton-zooplankton sampling in the Canadian Archipelago in collaboration with the ArcticNet program onboard the CCGS Amundsen (Figure 1, October 2011). This study builds on past air and water sampling conducted by the same team at sampling sites, shown in Figure 1. Results from this research combined with those from earlier studies, will allow us to assess any changes of the aquatic contamination in the Canadian Archipelago over time. This is particularly important in understanding the effect of climate change on arctic pollution.

Activities in 2011-2012

- Thirty-four air samples were collected between Kugtugluk and Quebec City via Baffin Bay in October 2011, these were analysed for OCPs, CUPs, PFAS and OPs.

- Eighteen 100-200-L samples were collected for OCPs, CUPs and OPs, including three depth profiles.

Figure 1: Map showing sampling locations in the Canadian Archipelago from 1992-2011.

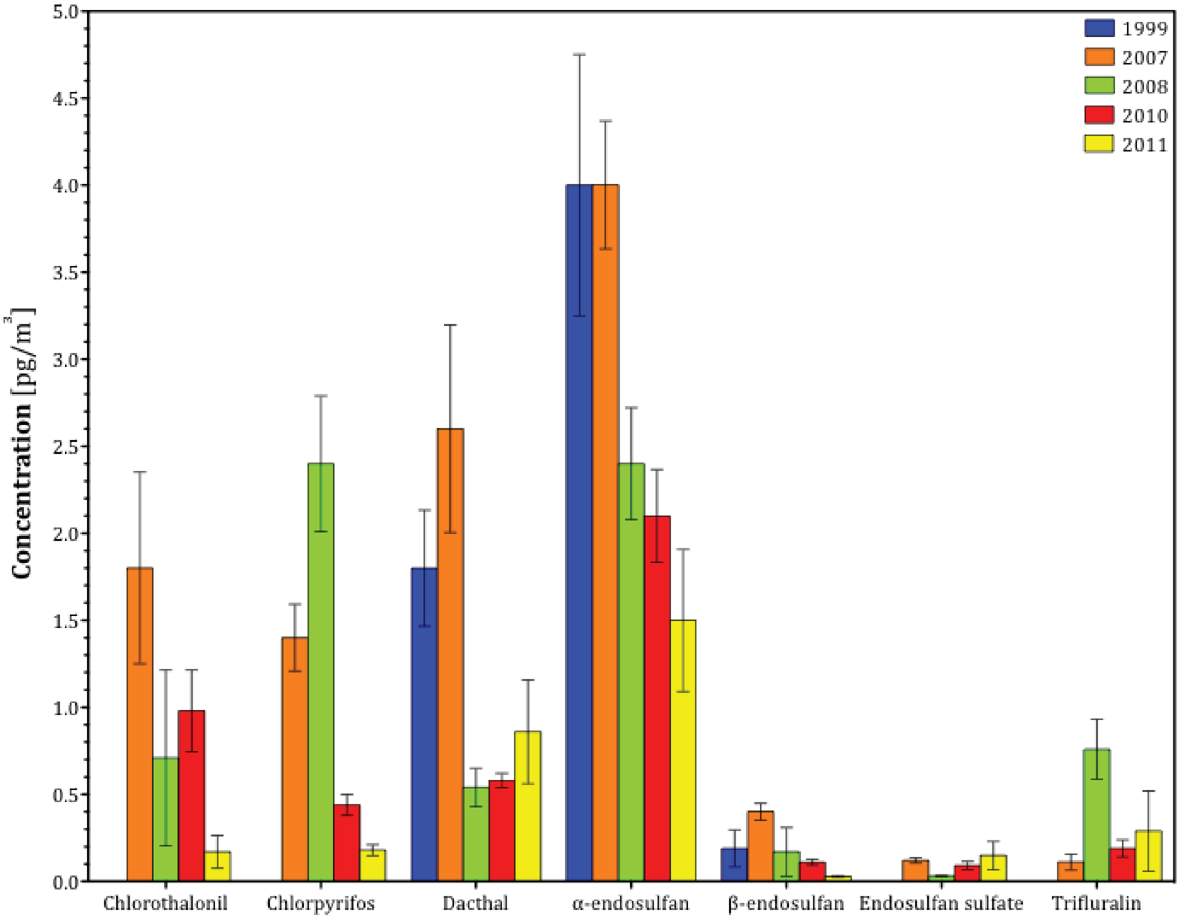
Alert 2008-2009	Ellesmere Island	◇
Resolute Bay 1992 and 1999	Cornwallis Island	☆
Tundra-North-West 1999	Archipelago	———————————
ArcticNet/IPY 2007	Quebec City to Churchill	———————————
IPY-CFL 2008	Beaufort Sea-Banks Island	○ ○ ○
ActicNet 2010	Kugluktuk to Iqaluit	———————————
ArcticNet 2011	Kugluktuk to Quebec City	-------------------------------------

- Thirty 1-L water samples were collected for PFAS, including eight depth profiles.
- Thirty-two surface water samples were taken for particulate matter, which included phytoplankton and other particulate organic carbon.
- Zooplankton samples were taken at seven locations using the monster nets that integrate the water column, from each sample a sub-sampled was taken for isotopic analysis.

Capacity Building: Unfortunately, during the cruise in October 2011, there was no opportunity to visit the local communities. Also, there were no Northerners on board the Amundsen for capacity building. During the 2010 sampling, students Anya Gawor and Fiona Wong were on board the leg with Schools on Board and were able to disseminate their work and findings to northerners that visited the ship.

Communications: We contacted local radio stations as the ship passed by, of those that responded, they required translation into Inuktitut. Unfortunately, there was not a translator on board the Amundsen to facilitate this. The student Anya Gawor, who was on board the Amundsen was interviewed by CBC- Iqaluit, they would like a follow-up interview when the project is complete. Anya was also interviewed by Jane George from the online newsletter Nunastiuq, available at: http://www.nunatsiaqonline.ca/stories/article/65674monitoring_shows_contaminants_still_pollute_the_arctic/

Figure 2: Air trends for CUPs between 1999-2011. Any samples with non-detects were assigned ½ of the instrumental detection limit.. Bars correspond to arithmetic mean concentrations, whereas lines correspond to the standard error of mean. Chlorothalonil, chlorpyrifos, endosulfan sulfate, and trifluralin were not investigated in 1999.



Traditional Knowledge Integration: The extraordinary changes in sea ice concentration and type currently being observed in the Arctic Ocean will have a definite impact on contaminant cycling and processes; and ultimately on biological exposure. Local community observational information on sea ice (past and present) will provide us with extremely valuable information needed to help interpret our results. We would like to integrate the Northerners ice knowledge and changes in ice cover into our ice maps that are used to estimate net gas exchange fluxes.

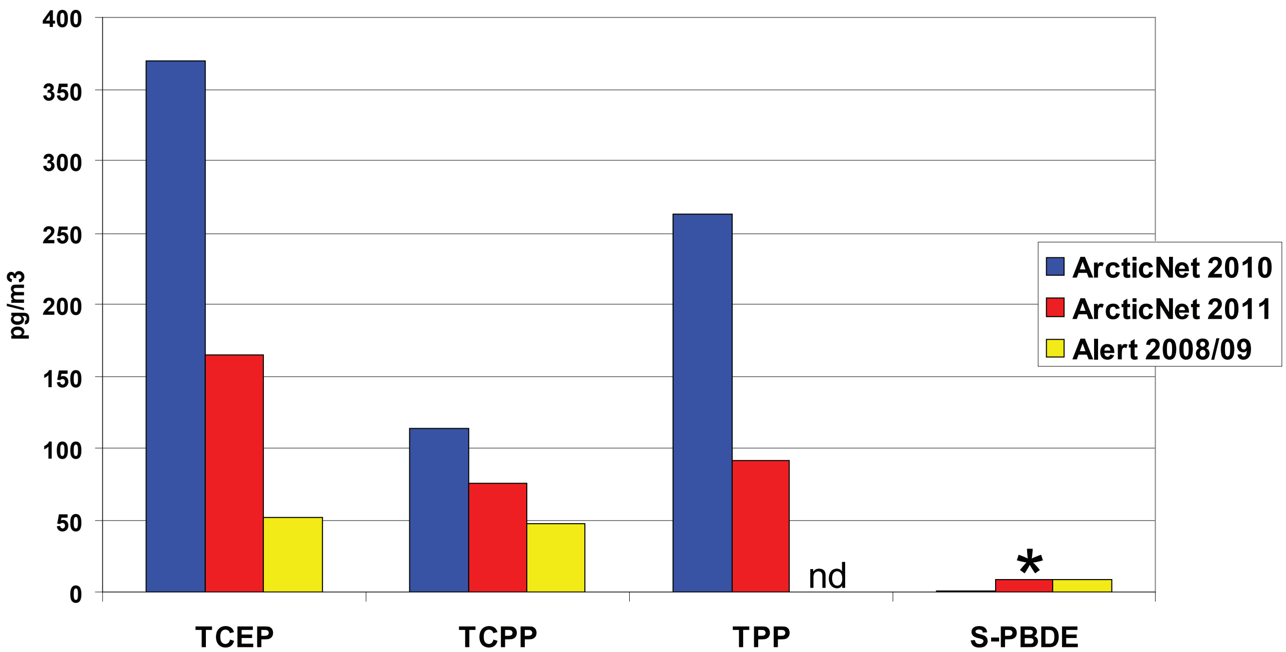
In addition, contaminant exposure in top predators such as ringed seal and beluga also depend on ice associated (top down) feeding behaviour. Knowledge of migration patterns and animal behaviour that can be provided by hunters will also be invaluable.

Results, Discussions and Conclusions

Air:

Organochlorine pesticides (OCPs) including hexachlorocyclohexanes and chlordanes continue to decline as seen with arctic monitoring stations (Hung et al., 2010). The declines between 2010 and 2011 are probably a combination of the declining concentrations and seasonality. Samples taken in 2011 were taken in October while samples from previous campaigns were taken in the late spring and summer.

Figure 3: Average concentrations of OPs during ArcticNet 2010 and 2011 and Alert 2008/09. *compared to the sum-PBDEs in Greenland, Ny Alesund and the Alert monitoring station (see Xiao et al., 2012 for references).



Current Use Pesticides (CUPs) have been analyzed in air samples from the Canadian Archipelago by our group since 1999, additional compounds were subsequently added. Generally concentrations in 2011 were lower than previous years. This, this may be due to sampling time differences as mentioned above. Endosulfan concentrations have been steadily decreasing over time where recent declines are probably due to restrictions on usage in Europe and North America (Health Canada, 2011 and US-EPA, 2010).

Organophosphate compounds (OPs) screened and quantified in air samples were TCEP, TCPP, TPP and TDCPP. These compounds were only found in the particulate phase on the glass fibre filter. These compounds are additive flame retardants and plasticizers. Since the banned of penta-BDE and octa-BDE, the usage of OPs have increased and probably will continue to do so. TCEP had the highest concentration found, followed by TCPP and TPP. The levels of OPs are much higher than the sum of PBDEs (Figure 3). As with PBDEs, OPs are added but not chemically bonded to plastics, lubricants and hydraulic fluids, but other differences that may contribute to the difference in concentration include production volumes, physical-chemical properties, persistence and long range transport potentials. Similar levels of OPs have been seen in the North Sea (Möller et al. 2012) and the Bering and Chukchi Seas (Möller et al. 2011). Ratios of TCEP/TCPP were about the same as the Bering Chukchi Sea (Möller et al. 2012) but in the North Sea the dominant compound was TCPP with much lower levels of TCEP (Möller et al. 2011), this is probably due to difference in usage patterns in Europe, North America and Asia. Levels found here are lower than those over Lake Superior and Toronto (Jantunen et al. 2012b) and much lower than at a sewage treatment plant in Ontario (Shoeib et al. 2012).

PFAS

Gaseous Phase:

The order of PFAS concentrations found is FTOH>> perfluorooctane sulfonamidoethanol (FOSE)> perfluorinated sulfonamides (>FOSA), Figure 4a and 4b. For FTOHs, generally the

Figure 4: Concentrations of PFAS in air compared to other studies in the arctic.

1) **Cornwallis Island, July 2004**; Stock et al. 2007.
2) **Cdn Archipelago, July 2005**; Shoeib et al. 2006.
3) **Labrador Sea, Summer 2007**; Ahrens et al. 2011.
4) **Hudson Bay, Summer 2007**; Ahrens et al. 2011.
5) **Beaufort Sea, Spring/Summer 2008**; Ahrens et Al. 2011.
6) This work; **August 2010**.
7) This work; **October 2011**.

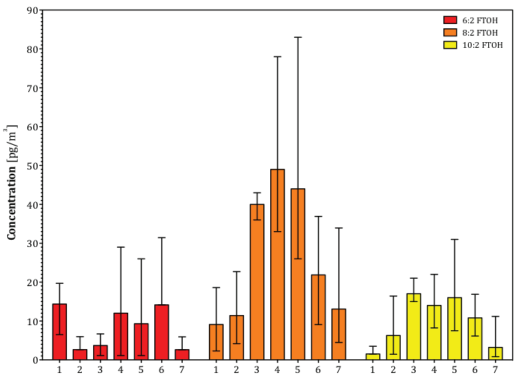


Figure 4a. Gaseous phase trends of FTOHs, 2004-2011.

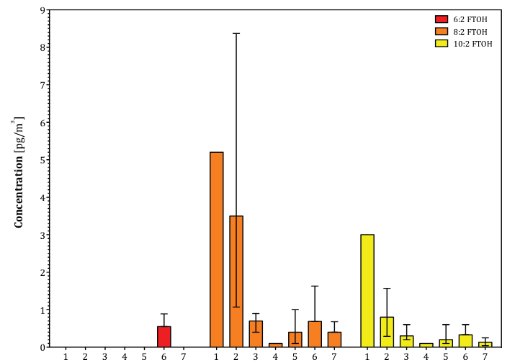


Figure 4b. Particulate phase trends of FTOHs, 2004-2011.

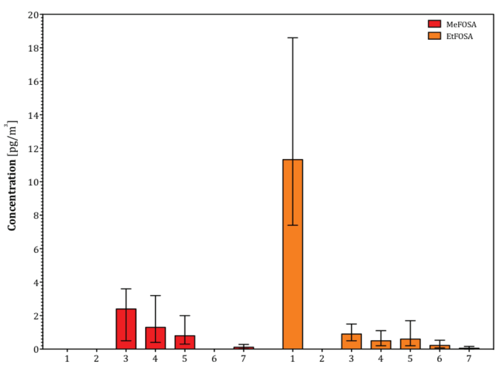


Figure 4c. Gaseous phase trends of FOSAs, 2004-2011.

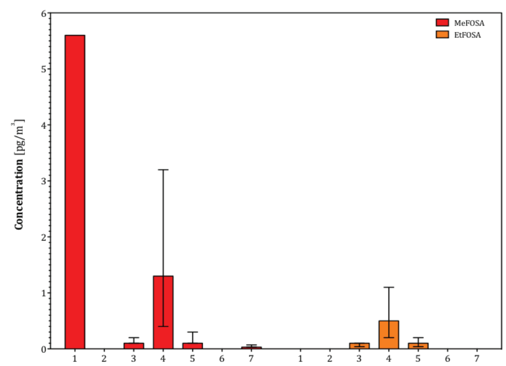


Figure 4d. Particulate phase trends of FOSAs, 2004-2011.

order was 8:2>10:2>6:2, Figure 4a. FTOH ratios (6:2/8:2/10:2) for 2010 and 2011 were 1.0/1.6/0.7 and 1.0/5.0/1.2, respectively. The ratios for 2011 closely match with previously reported arctic ratios (Ahrens et al. 2011; Shoeib et al., 2006). Ratios in 2010, however, were closer to the ratios found in lower latitudes, although another study found a different order of concentrations with FTOH ratios in the north Atlantic of 6:2>8:2>10:2 (Dreyer et al. 2009).

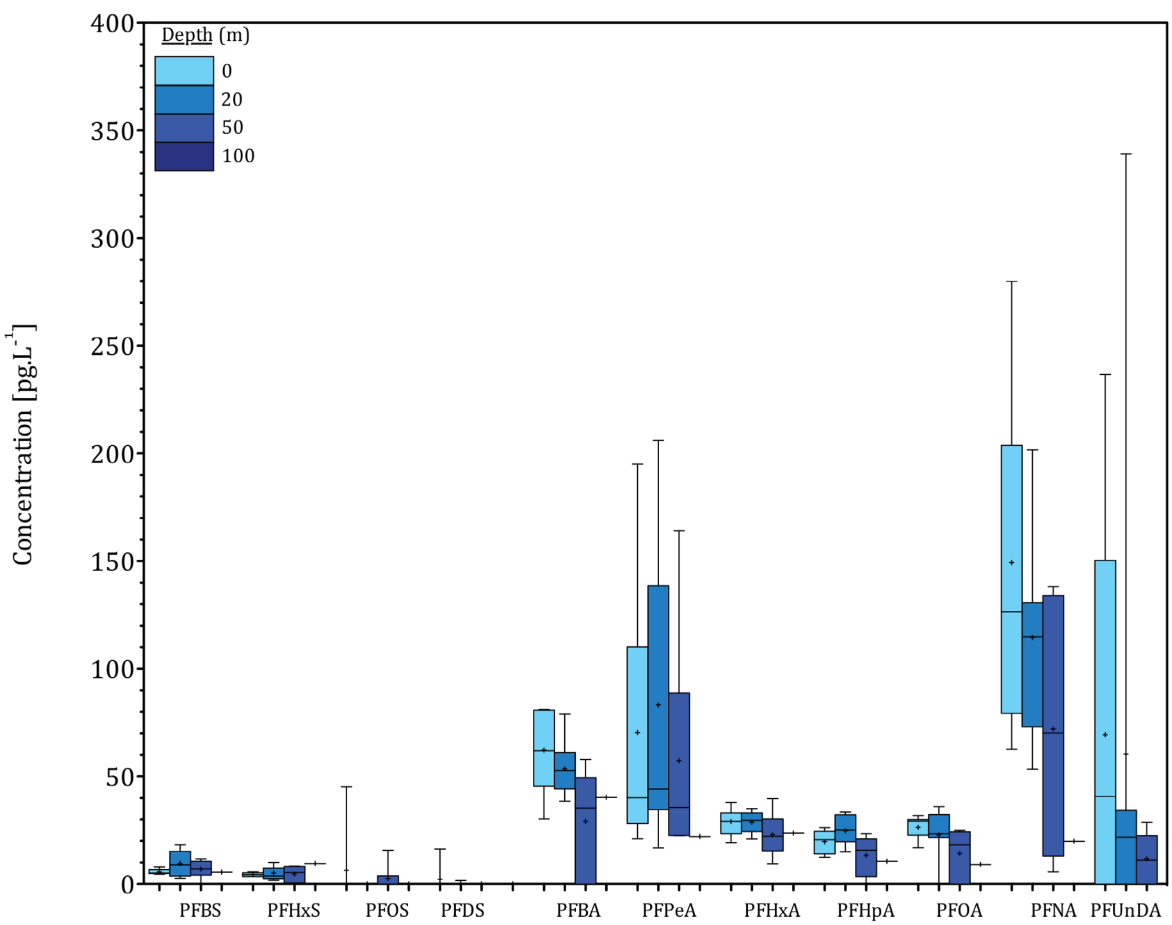
The FOSA/FOSEs found were methyl perfluorooctane sulfonamido ethanol (MeFOSE), ethyl perfluorooctane sulfonamido ethanol (EtFOSE), methyl perfluorooctane sulfonamide (MeFOSA) and ethyl perfluorooctane sulfonamide (EtFOSA). The higher levels of FTOHs over FOSA/FOSEs was also found in other studies, additionally, usage of electrochemical fluorinationfluorination based fluorosurfactants have been reduced or eliminated over the last decade (Butt et al. 2010) which has been reflected in the lower levels of FOSEs and FOSAs in arctic air.

Particulate
PFAS in the particle phase are much lower than the gaseous phase and are different in order of their concentrations. The order of concentrations for the PFAS were FOSEs> FTOHs>FOSAs (Figure 4b and 4d).

Combined: Gaseous + Particulate
Correlation analyses revealed that polyfluoroalkyl substances are related to one another. Highest correlation was seen between the 8:2 and 10:2 FTOH (0.87, p<0.0001), while about half of the substances correlated with each other at p<0.01. 6:2 FTOH showed no correlation with the other substances, indicating difference sources or transport mechanisms. Comparing field campaigns between 2005-2011, concentrations of FTOHs, FOSAs, and FOSEs (both gaseous and particulate) appear to be decreasing. This is in contrast to FTOHs are Alert, between 2006-2010 concentrations appear to be increasing (Hayley Hung, 2012 personal communication). Although it is uncertain whether the decreasing concentrations found here are a temperature or temporal trend since sampling was done in different seasons. More studies need to be conducted in order to confirm if this is a temporal or seasonal/ temperature variability and the affect of sea ice coverage. This emphasizes the importance of more campaigns like this, ideally during spring, summer and fall.

Water Samples
High Volume water sample processing methods are currently being modified due to blank problems for the OPs and newer lower level PFAS. No results are yet available.
Additional 1-L water samples were collected for PFAS, including eight depth profiles. Concentrations did not change with depth indicating the upper 50-100 m is well mixed

Figure 5: Depth profile of PFAS in the water column, this is still preliminary data to be verified.



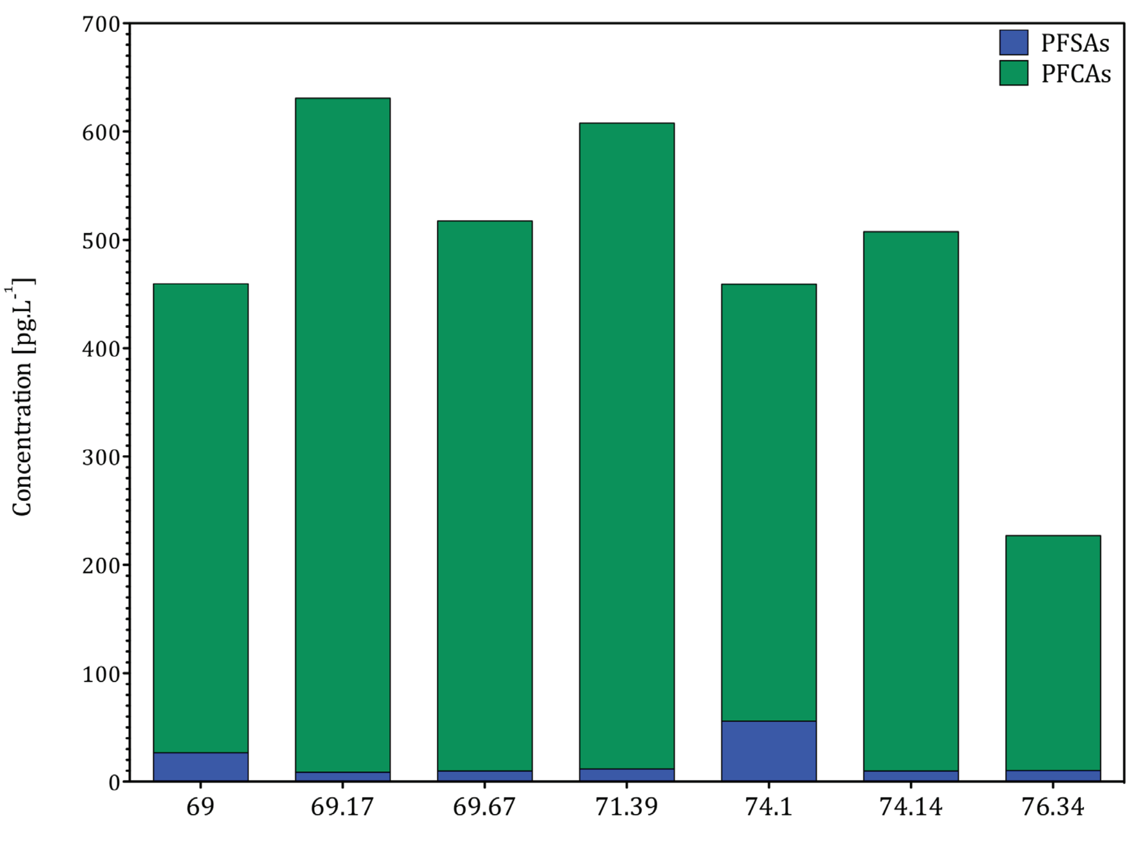
for the PFAS, Figure 5. PFCAs had the highest concentrations, particularly PFBA, PFPeA and PFNA. Additionally, there also is not a spatial distribution of PFAS, except lower concentrations were observed in Baffin Bay compared to the archipelago.

Phytoplankton
During ArcticNet 2011, PFAS compounds sought in phytoplankton were: perfluorohexanesulfonate (PFHxS), PFOS, perfluorodecane sulfonate (PFDS), FOSA and perfluoroundecanoic acid (PFUnDA) but only PFOS was found. Average concentration based on liters of water is 39 $fg{\cdot}L^{-1}$ or 17 $pg{\cdot}g^{-1}$ based on estimates of particles in the surface water, additionally there was no significant spatial trend of PFOS in surface particulate. OPs were also sought in these samples but are not reportable due to blank problems. OCPs and CUPs were below detection limits in these samples, in the future, samples will be combined in an attempt to obtain a value for the archipelago.

Zooplankton
These samples are currently at FWI, methods are being developed to remove the lipids but still have good recoveries of the OPs.

Gas Exchange
Air-water exchange of some CUPs, namely chlorpyrifos and dacthal indicate that arctic air and water are approaching equilibrium where endosulfan is still being deposited into the Arctic Ocean and has been that way since first measured by our group in the early 1990s. Gas exchange estimates of OCPs indicate they are near equilibrium or volatilizing into the air. These estimates of gas exchange will be updated once the water data for ArcticNet 2011 is available.

Figure 6: Latitudinal Profiles from ArcticNet 2011 of surface water PFAS. PFTriDA, PFPeDA, PFHxDA and PFODA are not yet included.



NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	0	• Unfortunately there were no northerners on board the Amundsen to engage. • We contacted local radio stations as the ship passed by, of those that responded, they required translation into Inuktitut unfortunately there was not a translator on board the Amundsen to facilitate this. • The student Anya Gawor was interviewed by CBC- Iqaluit, they would like a follow-up interview when the project is complete. • Anya was also interviewed by Jane George from the online newsletter Nunastiuq.
number of project-related meetings/workshops held in the North (April 1, 2011 – March 31, 2012)	0	This was not in the budget for this project
number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	1	Anya Gawor, University of Toronto.
number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	2011: 1 2012: 3	Unfortunately my requested travel to attend SETAC NA 2011 and the IPY 2012 to present these results were denied, but Anya Gawor presented at both. **SETAC NA 2011:** oral presentation by Gawor et al. 2011. **IPY 2012:** two posters Gawor et al. 2012 and Jantunen et al. 2012a. I will be attending the **BFR 2012** workshop and giving an oral presentation on OP flame retardant in arctic air, Jantunen et al., 2012b.

Expected Project Completion Date

- Analysis of air samples is complete, trajectory analysis is on going.
- Analysis of phytoplankton samples is complete, although samples will be combined in an effort to attain one detectable data point per sampling area for OCPs and CUPs.
- Analysis of PFAS in water samples is complete; QA/QC and correlation with sea ice cover is on going.
- The outstanding work that needs completion is the analysis of water and zooplankton samples.
  - The analysis of the water samples has been slower than predicted because processing methods for water samples

are being updated for new and emerging compounds and blank issues are being resolved for the OPs. This processing and analysis will be complete by September 2012.

  – Processing of the zooplankton samples has been more challenging than expected for the new and emerging compound, especially the OPs. Methods are being developed in association with FWI. Predicted completion date is December 2012.

- Manuscript preparation is on going.
- A supplementary report will be submitted for the year 2012-2013.

Acknowledgments

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We also thank Martina Koblizkova for help during sampling.

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Temporal Trends of "Legacy" POPs Contaminants in ringed seals of Eastern Amundsen Gulf sampled at Ulukhaktok, NT

Tendances temporelles de POP hérités du passé chez des phoques annelés de l'est du golfe d'Amundsen échantillonnés à Ulukhaktok, au T.N.-O.

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Abstract

Twenty ringed seal samples were collected at Ulukhaktok in May 2010 by a local hunter (J. Alikamik) under contract. Age, sex and condition of the 2010 samples have been measured. Blubber samples were analysed for "legacy" organochlorine pesticides (OCP) by NLET in early summer 2011. Sub-samples were analysed for PCDD/F, PBDE and co-planar PCBs during winter 2011-12. Data from the 2010 samples have been added to a database summarising residue concentrations and biological variables in Ulukhaktok ringed seals since 1972, and have been analysed statistically to establish trends over the interval 1972-2010. A previous examination (April 2011 interim report) of the QA/QC data recorded by the three laboratories which have carried out the analyses over the 38-y interval showed that data were comparable.

Statistical analysis of the cumulative data show that residues of the DDT-group of insecticides have declined steadily since 1972; exponential

Résumé

Un chasseur local (J. Alikamik) a prélevé dans le cadre d'un contrat 20 échantillons de phoques annelés à Ulukhaktok en mai 2010. L'âge, le sexe et la condition des échantillons de 2010 ont été déterminés. Le Laboratoire national des essais environnementaux (LNEE) a analysé des échantillons de graisse à la recherche de pesticides organochlorés (POC) hérités du passé au début de l'été 2011. Des sous échantillons ont été analysés aux fins de détection de PCDD/F, de PBDE et de PCB coplanaires à l'hiver 2011-2012. Les données des échantillons de 2010 ont été ajoutées à la base de données résumant les concentrations de résidus et les variables biologiques observées chez les phoques annelés d'Ulukhaktok depuis 1972, puis on les a soumises à des analyses statistiques en vue d'établir des tendances sur l'intervalle 1972-2010. Un examen antérieur (rapport provisoire d'avril 2011) des données d'AQ/de CQ consignées par les trois laboratoires ayant mené les analyses pendant l'intervalle de 38 ans ont montré que les données étaient comparables.

half-life is around 20 y, and is slightly shorter in females, probably due to losses during lactation, than in males. *p,p'*-DDE has represented an increasing proportion of the total DDT group and if the present trend continues, all the DDT components will be converted to *p,p'*-DDE by about 2025. Since *p,p'*-DDE is metabolically (word not necessary) a dead end, the decline in total DDT residues will slow further at that point. PCB residues (as Aroclor 1254) declined rapidly between 1972 and 1991 (exponential half-life < 10y). However, a group of widely analysed congeners (the "ICES PCBs" + CB 170) has declined more slowly between 1981 and 2010, with an exponential half-life of about 40 y in females. (Analysis of trends in males is confounded by differences in ages of animals sampled at various times.) This suggests that the relatively rapid decline of PCBs in the 1970s-1980s may have been due to degradation of the less refractory congeners, and that the remaining PCB congeners are more persistent. Among other OCP, trans-nonachlor declined significantly in females between 1981 and 2010, but oxychlordane, heptachlor epoxide and dieldrin concentrations remained fairly constant.

L'analyse statistique des données cumulatives montre que les quantités de résidus du groupe d'insecticides à base de DDT ont décliné de manière soutenue depuis 1972; la demi-vie exponentielle est d'environ 20 ans, et elle est légèrement plus courte chez les femelles que chez les mâles, probablement en raison des pertes pendant la lactation. Le *p,p'*-DDE constitue une proportion croissante du groupe du DDT total et, si la tendance actuelle se maintient, toutes les composantes du DDT seront converties en *p,p'*-DDE d'ici 2025 environ. Comme le *p,p'*-DDE est le produit de métabolisation ultime, le déclin des résidus de DDT total ralentira encore plus à partir de ce point. Les teneurs en résidus de PCB (tels que l'Aroclor 1254) ont baissé rapidement entre 1972 et 1991 (demi-vie exponentielle < 10 ans). Toutefois, un groupe de congénères ayant fait l'objet de nombreuses analyses (les « PCB définis par le CIEM » + CB 170) ont connu un déclin plus lent entre 1981 et 2010, la demi-vie exponentielle étant d'environ 40 ans chez les femelles. (L'analyse des tendances chez les mâles est compliquée par la différence d'âge des animaux échantillonnés à des moments différents.) Il se peut donc que le déclin relativement rapide des PCB dans les années 1970 et 1980 soit dû à la dégradation des congénères moins réfractaires et que les autres congénères des PCB soient plus persistants. Parmi les autres POC, les concentrations de trans-nonachlor ont rapidement diminué chez les femelles entre 1981 et 2010, mais celles de l'oxychlordane, de l'heptachlor époxyde et de la dieldrine sont restées plutôt constantes.

Key Messages

Residues of many "legacy" POPs contaminants in ringed seals from Ulukhaktok (formerly Holman) NT have been declining since 1972, presumably in response to the restrictions in the manufacture and use of these compounds introduced during the 1970s.

Messages clés

Les quantités de résidus de nombreux POP hérités du passé chez les phoques annelés d'Ulukhaktok (anciennement Holman), au Nunavut, baissent depuis 1972, probablement grâce aux restrictions visant la fabrication et l'utilisation de ces composés introduits dans les années 1970.

Objectives

(a) Obtain 20 samples of ringed seal blubber covering a defined range of ages and condition during the subsistence hunt in spring 2010 *(completed spring 2010);*

(b) Confirm reliability of analyses undertaken previously (by assessing the relevant laboratory's performance in analysis of standard or certified reference materials) and so establish the comparability of analytical data *(completed spring 2011)*;

(c) Update "legacy" POP concentrations in Ulukhaktok ringed seals, including selected OC pesticides and polychlorinated biphenyls (PCBs) until 2010, and carry out trend analysis on the data *(completed for OCP, spring 2012; PCDD/F and PBDE trends will be completed sumer 2012)*.

Introduction

Ringed seals (*Phoca hispida*) from Ulukhaktok, NT (formerly Holman, NWT) have been analysed for a range of persistent organic pollutants (POPs) at intervals since the early 1970's; the data set is probably the longest available for marine mammals in the Canadian Arctic, and reflects contaminant trends in the habitat and range of these seals, mainly in the SE Amundsen Gulf. The objective of this work is to compile and bring up-to-date (i.e. to 2010) data for:

- the DDT-group of insecticides and polychlorinated biphenyls (PCBs) which were last summarised to 1991 by Addison and Smith (1998); data are now available for samples from 2001, 2006 and 2010;

- miscellaneous other chlorinated pesticides, also last summarised to 1991 by Addison and Smith (1998); data are now available for samples from 2001, 2006 and 2010;

- polybrominated diphenyl ethers (PBDEs), last summarised to 2000 (Ikonomou et al, 2002); data are now available for 2010 samples;

- polychlorinated dibenzo- dioxins and furans (PCDD/F) which have been summarised to 2000 (Addison et al. 2005); data are now available for 2010 samples.

Activities and Results 2010-2012

(i) Objective(a) and (b) above.
This work was completed by spring 2011 and is summarised in the April 2011 interim report.

(ii) Objective (c) above.
Trends in the DDT-group of insecticides in Ulukhaktok ringed seal blubber between 1972 and 2010 are shown in Figs. 1 and 2. Fig. 1 shows concentrations of total DDT (*p,p'*-DDT + *p,p'*-DDE) in blubber of males and females. Females generally had lower concentrations than did males, because of losses during lactation (Addison and Brodie, 1977; 1987; Addison, 1989). Also, the rate of decline was slightly faster in females, again probably due to losses during lactation, but in both males and females, the half life of total DDT was about 20y. However, this simplified conclusion is complicated by two factors: (a) the steady conversion of *p,p'*-DDT to *p,p'*-DDE (Fig. 2) which may be for practical purposes a metabolic "dead-end" (e.g., Addison and Willis, 1978) and (b) the declining blubber thickness throughout the sampling period, resulting from samples being taken progressively later in the year (Harwood et al., 2000). The effect of the *p,p'*-DDT to p,*p'*-DDE conversion is that DDT residues will probably decline more slowly after about 2025, when conversion of *p,p'*-DDT to *p,p'*-DDE should be complete. However, the effect of decreasing blubber thickness in more recent samples is to increase the *concentration* of DDT residues, which in turn would lead to a lower estimate of declines in DDT group *burdens.* Analyses of covariance,

and multiple (linear) regression led to the conclusion that in females, *p,p'*-DDT declines at about 7% • y^{-1}, whereas *p,p'*-DDE declines at only about 3% • y^{-1}; the rates are about 5-10% slower in males.

Fig. 3 shows declines in concentrations of PCBs (analysed as Aroclor 1254) between 1972 and 1991 in male and female seals. PCBs declined fairly rapidly with an exponential half-life of <10 y. However, after about 1980, the rate

Figure 1. Exponential regression of total DDT (*p,p'*-DDE + *p,p'*-DDT) concentrations on year in blubber of ringed seals *(Phoca hispida)* from Ulukhaktok, NT, between 1972 and 2010. Concentrations in females are shown in red, in males, blue.

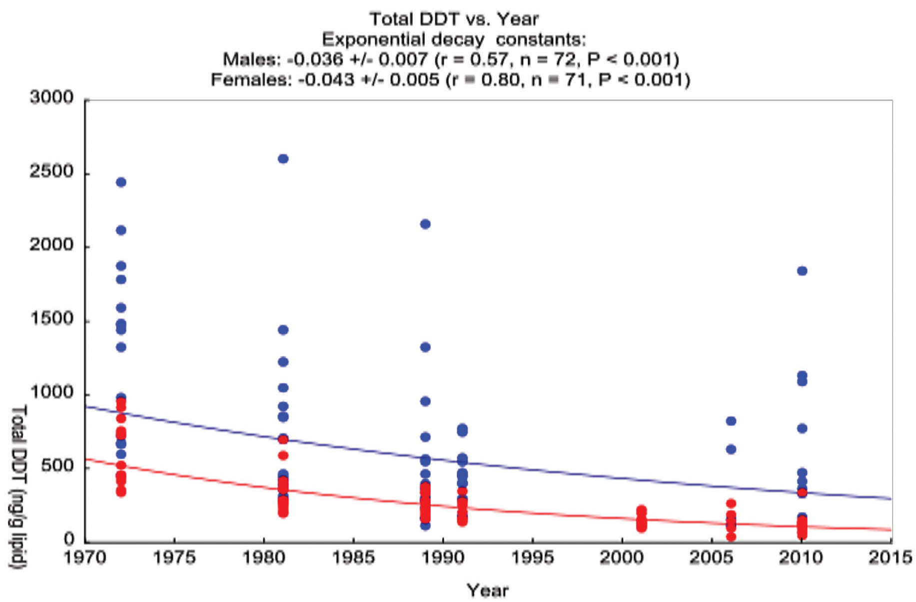
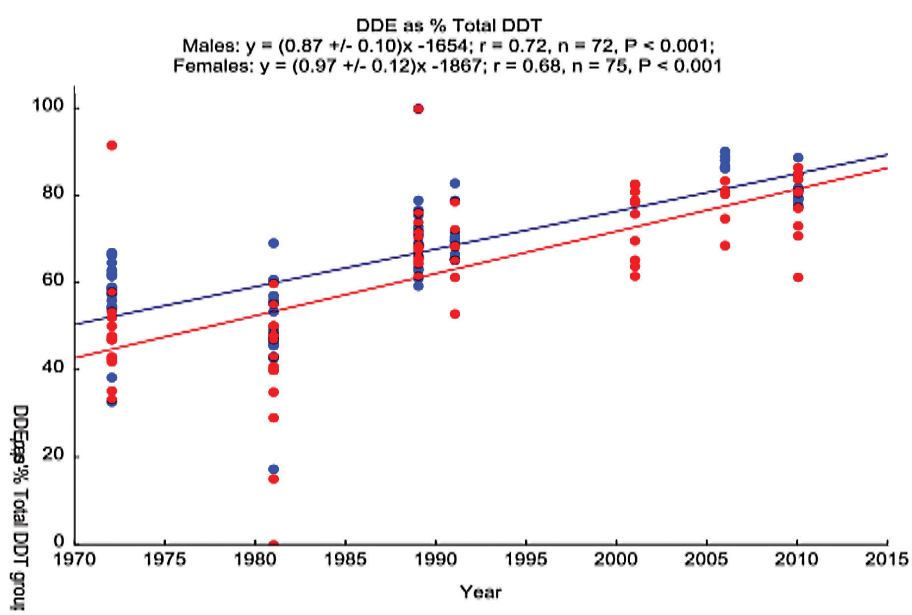


Figure 2. Linear regression of *p,p'*-DDE as a percentage of *p,p'*-DDE + p,p'-DDT on year in blubber of ringed seals *(Phoca hispida)*) from Ulukhaktok, NT between 1972 and 2010. Concentrations in females are shown in red, in males, blue



of decline appeared to slow: a number of individual congeners ("the ICES CBs" + CB 170) declined with an exponential half-life of about 40 y between 1981 and 2010 (Fig. 4). While interpretation of these results is complicated by the change in methods of PCB analysis (from Aroclor-based determinations to analysis of individual congeners) the simplest explanation of the data is probably that the more labile congeners were degraded rapidly during the 1970s, but the residual congeners (which have survived until now) are more refractory. As

Figure 3. Exponential regression of total PCB concentrations (as Aroclor 1254) on year in blubber of ringed seals *(Phoca hispida)* from Ulukhaktok, NT, between 1972 and 1991. Concentrations in females are shown in red, in males, blue.

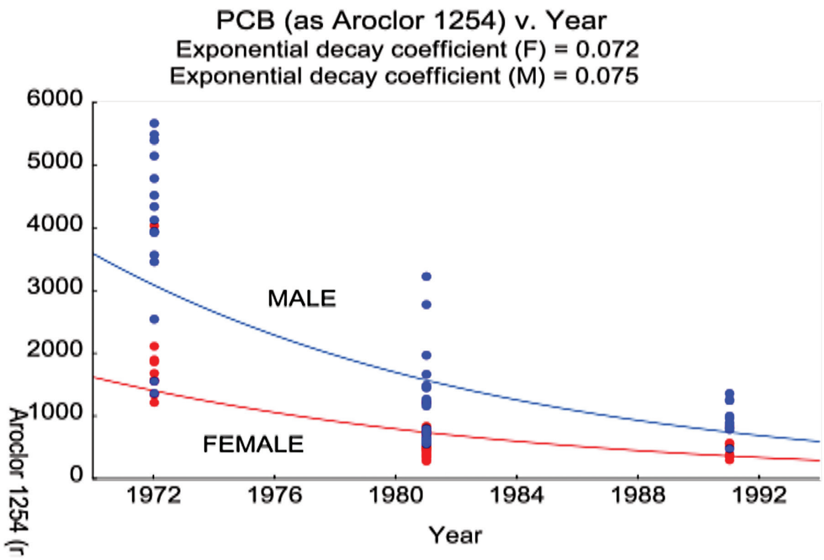
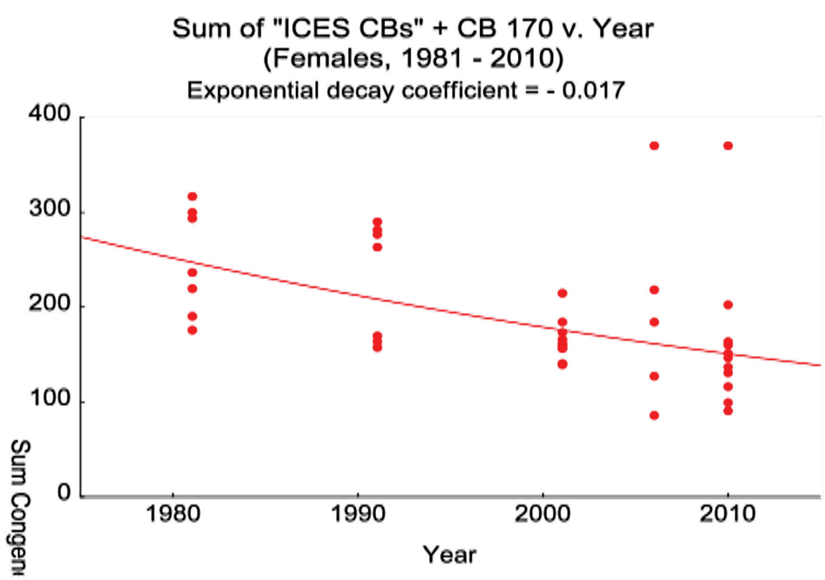


Figure 4. Exponential regression of PCB congeners ("ICES PCBs" + CB 170) on year in blubber of female ringed seals *(Phoca hispida)* from Ulukhaktok, NT, between 1981 and 2010.



in the case of the DDT-group, the decreasing blubber thickness in more recent samples "skews" the estimated half-life to a longer range. However, ANCOVA and multiple linear regressions suggest a (linear) decline of about 2% · y^{-1} in both males and females.

Of the other legacy OCP, only *trans*-nonachlor showed any significant decline, and then only in females (exponential half like estimated to be about 15y). Concentrations of other OCP (notably oxychlordane, dieldrin and heptachlor epoxide, all of which had been reliably analysed between 1981 and 2010) remained fairly constant.

Data for PBDE and PCDD/F concentrations in 2010 samples became available in spring, 2012. These will be added to existing data (from samples taken during the 1990s) and analysed during summer, 2012.

A preliminary draft (Results and Discussion) of the legacy OCP data has been circulated for comment to project team members. It is expected that a final manuscript will be prepared for submission in summer 2012.

Traditional knowledge

Sample collection by the seal monitor (JA) from Ulukhaktok relied on his knowledge and experience, not only of specific aspects of sampling, but also, of his "contextual" ecological knowledge and experience. He will be asked to comment on aspects of data interpretation (particularly on inter-annual variation in condition or blubber thickness) later this summer.

Discussion and Conclusions

While the project has proceeded essentially as planned, there have been delays in obtaining data from NLET due to circumstances beyond the control of the project team. However, the legacy OCP data have now been compiled, analysed statistically and interpreted, and incorporated into a draft Results and Discussion section of a paper scheduled for completion in summer 2012. PCDD/F and PBDE data for the 20102 samples have also become available (in spring 2012) and will be analysed statistically in summer 2012.

The conclusions to date are that most of the "legacy" OCP residues in seal blubber are declining at the rate of a few percent per year; the figures vary with compound and with sex of the animals sampled, but exponential half-lives are estimated to be in the range 10-40y. The exceptions appear to be some of the cyclodiene OCPs whose concentrations seem to be staying fairly constant. Whether this reflects longer use of these compounds (compared to that of DDT) or to greater persistence remains to be established.

Expected Completion Date

Sample analyses were completed by March 2012. Data analysis of legacy OCPs is essentially complete, and preparation of a manuscript for submission will be competed in summer 2012. Analysis of PCDD/F and PBDE data will also be carried out this summer with a view to completing a manuscript by the end of 2012.

NCP Performance Indicators

Performance Indicator	Number	Details / Description
Number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	40	L. Skinner (INAC) presented a summary description of this project to about 40-50 members of the Ulukhaktok community (Aug 12 2010).
Number of project-related meetings/ workshops held in the North (April 1, 2011 - March 31, 2012)	1	Preliminary data were presented by D. Muir at the 2010 NCP Results Workshop and by R. Addison at the 2011 NCP Results Workshop.
Number of students (both northern and southern) involved in your NCP work (April 1, 2011 - March 31, 2012)	0	
Number of citable publications (e.g., in domestic/ international journals, conference presentations, book chapters, etc)	0	

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

Surveillance communautaire de l'eau de mer en vue d'y trouver des contaminants organiques hérités du passé et en cours d'usage dans l'archipel du Haut-Arctique canadien

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  Adam Morris, University of Guelph, Guelph, ON
  Peter Amarualik Sr., Hunter's and Trapper's Organization, Resolute, NU

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Abstract

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 Jeffery Amarualik using equipment supplied by Environment Canada. Passive water samplers consisting of a polyethylene film (similar to "Saranwrap") were deployed under the ice. Preliminary results show low (picogram/ 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. Samples

Résumé

L'échantillonnage de l'eau de mer a été réalisé en mai-juin 2011, dans le détroit de Barrows, dans le cadre d'une étude communautaire sur les contaminants présents dans l'océan. Le but était d'obtenir des échantillons à des moments clés (aucune fonte, demi-fonte, forte fonte, eaux libres) pour donner un aperçu de la manière dont la couverture de glace et sa fonte influent sur les concentrations de contaminants traces dans l'eau de mer. L'échantillonnage a été réalisé par Peter et Jeffery Amarualik au moyen d'un équipement fourni par Environnement Canada. Des échantillonneurs d'eau passifs composés d'un film de polyéthylène (semblable à du « Saran Wrap ») ont été déployés sous la glace. Les résultats préliminaires montrent de faibles concentrations (picogramme/ litre) de PCB et de pesticides chlorés dans

for perfluorinated chemicals in under the ice seawater were collected successfully at multiple depths. Additional passive samples could not be collected due to shifting ice conditions.

les échantillonneurs de polyéthylène. L'échantillonnage de l'eau de mer en faisant passer cette dernière dans une colonne XAD au moyen d'une pompe à fort volume n'a pas été fructueux, car la pompe a subi des défaillances. Des échantillons aux fins d'analyse de détection de composés perfluorés ont été prélevés avec succès dans l'eau sous la glace, et ce, à de multiples profondeurs. On n'a toutefois pas pu prélever d'autres échantillons passifs en raison des conditions changeantes de la glace.

Key Messages

- Passive samplers consisting of thin plastic film successfully collected PCBs and other POPs in seawater during a 1 month deployment in Barrow Strait
- The cold environment and shifting ice prevented some sample collection and illustrate the challenges of operating seawater sampling equipment in the arctic

Messages clés

- Des échantillonneurs passifs composés d'un mince film de plastique ont détecté avec succès des PCB et d'autres POP dans l'eau de mer pendant 1 mois dans le détroit de Barrows.
- L'environnement froid et les conditions changeantes de la glace ont empêché le prélèvement de certains échantillons, ce qui fait ressortir les défis que présente l'utilisation d'équipement d'échantillonnage d'eau de mer dans l'Arctique.

Objectives

1. Using a community based approach, sample seawater using active and passive methods over the spring-summer season during sea-ice melt in Barrow Strait near Resolute Bay
2. Combine data accumulated in 2011 with data from other recent studies) for 2006, 2007, 2008 and 2010, as well as older data of Hargrave et al for organochlorines, in order to establish temporal trends of these organohalogens in high central Canadian Arctic seawater.
3. Provide advice to the NCP on the use of passive samplers for measuring POPs and related organohalogen compounds in ice-covered and ice-free areas.

Rationale

The NCP Blueprint for environmental monitoring and research (reference) called for additional Arctic seawater data to among other requirements "apply the ocean contaminant data to the design of a practical monitoring strategy for Canadian Arctic waters". There is a relatively large amount of published seawater data for legacy chlorinated pesticides in the Canadian Arctic (de Wit et al. 2004);CACAR 2012). Almost all of this work was done during oceanographic cruises which, while providing excellent geographical coverage, are typically only carried out within a two or three month time window (July-September). An exception is the study by Hargrave et al.(1997) at Barrow Strait which examined seasonal fluctuations of POPs in Canadian arctic seawater over a

12 month period using the community of Resolute as a base for the work. This study, conducted in 1993, still represents the most detailed study POPs at one location. They found that HCHs, *cis* and *trans*-chlordanes and dieldrin all had winter or early spring maximum concentrations, while α - endosulfan had a fall maximum and HCB stayed constant throughout the year.

Hargrave et al. (1997) did not determine PCBs and in general data for PCBs in Arctic Ocean waters is much more limited than for legacy chlorinated pesticides. Carrizo and Gustafsson (2011) have summarized the most recent PCB data for Arctic Ocean shelf and ocean basin areas and noted the lack of data from the Canadian archipelago. Macdonald et al. (2009) reported PCBs in large volume samples from the southern Beaufort Sea which are in general agreement with results of Carrizo and Gustafsson (2011). The overall effects of ice cover and snow/ice melt are still not entirely clear, and how current use semi-volatile and less volatile contaminant concentrations are influenced by melt water is currently unexplored.

There is also a noticeable lack of data on any new contaminants such as brominated flame retardants (BFRs), current use pesticides (CUPs) and perfluorinated chemicals (PFCs) in Arctic seawater. Published trends in CUPs in seawater were reviewed in Hoferkamp et al. (2010). The most recent data available is for a suite of CUPs (Jantunen et al. 2008; Morris et al. 2010) including endosulfan, dacthal, chlorothalonil, and chlorpyrifos which have been detected in the low pg/L range. Morris et al. (2010), sampling in Barrow Strait, found significant inter-year variability for CUPs in seawater collected once annually in June 2007 to 2010 possibly due to the effects of ice melt influencing observed concentrations in some years. There are no published data for PBDEs or new use BFRs in Canadian Arctic seawater to our knowledge. Morris et al. (2009) showed that di-hepta PBDEs were present in low pg/L concentrations in Arctic seawater collected under the ice in Barrow Strait, with BDE-47 and BDE-99 predominating.

Benskin et al. (2012) reported PFCs in seawater from across the Canadian arctic based on a cruise of the Oden in 2005. Additional studies conducted in 2007 and 2010 have investigated profiles of PFCs under melting ice in Barrow Strait (Muir, Morris and Sturman unpublished data) show that the snow melt and release of deposited PFCs creates a different depth profile compared to open water conditions.

The studies reviewed above have all involved active sampling of large volumes for determination of PCBs, BFRs and CUPs as well as smaller volumes (0.5-1L) for PFOS and other PFCs. One problem with using active sampling methods for these trace organic contaminants is the very large sample sizes required to overcome blank issues, lower detection limits and obtain measurable concentrations in the low pg/L range. Lohmann and Muir (2010) noted that passive sampling for seawater monitoring was feasible and that polyethylene (PE) provided cheap and effective passive samplers that could sample the equivalent of 20 - 2000 L of water. Passive PE samplers could potentially be used in conjunction with and/or in place of active samplers for hydrophobic contaminants once comparisons of their efficiency are made in Arctic regions. However, it is unknown whether we can deploy and retrieve them in the appropriate time frames given variable ice-conditions.

Activities in 2011-12

Sample collection:
Seawater samples (1 L) were collected in June 2011 using a Van Dorn apparatus in order to establish a depth profile and temporal trends for PFCs in Barrow Strait. The field team used an acid washed, methanol and seawater rinsed Van Dorn in order to obtain 2 x 1 L seawater samples at depths of 0, 1, 4, 10, 50 and 100 m. The under-ice and mid-melt samples were obtained successfully; however, the open water sample set was not obtained due to the unpredictable conditions mentioned previously.

Large volume samples:
Seawater was collected with a portable pump system built by Environment Canada (Figure

1). We had success previously in obtaining large volume water samples (100 – 425 L) with this system in several temperate freshwater systems and in Arctic marine systems in Resolute Bay, Gjoa Haven and Pangnirtung, NU (Morris et al. 2010). It was deployed April 28 on the ice in Barrow Strait for 24 hours (at a flow rate of about 400 ml/min) hours in order to obtain the large volume samples needed for detections. Unfortunately when Peter and Jeffrey returned approximately half way through the sampling period, the pump had stopped, seized and burnt itself out. The external air temperature was significantly lower than when we had previously sampled on-ice in June 2007, 2008 and 2010, and although the pump was insulated this may have played a role in failure of this unit. A second attempt was made June after indoor testing showed the pump was still working. Unfortunately the rapid and unexpected ice break up in mid-late June prevented deployment of the sampler.

Passive samples:

The passive sampling apparatus is pictured in figure 1A and 1B. The PE strips were clipped into the center of cylindrical, stainless steel mesh housings and secured on rope at 10 m depth. For under-ice sampling, the rope was weighted and suspended from an 8” x 8” piece of wood used to straddle an augured hole in the sea-ice (Figure 1A). For open water or semi-covered conditions, the housings were attached on an anchored and buoyed rope with a marker float (Figure 1B). The under-ice passive sample was collected successfully, being deployed from April 28, 2011 – June 1, 2011. The mid-melt sampling strips were deployed immediately, changing over to the sampling setup to that shown in 1B. The apparatus was checked 1-2 times per week, however a break in the sea-ice followed by strong southerly winds pushed a lot of sea-ice out from the land and destabilized the land fast ice making travel dangerous. Our field team was unable to locate the apparatus. This posed a 2 fold problem 1) the loss of the mid-melt samples and 2) the loss of all of the sampling gear. We built and shipped replacements to Peter, but they didn’t arrive until late August. Ice blowing in and out of the bay for most of the summer and in early September resulted in the locals having to remove their boats from the water

Figure 1. Pumping system consisting of batteries, high volume pump and flow meter and electronics in orange case. Column system consisting of primary and secondary XAD column with high capacity glass fibre cartridge pre-filter (resting on the snow).

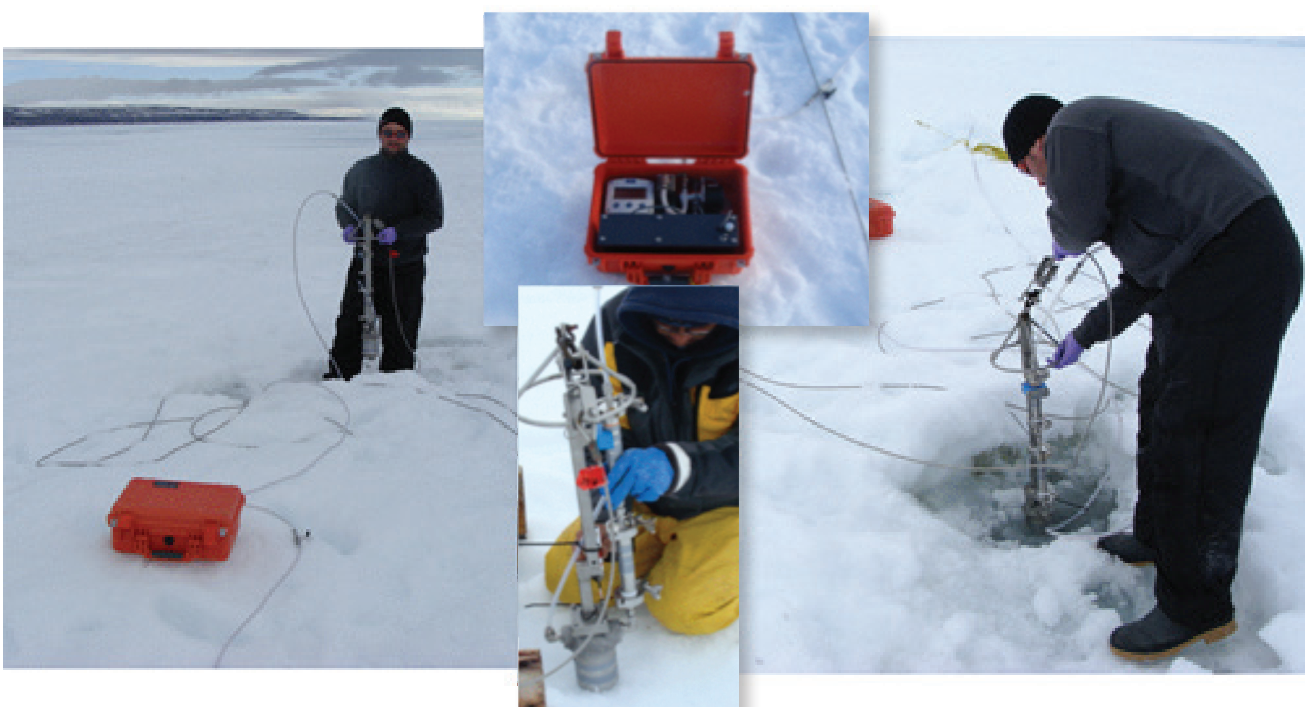
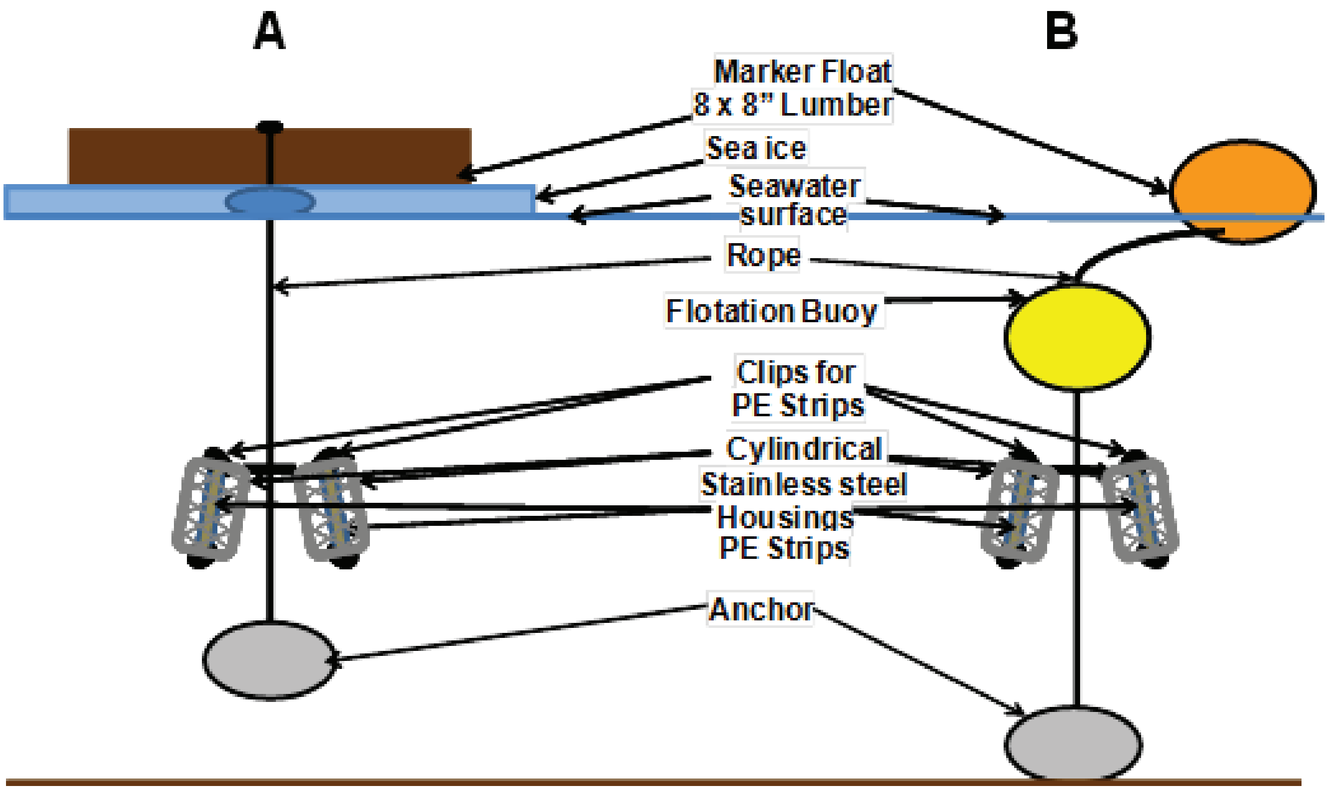


Figure 2. Setup for using passive polyethylene (PE) sampling strips in A ice covered conditions or B) semi open or open water conditions



regularly, and having to remove them for the season far earlier than expected. Therefore the last set of passive samples could not be obtained as there would be no way to retrieve them once the boats were out of the water. The loss of the apparatus offset the sampling times enough that we couldn't recover from the setback. In 2012, there are an additional set of housings and floats being supplied to the field team.

Chemical analysis:

PFC Extraction & Clean Up: Seawater samples were spiked with a suite of ^{13}C-labelled C_8-C_{12} PFCAs and PFOS and analysed as described in Benskin et al (2012) at Environment Canada, Canada Centre for Inland Waters (CCIW) in Burlington, ON. In brief, water samples were extracted by slow elution through Oasis WAX solid phase extraction (SPE) cartridges. The cartridges were then eluted with methanol (Fraction A) and 0.1% ammonia in methanol (Fraction B). Samples were evaporated to near dryness under a gentle stream of nitrogen, spiked with an instrument performance standard and prepared in methanol:water (1:1) for analyses. Procedural blanks were run with each batch of samples to correct for contamination during processing. Samples were analyzed for PFCs using liquid chromatography-tandem mass spectrometry (LC-MS/MS; API Sciex 4000) operated in electro-spray ionization mode with multiple reaction monitoring. A reverse-phase Gemini NX C_{18} (Phenomenex) column was used to achieve analyte separation using either (1) 0.01 M ammonium acetate in SPE cleaned, HPLC water (pH 9) (Fraction A) or (2) 0.01M ammonium acetate in methanol (Fraction B) as the mobile phase at 250 µl/min.

PE Extraction & Clean Up: PE strips were shipped sealed to the Lohmann Lab (Univ of Rhode Is) where they were removed from their packaging in the clean room. Prior to extraction, PE strips were thawed, rinsed in distilled water and dried with sterile Kimwipes to remove any solids or debris. Internal standards were added upon extraction in two consecutive extractions in DCM. Extracts were combined,

Table 1. Average concentrations (pg/L) of POPs in seawater using passive samplers deployed in May-June 2011

ΣPCBs	ΣCl2-CBs	ΣCl3-CBs	ΣCl4-CBs	ΣHCH	ΣDDT	ΣCHL	HCBz	ΣEndo
21.2	9.0	1.3	4.9	94.4	<0.05	<0.05	<0.05	0.10

reduced in volume (Turbovap/N2) and analysed directly by GC-MS/MS in electron impact mode for PCBs and OC pesticides. Samples were then analyzed by Environment Canada (Muir lab) for BFRs and CUPs via low resolution gas chromatography-mass spectrometry (GC-MS) operated in negative chemical ionization mode using helium as the carrier gas. Calculation of dissolved concentration followed the procedures detailed in Morgan and Lohmann (2008).

Results

The Lohmann lab has successful extracted the set passive samples (2 sample strips + 2 blanks). They have been analyzed for PAHs, OCPs and PCBs (Table 1). The analysis of CUPs and BFRs in Burlington, ON is pending. The Muir group has begun the extraction and analyses of the PFC samples and analyses are pending.

Concentrations of ΣPCBs (sum of 29 congeners) were in a similar range to those reported by Macdonald et al (2009) who used XAD based high volume active samplers in the Beaufort Sea and reported ΣPCBs ranging from 0.2 to 10 pg/L. The congener profile was similar, dominated by di- and trichlorobiphenyls (ΣCl2-CBs and ΣCl3-CBs). Total endosulfan concentrations (ΣEndo) were lower than we have found previously using active sampling in Barrow Strait (0.5-0.7 pg/L) (Morris et al 2009). Almost all analytes were not near equilibrium concentrations predicted from partition coefficients of these chemicals with PEM. Thus longer deployment times could result in higher concentrations.

Discussion and Conclusions

This was the first year of the study and also the first attempt, to our knowledge, to deploy passive samplers in the Canadian Arctic. The detection of PCBs and OC pesticides was encouraging however, deployment times likely needed to be longer. The failure of the large volume sampler due to cold weather is another indication of the challenges of operating in the Arctic where the delays in sending replacement parts for equipment can be very long. However, we are confident this can be overcome. Also it is worth noting that Hargrave et al. successfully deployed Seastar pumps in 1993 during the winter and Morris et al (2010) deployed the pumping system shown in Fig 1 previously during late May early June. For the 2012 field season, a re-design of the pump system has been undertaken, focusing on clean sampling and proper insulation of the sampling columns, pump itself and power supply. The whole unit

NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project	2	Peter Amarualik Sr. led the field team and conducted all sampling with the help of his son Jeffrey.
Number of meetings/workshops held in the north	1	Team member Adam Morris met with Peter to initiate the project in late March 2011.
Number of students involved in the project	0	
Number of citable publications	0	None

was field tested and with a member of the field team (Peter Amarualik Sr.) in March 2012 at Environment Canada, Burlington prior to deployment in the field in 2012.

One of the project goals was to increase involvement and engagement of the local Inuit community in Resolute Bay and to provide scientific training to another member in the community. Peter worked with and trained his son Jeffrey in the sampling procedures and there was much exchange over the phone regarding operation of the samplers. Thus we believe much was accomplished during 2011 despite sampling challenges.

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Monitoring of Radioactivity In Caribou And Beluga in Response to The Fukushima Accident

Surveillance de la radioactivité chez les caribous et les bélugas à la suite de l'accident de Fukushima

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Abstract

This project was initiated by concerns raised by Inuvialuit hunters who harvest whales that winter in the Bering Sea, in response to the Fukushima Daiichi nuclear accident. Thus this project will determine the radioactive contaminant levels in two important and valued country food species in the Western Canadian Arctic; caribou and beluga whale. These measurements will determine whether contaminant levels in these resources have changed since the accident relative to previous levels.

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.

The project has had a few setbacks and will continue through 2012-2013. Although these setbacks have been overcome, they have delayed

Résumé

Le présent projet, lancé après l'accident nucléaire de Fukushima Daiichi, répond à des préoccupations exprimées par des chasseurs inuvialuits qui chassent les baleines dans la mer de Béring à l'hiver. Ce projet déterminera donc les teneurs en contaminants radioactifs chez deux espèces importantes et valorisées dans l'alimentation traditionnelle dans l'ouest de l'Arctique canadien : le caribou et le béluga. Ces mesures détermineront si les teneurs en contaminants dans ces ressources ont changé depuis l'accident par rapport aux concentrations passées.

Des études antérieures ont montré des niveaux accrus de radioactivité chez les caribous et les rennes après la catastrophe de Tchernobyl en 1986. Bien que les niveaux de radioactivité chez les caribous de la Porcupine indiquent que ces derniers étaient propres à la consommation, il est important de vérifier qu'il en est ainsi après l'accident nucléaire de Fukushima pour assurer la salubrité des aliments et répondre aux inquiétudes des populations du Nord.

the project. A description of these setbacks, how they were overcome and the work done so far, is described below.

Le projet a connu quelques retards et continuera donc en 2012-2013. Bien que ces retards aient été rattrapés, ils ont ralenti la réalisation du projet. Une description des retards, de la façon dont on les a surmontés et des travaux effectués jusqu'à maintenant est fournie ci-dessous.

Key Messages

- Unfortunately due to unforeseen delays, the results of this project are not available at this time. However, these setbacks have been overcome and analysis is underway.

Messages clés

- Malheureusement, à cause de retards imprévus, les résultats du projet ne peuvent pas être présentés à l'heure actuelle. Toutefois, ces retards ont été rattrapés, et une analyse est en cours.

Objectives

- To determine if radioactivity from the Fukushima accident has affected Canadian Arctic caribou and beluga whales.

Introduction

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).

Activities in 2011-2012

Samples from two NCP projects were sent to the Radiation Protection Bureau for measurement of radioactivity. These were samples of caribou, beluga, lichens and mushrooms.

The samples were received late in the 2011/12 fiscal year . The first set back was that these samples were not homogeneous, so they had to be sent out to another lab to be homogenized Unfortunately not all of the samples were sent out for this process. This has been rectified and as this report is being written, the samples are being homogenized by an Environment Canada lab in Burlington. Another setback was that the computer program to estimate the gamma ray efficiencies of the detection system is no longer available. So the efficiencies had to be modeled using a more versatile but more complicated program EGSnrc [Kawkrakow (2003)]. This has been done and can now be used to estimate the efficiencies. Modeling of efficiencies of the detection system has to be done because the samples are of different thicknesses after homogenization. This must be taken into account when determining final concentrations of radioactive elements in tissues.

In order to model the efficiencies the density and the composition of the samples must be known. The composition of muscle tissues have been well studied in the domain of medical physics. Although the composition of lichens/mushrooms have not been studied in that domain, a literature search provided the information for the lichen species of interest. [Scotter (1972, Scotter (1964)].Sizes of the lichen samples are currently being determined so their efficiencies can be modeled and their activity concentrations can be calculated.

Table 1: The status of each of the samples. 1=homogenized or sent for homogenization. 2=measured using gamma-ray spectroscopy. 3= measured for sample thickness.

Sample Type	#	status
Lichens	7	1,2,3
Mushroom	12	1,2,3
Caribou	34	1
Beluga	41	1

NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	18	Caribou: 12 hunters, 1 northern consultant; Beluga: 4 monitors and 1 northern youth
number of project-related meetings/workshops held in the North (April 1, 2011 – March 31, 2012)	0	
number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	1	Beluga: 1 youth
number of citable publications (e.g., in domestic/ international journals, conference presentations, book chapters, etc)	2011:0 2012: 1	

Results and Discussion

Lichen and mushroom samples have been measured for radioactivity. Efficiencies of the detection system are being calculated to be used to determine the activity concentrations in these samples. The detection system that was used to make these measurements has been characterized using the EGSnrc simulation software. The software was used to model a liquid water source with the following radioisotopes in it: ^{210}Pb, ^{241}Am, ^{109}Cd, ^{57}Co, ^{139}Ce, ^{203}Hg, ^{113}Sn, ^{137}Cs, ^{88}Y, and ^{60}Co. The percent difference for all of the isotopes (except ^{210}Pb) were less than or equal to 5% as indicated in figure 1.

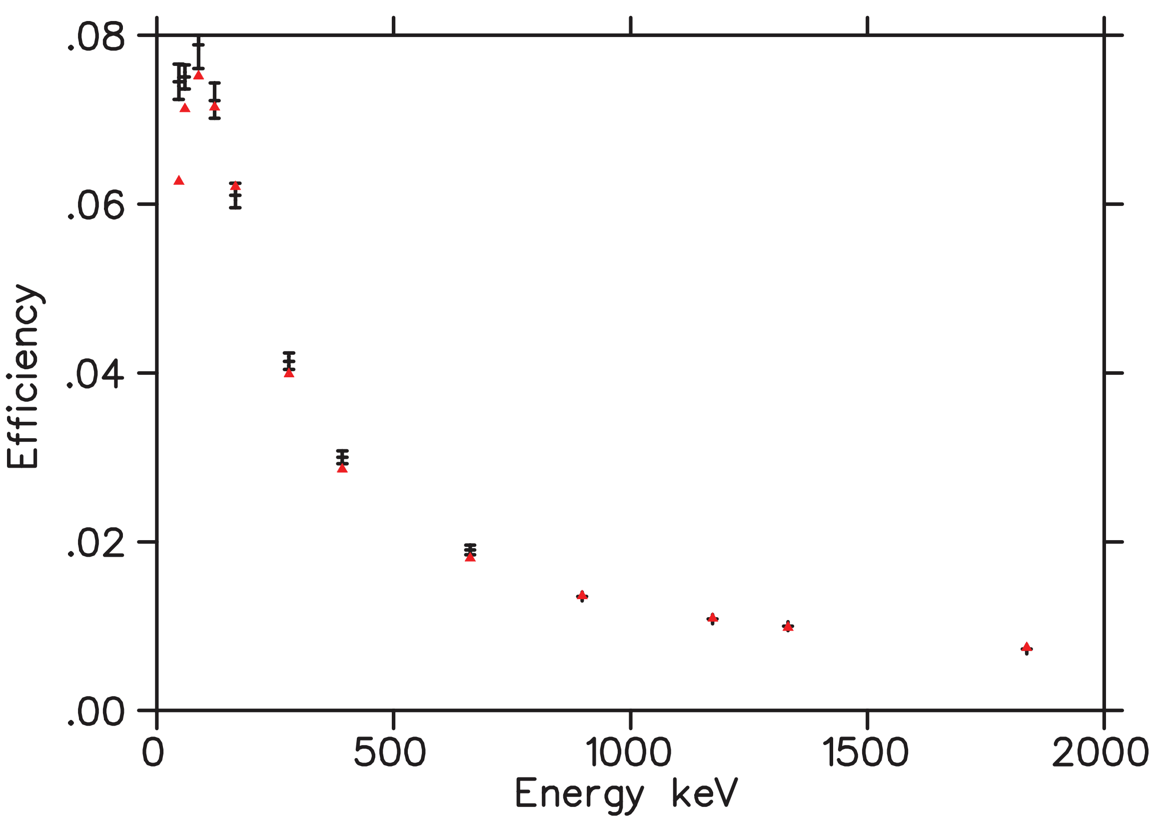
The EGSnrc simulation model will be modified to include the dimensions of the samples and physical characteristics of each of the samples (for example the thickness and the density and the chemical compositions of the samples). Then the efficiency for that sample will be calculated. This will be used to convert the number of gamma rays measured to an activity concentration.

Table 1 indicates the current status of the samples. There are 3 separate steps for each sample. In the table, step 1 indicates that the sample has been homogenized, or has been sent to be homogenized. Step 2 indicates that the sample has been measured for radioactivity. Step 3 indicates that the sample has been measured to determine its thickness (this will be used for the efficiency calculations).

Expected Project Completion Date

We anticipate that results will be presented to the communities in the early fall, 2012.

Figure 1: The detection system efficiency vs. energy for the detection of gamma rays.



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Communications, Capacity, and Outreach

Communications, capacités et sensibilisation

Gwich'in Tribal Council Communication & Education of the NCP

Conseil tribal des Gwich'in Communication et éducation – Programme de lutte contre les contaminants dans le Nord

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♦ **Project Team:**
Northwest Territories Regional Contaminants Committee
Designated Gwich'in Organizations
Gwich'in Renewable Resource Councils
Gwich'in Communities

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Abstract

The Gwich'in Community Liaison for the Northern Contaminants Program is Mardy Semmler, the Director - Lands and Resources. This position enables the Gwich'in to be a member of the NWT Regional Contaminants Committee (RCC) and participate in research programs established by the Northern Contaminants Program (NCP).

The representative has continued to promote dialogue and information between the Gwich'in communities, Designated Gwich'in Organizations (DGO's), Gwich'in Renewable Resource Councils (RRC's), the Gwich'in Tribal Council (GTC), NCP representatives, and NCP scientists and researchers.

The representative has participated in NWT RCC meetings including proposal and communications reviews, and has provided relevant contaminant information to Gwich'in communities and organizations. The representative, along with the GTC Lands and Resources Officer, attended the NCP annual results workshop held in Victoria, BC in September 2011.

Résumé

M[me] Mardy Semmler, directrice, Terres et ressources, agit à titre d'agente de liaison communautaire des Gwich'in pour le Programme de lutte contre les contaminants dans le Nord (PLCN). Ce poste permet aux Gwich'in d'être membres du Comité régional des contaminants des Territoires du Nord Ouest (ci après, le Comité régional) et de participer aux programmes de recherche mis sur pied dans le cadre du PLCN.

La représentante a continué de faire la promotion du dialogue et de l'échange d'information entre les collectivités des Gwich'in, les organismes désignés gwich'in, le Conseil gwich'in des ressources renouvelables, le Conseil tribal des Gwich'in ainsi que les représentants et les chercheurs du PLCN.

La représentante a participé à des réunions du Comité régional, y compris pour l'examen des propositions et du matériel de communication, et elle a fait part des renseignements pertinents sur les contaminants aux collectivités et aux organisations des Gwich'in. La représentante,

accompagnée de l'agent, Terres et Ressources, du Conseil tribal des Gwich'in, a participé à l'atelier annuel sur les résultats du PLCN tenu à Victoria, en Colombie Britannique, en septembre 2011.

Key Project Messages

- The Gwich'in Tribal Council (GTC) Director – Lands and Resources has continued to promote dialogue and information exchange between the Gwich'in communities, Gwich'in Organizations including the Gwich'in Tribal Council, NCP representatives, and NCP scientists and researchers.
- The representative had the opportunity to attend workshops (e.g. NCP results workshop) including information sessions and training courses to enhance capacity to carry out the duties of the NWT RCC membership.
- The representative actively participated in both in-person and conference call meetings of the NWT RCC throughout 2011/12.
- The representative provides information and feed back to the NWTRCC during annual social and cultural proposal reviews that is relevant to the region, including incorporation of traditional knowledge, communications strategy, community capacity development, organization contacts, etc for the scientists and researchers conducting studies with the GSA and the NWT.
- The representative reviews all research project applications submitted to the Aurora Research Institute and provides comments for all research being conducted within the GSA including research that is being conducted through the NCP.

Messages clés

- La directrice, Terres et Ressources, du Conseil tribal des Gwich'in a continué de promouvoir le dialogue et l'échange d'information entre les collectivités des Gwich'in, les organismes gwich'in, y compris le Conseil tribal des Gwich'in, ainsi que les représentants et les scientifiques et chercheurs du PLCN.
- La représentante a eu l'occasion de participer à des ateliers (p. ex. l'atelier sur les résultats du PLCN), y compris à des séances d'information et à des formations visant à rehausser la capacité d'effectuer les tâches confiées aux membres du Comité régional.
- La représentante a participé activement à des réunions et à des conférences téléphoniques du Comité régional en 2011 et 2012.
- M^me^ Semmler fournit des renseignements et des commentaires au Comité régional pendant l'examen annuel des propositions sociales et culturelles. Les renseignements pertinents pour la région comprennent entre autres des connaissances traditionnelles, une stratégie de communication, le développement des capacités communautaires et les personnes-ressources d'organisations. Ces données seront utilisées par les scientifiques et les chercheurs qui mènent des études dans la région visée par le règlement de la revendication des Gwich'in et les Territoires du Nord-Ouest.
- La représentante passe en revue toutes les demandes de projets de recherche qui sont présentées à l'Institut de recherche Aurora et formule des commentaires pour toutes les recherches menées dans la région visée par le règlement de la revendication des Gwich'in, incluant celles qui sont réalisées dans le cadre du PLCN.

Objectives

The objectives of this project are to facilitate the process of collaborative study, assessment and communication of information to residents of the Gwich'in Settlement Area (GSA) about the presence and possible effects of contaminants in the air, land, water and wildlife. The Director – L & R goals are:

1. To promote the role of the Gwich'in Tribal Council (GTC) as a partner in the NCP;
2. To assist the Gwich'in Communities to identify proposed research projects & development and/or contaminant concerns;
3. To inform and educate the public and the Gwich'in Participants about contaminants within the GSA;
4. To increase capacity at the regional / local level;
5. To coordinate and/or assist with regional contaminant studies, where applicable;
6. To identify complementary environmental issues and funding sources;
7. To review NWT Proposals for the NCP for social/cultural criteria prior to full technical reviews;
8. To actively participate in all NWT RCC meetings and related tasks.

Introduction

This was the thirteenth year that the GTC has been actively involved in the Northern Contaminants Program. Over the course of involvement with the NCP the Gwich'in representative for the GTC has established a very good track record. The Gwich'in are concerned about long range contaminants and want to continue to be well informed about levels of contaminants in their traditional foods and/or the environment within which they practice their traditional and cultural activities. Participation in the NCP through the NWT RCC provides a valuable opportunity for two-way communication about contaminants in the GSA and the NWT.

Activities in 2011 - 2012

- The Director – L & R participated in several teleconferences of the NWT RCC and two in person meetings.
- The Director – L & R attended the NCP results workshop in Victoria, BC.
- Continued to relay information to the Gwich'in communities and Aboriginal partners of the NWT RCC, which will relay major concerns to the NCP management committee and vice versa.
- The Director – L & R attended Gwich'in Renewable Resource Council meetings in 2011 and early 2012 to discuss the NCP with the community members and to continue to relay the importance of the NCP to community members. Communities visited were Fort McPherson, Tsiigehtchic, Aklavik and Inuvik.
- The Director – L & R attended the GTC Annual Assembly in August 2011 in Tsiigehtchic and displayed NCP resource information and reports and discussed the program with Participants of the Gwich'in Annual Assembly requesting information about the NWT RCC and Northern Contaminants Program in general.
- The Director – L & R included in the annual report the membership of the GTC on the NWT RCC, the objectives of the committee and the GTC's role on the NWT RCC.
- A proposal was submitted to NCP for continued participation of the GTC in NCP activities and the NWT RCC for 2012/13.

Results

In addition to the activities outlined above, the Director – L & R highlighted several concerns from Gwich'in communities and organizations to the NWT RCC during the teleconference calls and funding proposal reviews. These concerns ranged from long term monitoring of contaminant levels in important traditional foods such as caribou, moose, berries, fish and marine mammals such as beluga whales and seals to local contaminants concerns including water quality issues, and the relationship between contaminants and potential human health concerns.

The Gwich'in Participants continue to harvest traditional foods for subsistence as the cost of food in Gwich'in communities is very expensive. The traditional diet for Gwich'in participants consists of caribou, moose, fish and berries that are gathered throughout the GSA, including beluga and caribou that is harvested from the Beaufort Coast. Contamination through long range transport of different chemicals used in industrial nations are of great concern to the Gwich'in Participants and continued research within the GSA and Beaufort Delta and Coast to track these levels are very important to the Gwich'in Participants.

Discussion and Conclusions

In 2011/2012, the Director – L & R has continued to address concerns of the residents of the Gwich'in Settlement Area by gathering, organizing, and distributing information when requested, not only to the participants of the GSA, but also to the NCP NWT RCC, scientists and researchers and the GTC. The Director – L & R attended workshops and meetings to enhance capacity to carry out the duties of the NCP NWT RCC membership. Furthermore, based on requirements of the information by the residents of the Gwich'in Settlement Area, it has been demonstrated that this position is an integral part of the NCP and the Gwich'in Settlement Area.

The GTC NCP NWT RCC representative was re-nominated Chair for the 2011/12 term and assisted the NCP Secretariat in agenda development and chairing the NWT RCC meetings. The GTC NCP NWT RCC representative also attended the NCP Management Committee meeting held in April 2011 to discuss the funding proposal submissions.

The GTC is confident that the Director – L & R will continue this successful relationship in the future with NCP NWT RCC. The Director – L & R sits on other committees and working groups in the NWT and the Yukon and information and capacity gathered through the NWT RCC assist the Director – L & R in being able to participate in a meaningful manner on these committees and working groups, including Protected Area Strategy Steering Committee, Cumulative Impact Monitoring Program Working Group, NWT Water Stewardship Strategy Aboriginal Steering Committee, Yukon Environmental and Socio Economic Assessment Board Review Committee, etc.

Based on the natural disasters affecting other parts of the World, specifically Japan and the nuclear radiation crisis, more concerns with regard to nuclear radiation contamination through long range transport will be brought up by Participants in the near future, including the effects to traditional country foods and human health.

Expected Project Completion Date

The Director – L & R will continue to represent the Gwich'in Participants by continuing to be a part of the NWT RCC, and address concerns relating to contaminants in the Gwich'in Settlement Region including areas of overlap in the Beaufort Delta and Yukon.

Nunavik Nutrition and Health Committee: Coordinating and Learning from Contaminants Research in Nunavik

Comité de la nutrition et de la santé du Nunavik : coordonner la recherche sur les contaminants au Nunavik et en tirer des leçons

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Abstract

The Nunavik Nutrition and Health Committee (originally named the PCB Resource Committee) was established in 1989 to deal with issues related to food, contaminants, the environment and health in Nunavik. Since its inception, the committee has broadened its perspective to take a more holistic approach to environment and health issues inclusive of both benefits and risks. Today, the committee acts as the authorized review and advisory body for health and nutrition issues in the region, and includes representation from many of the organizations and agencies concerned with these issues, as well as those conducting research on them. The committee provides guidance and acts as a liaison for researchers and agencies from both inside and outside the region, directs work on priority issues,

Résumé

On a mis sur pied le Comité de la nutrition et de la santé du Nunavik (qui s'appelait au départ Comité des ressources sur les BPC) en 1989 pour traiter des questions se rapportant aux aliments, aux contaminants, à l'environnement et à la santé au Nunavik. Depuis sa création, le Comité a élargi son champ d'action et a ainsi adopté une approche plus globale quant aux questions touchant l'environnement et la santé, notamment sur les plans des avantages et des risques. Aujourd'hui, le Comité est l'organe autorisé d'examen et de consultation en matière de santé et de nutrition dans la région. Le Comité comprend des représentants de bon nombre d'organismes qui s'intéressent à ces questions ainsi que de ceux qui effectuent des recherches à ce sujet. Le Comité donne une orientation et assure la liaison pour les

communicates with and educates the public on health and environment topics and research projects, and represents Nunavik interests at the national and international levels. All activities are conducted with the goal of protecting and promoting public health in Nunavik, through more informed personal decision making. In 2011-2012, the committee focussed its efforts on the release of the results and public health implications from the Nunavik Child Development Study (NCDS) and continued to develop regional long-term strategies for communication activities based on regional needs and priorities in cooperation with the NCP Secretariat.

Key Messages

- The Nunavik Nutrition and Health Committee is the key regional committee for health and environment issues in Nunavik
- The committee advises the Nunavik Public Health Director about educating the public on food and health issues, including benefits and risks associated with contaminants and country foods
- The committee continues to be active within the NCP, reviewing and supporting research in the region, ensuring liaison with researchers and helping in the communication of research results in a way that is appropriate and meaningful to Nunavimmiut.

chercheurs et les organismes de la région et de l'extérieur, dirige les travaux qui portent sur les questions importantes, transmet des renseignements au public et éduque celui ci au sujet de l'environnement et de la santé et des projets de recherche, et représente les intérêts du Nunavik sur les scènes nationale et internationale. Toutes les activités réalisées visent à protéger la santé publique au Nunavik et à faire la promotion de cet aspect, en favorisant une prise de décisions personnelles plus éclairées. En 2011-2012, le Comité a axé ses efforts sur la diffusion des résultats et des répercussions pour la santé publique de l'Étude sur le développement des enfants au Nunavik. Il continue également d'élaborer des stratégies de communication régionales à long terme qui répondent aux priorités et aux besoins régionaux, et ce, en collaboration avec le Secrétariat du Programme de lutte contre les contaminants dans le Nord.

Messages clés

- Le Comité de la nutrition et de la santé du Nunavik est le principal comité régional chargé des questions liées à la santé et à l'environnement au Nunavik.
- Le Comité conseille le directeur de la santé publique du Nunavik à propos des activités d'information et d'éducation concernant la nutrition et la santé, y compris les bienfaits et les risques associés aux contaminants et à la nourriture de la région.
- Le Comité continue de participer activement au Programme de lutte contre les contaminants dans le Nord : il étudie et finance la recherche dans la région, assure la liaison avec les chercheurs et favorise la communication des résultats des recherches d'une manière qui est appropriée et convenable pour les Nunavimmiut.

Objectives

- To provide the population and regional health workers with background information to help them understand and contextualize environmental health, nutrition and contaminants research, objectives and results;
- To identify elements of public concern that have not been addressed to date, and to steer and support research activities towards providing the data needed to address these concerns;
- To undertake public communication of environmental health data, including results of Northern Contaminants Research Projects, and help develop regional communication and evaluation strategies for this information;
- To prepare summaries on the state of the knowledge on these issues to assist in communication and intervention activities of local health and environment officials;
- To facilitate research on environmental communications and risk-perception issues;
- To help researchers translate their data into meaningful information for the public;
- To support partnerships in various research and intervention activities related to country foods, nutrition and health.

Introduction

In Nunavik, a group of individuals representing different organizations concerned with health, the environment and nutrition issues has formed to address these topics and communicate with and educate the public to ensure more informed personal decisions. This group, the Nunavik Nutrition and Health Committee, evolved from the original PCB Committee, created in 1989 and later renamed the Food, Contaminants and Health Committee. The name has changed over the years as the group has learned of the importance of focusing not only on negative impacts of contaminants but also on the need for a more holistic approach to nutrition, health and the environment, including benefits. On an ongoing basis, the committee addresses a number of issues relating to food, contaminants, nutrition and health, and the relationship to the environment.

This evolution and recognition of the NNHC places it in an important role in addressing issues related to contaminants, food, health and the environment in the region. The committee is therefore well positioned and has the necessary capacities to support research activities (through review, facilitation and communication) related to these issues under the Northern Contaminants Program as the regional contaminants committee. This report represents a synopsis of the committee's activities for the 2011-2012 year.

Activities in 2011-2012

In 2011-2012, the committee met face to face three times. Two of the meetings were held in Kuujjuaq, in June 2011 and November 2011. These meetings lasted two days and dealt with different topics linked to nutrition, contaminants and Nunavimmiut health.

The third meeting was held in February 2012 in Quebec city over three days. This meeting was held in the South in order to meet the researchers in person. The meeting was convened to review NCP proposals for 2012-2013, meet with researchers regularly working in the region and address regular business items of the NNHC. The first part of the meeting consisted of reviewing each proposal among the committee members only. For the second part, all researchers who had submitted a proposal to the NCP this fiscal year were invited to meet the committee in person. They were asked to answer questions the committee had in regards to their proposed work. This process of meeting with researchers at the same meeting when the committee reviewed proposals was found to be an efficient process: first, to clarify aspects of the review of NCP proposal; second, to provide an opportunity for the committee to suggest adaptations to proposals (if funded) early in the funding and review process; and third, to make updates on the work accomplished in the past year when relevant.

Summary of Regular Topics Managed by the NNHC

Below is a list of ongoing NCP-related files managed by the NNHC and for which actions were taken in 2011-2012:

Review of Research Proposals and Liaison with Researchers

In 2011-2012, the committee reviewed all research projects to be carried-out in the region or involving data from the Nunavik population proposed under the NCP. As discussed above, this review included meeting with the researchers to discuss and question aspects of their proposed work to better understand and discuss their proposals.

Food Insecurity

Food insecurity is a major concern in the region.The committee is seeking information to know more about the real situation of food insecurity. The NNHC will try to maximize the use of current databases to improve the knowledge on that issue. Some members of the NNHC are part of a food security working group looking at the analysis of existing data available in the region.

Regional Food Policy

A Regional Food Policy is one of the Public Health priorities. Nunavimmiut encounter various concerns relating to food and nutrition, namely traditional food access, food insecurity, high costs, etc. The Qanuippitaa 2004 health survey has revealed deterioration in the nutritional status of Nunavimmiut, linked to a decrease in country food consumption and increase in junk foods consumption. The adoption of a Nunavik-specific regional food policy would contribute to country food promotion, improvement of the Nunavimmiut nutritional status, job creation, etc. The objective is to bring the regional actors together to develop a Nunavik-specific regional food policy. NNHC will be an important partner in the development of this regional food policy.

Nunavik Child Development Study (NCDS)

During the year 2010-2011 and 2011-2012, a working group including NNHC members, researchers and field workers have actively worked on the revision of key findings of the study, the development of public health messages to be provided to frontline workers, organizations and communities, and the revision of the communications tools developed in 2004 by the NNHC and the PHD for communication of results from a previous follow-up of Nunavik children. In 2011-2012, the working group worked on the development of new tools and products to present the study results and public health messages to appropriate frontline workers, organizations and communities and the development of a detailed communication plan.

The communication activities occurred mainly in the fall 2011. In September 2011, Nunavik Child Development Study (NCDS) results and public health implications were presented to NCP secretariat and representatives of Northern regions of Canada. On October 3, 2011, this information was presented to Inuit leaders from Nunavik. Many key stakeholders attended this meeting. On October 5, 2011, the NCDS study results and public health implications were presented during the NRBHSS annual general meeting. A phone-in radio show broadcast throughout Nunavik was organized on October 7, 2011, to disseminate the information to Nunavimmiut; Serge Déry, Elena Labranche and Gina Muckle participated.

The NNHC is surprised that there have been no reactions to these results and public health implication since the release. We strongly think that it will be important to make sure that people adequately understood these recommendations in a near future. A proposal has been submitted to the NCP for 2012-2013.

Results of the Contaminant-nutrient Interaction study in daycare center: Communication of the results

At the November meeting, Dr Huguette Turgeon O'Brien and Doris Gagné presented the results they expect to publish to the committee. The committee asked them to prepare a written report of all the results in order to provide feedbacks and collaborate in the development of a communication plan, if applicable.

Lead Pellets Shots – Action Plan

Last year, the committee supported the work of Ariane Couture, a master's student in community health at Laval University working on the current profile of lead exposure in Nunavik to evaluate the need to repeat the intervention carried out about 10 years ago. This study revealed that ammunition containing leat pellets is back on store shelves in many Nunavik communities. The committee strongly believes there is an urgent need to address this issue with concrete regional actions. The NNHC would like to collaborate in reinstalling the ban and organizing efficient communication activities. This file can be managed by an environmental-health officer, but we currently do not have such a position on our team.

Meaning of Food Security for Nunavimmiut

The committee supported Léa Laflamme's research project. Léa Laflamme did an internship in nutrition in Nunavik in 2009 with Marie-Josée Gauthier. She is studying community health at Laval University and is supervised by Dr Christopher Fletcher and Dr Anne-Marie Hamelin. The general objective of this research is to attain a better understanding of the meaning of food security from the perspective of Inuit. The project will be carried out in the village of Inukjuak.

Monitoring spatial and temporal trends of environmental pollutants in maternal blood in Nunavik (Dewailly and PHD project)

The NNHC supported Dr Eric Dewailly and the Public Health Department in this monitoring project. The pilot phase of the monitoring project started during the fall 2011 and lasted until March 31, 2012. This year, the recruitment was very hard and the research team had to find a way to increase the recruitment rate among mothers for the year 2012-2013. A meeting with some members of the NNHC as well as representatives of both health centers was held in Kuujjuaq on March 26, 2012. Both health centers were satisfied with the reviewed proposal submitted (research nurse sent on the field).

To Build Food Security and to Promote Healthy Weights in Inuit Communities – Phase I

The NNHC supported Dr Hamelin of McGill University in the research project entitled *"To Build Food Security and to Promote Healthy Weights in Inuit Communities – Phase I: Developing Partnerships, 2011-2012"*. The implementation of this project began in September 2011 in two communities: Kangiqsualujjuaq and Umiujaq.

Validation of a dioxin-responsive, chemically activated luciferase gene expression (DR-CALUX) assay for the analysis of dioxin-like substances in human plasma samples

The committee supported th research project of Dr Pierre Ayotte of the CRCHUQ. At the June meeting, the NNHC met with the researcher and came away satisfied with the answers to its questions.

Nunavik Environmental-Health Officer

The Nunavik Regional Board of Health and Social Services is collaborating with the Public Health Agency of Canada to hire an environmental-health officer for Nunavik. The negotiations are not finalized yet. We hope to be able to fill the position in 2012.

Review of criteria for NCP proposals evaluation

In 2010-2011, the committee looked at criteria and score system from grids used in other regions or for national northern projects. At the March meeting, the committee discussed about our actual scoring system as well as the ones used in other northern regions. According to the conclusions of that discussion, a new grid was prepared by the Nunavik Director of Public Health and presented to all committee members in June 2011. The committee reviewed the new grid in the June meeting and finalized it during the November meeting. The NNHC used this evaluation grid for its February 2012 review meeting in Quebec city.

NNHC Members' Participation in Workshops and Meetings

Several committee members are active in research and policy issues relative to food, nutrition and health, and contaminants and attended workshops and meetings this past year to promote the activities of the committee and its specific initiatives, learn about other regional and international initiatives and communicate the results of regional research projects. Members attended the NCP Management Committee meetings, the NCP results workshop 2011, Food Security Reference Group Meetings, Nutrition North Canada meetings, among others.

Acknowledgments

The committee would like to thank all Nunavimmiut for their ongoing participation and support in contaminants, health and environment research. Furthermore, the NNHC is grateful to the Northern Contaminants Program and the Nunavik Regional Board of Health and Social Services for ongoing support and funding of its activities related to health, contaminants and nutrition in the region.

Environmental Contaminants and human health in Nunatsiavut – managing relationships and ensuring Nunatsiavummiut have the information they need

Les contaminants environnementaux et la santé humaine au Nunatsiavut – gérer les relations avec les Nunatsiavummiut et répondre à leurs besoins d'information

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- **Project Team:**
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Abstract

In 2011-2012, the Northern Contaminants Researcher continued to communicate and educate Nunatsiavummiut about contaminants and the benefits of traditional/country foods, so that Labrador Inuit may make informed decisions in their daily lives. This happened through various initiatives, including the Nunatsiavut Health and Environment Research Committee (NHERC), the Avativut Newsletter that is funded under the Northern Contaminants Program and others, and community activities operating out of the Nain Research Centre. NHERC members travelled the Nunatsiavut coastal communities again this past year to communicate about various contaminant-related research and monitoring programs in the region. The Avativut Newsletter was published in January 2012, and included information about ongoing and future research for the Nunatsiavut communities

Résumé

En 2011-2012, l'agent de recherche sur les contaminants dans le Nord a poursuivi ses activités de communication et d'éducation sur les contaminants et les avantages des aliments traditionnels auprès des Nunatsiavummiut, afin que les Inuit du Labrador puissent prendre des décisions éclairées dans la vie de tous les jours. Il a mené ses activités par l'intermédiaire d'initiatives et de groupes de travail comme le Comité de recherche sur la santé et l'environnement du Nunatsiavut (CRSEN), le bulletin Avativut Newsletter qui est financé par le Programme de lutte contre les contaminants dans le Nord et d'autres sources et des activités communautaires oraganisées par le Centre de recherche de Nain. Les membres du CRSEN se sont de nouveau rendus dans les collectivités côtières du Nunatsiavut au cours de la dernière année pour diffuser de l'information concernant divers programmes de recherche et

as well as the benefits and risks of contaminants and traditional/country foods. The newly operational Nain community freezer, which is based in the Nain Research Centre, provided many opportunities to discuss the importance of country foods for physical and mental health in the region. The Northern Contaminants Researcher was also an active member on the Nunatsiavut Steering Committee for the Inuit Health Survey, providing both guidance and translation services for the contaminants portion of the IHS, the results of which are expected to be released publically in summer 2012. Finally, the Northern Contaminants Researcher was instrumental in the implementation of Tukisimakatigennik ('understanding together'), a community-led ringed seal knowledge (Inuit and science) project, that included a workshop bringing together harvesters and scientists in Nain, the outcomes of which have influenced the process through which ringed seal contaminant monitoring programs will be carried out in the region, going forward.

de surveillance axés sur les contaminants dans la région. L'Avativut Newsletter, qui a été publié en janvier 2012, faisait état des études actuelles et futures dans les collectivités du Nunatsiavut ainsi que des avantages des aliments traditionnels et des risques associés aux contaminants. Le nouveau congélateur de la collectivité de Nain, qui se trouve au Centre de recherche de cette localité, a créé de nombreuses occasions de discuter de l'importance de la nourriture traditionnelle pour la santé physique et mentale des habitants de la région. L'agent de recherche sur les contaminants dans le Nord a également participé activement à l'Enquête sur la santé des Inuit par l'entremise du Comité directeur du Nunatsiavut, en fournissant des services de traduction et des conseils relativement à la partie sur les contaminants de l'enquête, dont les résultats devraient être publiés à l'été 2012. Enfin, l'agent de recherche a contribué à la mise en œuvre du projet communautaire de connaissances (inuites et scientifiques) *Tukisimakatigennik* (« comprendre ensemble ») sur le phoque annelé, qui comprenait la tenue à Nain d'un atelier réunissant des chasseurs de phoques et des scientifiques. Les résultats de cet atelier ont eu une incidence sur la façon dont les programmes de surveillance de cette espèce seront menés dans la région.

Keys Messages

- The Northern Contaminants Program Researcher for the Nunatsiavut Government continues to communicate contaminants, research and environmental issues, conduct research and promote networking relationships between the communities of Nunatsiavut and outside scientists.
- Nunatsiavut residents continue to have concerns and interest in contaminants, health and research in their communities. Members of NHERC travelled the Nunatsiavut communities and heard first-hand some of these concerns while also presenting research and contaminant-related programs operating in the region.
- The Northern Contaminants Researcher was an active member on the Nunatsiavut

Messages clés

- L'agent de recherche sur les contaminants dans le Nord du gouvernement du Nunatsiavut poursuit des activités de communication sur les contaminants, les travaux de recherche et les préoccupations environnementales, mène des études et fait la promotion des relations de réseautage entre les collectivités du Nunatsiavut et les scientifiques de l'extérieur.
- Les résidents des collectivités du Nunatsiavut restent préoccupés par les contaminants et la santé communautaire et continuent de s'intéresser aux études menées dans leurs collectivités. Des membres du CRSEN se sont rendus dans les collectivités du Nunatsiavut et ont recueilli directement les préoccupations des résidents de ces collectivités. Ils ont également présenté des travaux de recherche

Steering Committee for the Inuit Health Survey, providing both guidance and translation services for the contaminants portion of the IHS, the results of which are expected to be released and communicated to the public in summer 2012.

- The Northern Contaminants Researcher worked with the Inuit Research Advisor to run several 'on-the-ground' traditional foods and healthy eating events in the community of Nain, the largest community in Nunatsiavut. These events were highly successful and included research and contaminants-related information displayed throughout the Nain Research Centre for people to read and ask questions about while they enjoyed country foods (eg. caribou soup, seal, char) that were being served. We hope that these traditional food and healthy eating events will continue to promote the healthiness and richness of wild foods in Nunatsiavut, while placing contaminants-related information in an appropriate context.

et des programmes sur les contaminants qui se déroulent dans la région.

- L'agent de recherche sur les contaminants dans le Nord a participé activement à l'Enquête sur la santé des Inuit par l'entremise du Comité directeur du Nunatsiavut, en offrant des services de traduction et des conseils pour la partie de l'Enquête portant sur les contaminants. Les résultats de cette enquête devraient être publiés et communiqués au public à l'été 2012.

- L'agent de recherche sur les contaminants dans le Nord a travaillé en collaboration avec le conseiller en recherche inuite afin d'organiser plusieurs événements « sur le terrain » pour faire la promotion des aliments traditionnels et de saines habitudes alimentaires dans la collectivité de Nain, la plus importante au Nunatsiavut. Ces événements ont remporté un vif succès et ont permis au Centre de recherche de Nain de diffuser de l'information écrite sur la recherche et les contaminants et d'interroger les résidents lorsque ceux ci participaient à des dégustations d'aliments traditionnels (soupe au caribou, phoque, omble). Nous espérons que ces dégustations d'aliments traditionnels et activités de promotion de saines habitudes alimentaires se poursuivront afin de faire connaître les bienfaits des aliments sauvages au Nunatsiavut, tout en présentant l'information sur les contaminants dans un contexte approprié.

Objectives:

- Serve as liaison between Inuit and regional/national organizations dealing with contaminants, environment and human health research in Nunatsiavut.
- Serve as ambassador to Nunatsiavimmiut concerns related to contaminants, environment and health.
- Ensure that issues and research related to contaminants, environment and health are communicated to Nunatsiavimmiut in an effective, meaningful and sensitive manner, pulling in appropriate expertise to assist where necessary.
- Maintain communication with ITK to ensure a national understanding of Labrador Inuit needs for communicating about contaminants, environment and human health issues.

- Provide assistance to Nunatsiavimmiut for informed decision-making related to health and nutrition by providing information in the Avativut Newsletter regarding the nutritional content of various traditional foods and related recipes.

- Identify contaminants, environment and health-related research needs in the region, and work towards ensuring that these needs are met through connections with NCP and the greater research community and facilitation of researcher-community relationships.

- Provide guidance/advice to the Nunatsiavut Government Minister and Deputy Minister of Lands and Natural Resources with regards to contaminants and health issues.

- Work with the Nunatsiavut Inuit Research Advisor and the Nunatsiavut Government Research Advisory Committee to further develop a research support system and infrastructure in Nunatsiavut.

- Develop and assess common Inuit communication activities and set Regional priorities.

- Compile concerns and suggestions from each community on all issues related to contaminants.

- Identify contaminants research needs and possibilities in Nunatsiavut.

Introduction

Nunatsiavummiut are sustained by the animals, birds, fish and plants of the region. Research has shown that contaminants are present in these food sources due to the environment being contaminated by varying sources of pollution (local as well as distant, which are then transported to the north via atmospheric and oceanic mechanisms). Also, climate change effects are evident in the Canadian Arctic. The levels of contaminants in these foods which sustain Nunatsiavummiut and potential effects they may have on residents of the coastal communities are of concern to the Inuit of Nunatsiavut. The Nunatsiavut Government and Nain Research Center help ensure that Nunatsiavummiut are heard and their concerns with regard to both national and local contaminants issues are assessed and communicated. The current issues for Nunatsiavut Inuit are similar to those of other Inuit regions, but there are also local concerns that need to be communicated.

Hopedale, Labrador, a community of approximately 625 residents, has a former US Air Force early-warning radar station near the community and residents have voiced their concerns about PCB contamination in the area for years. The Northern Contaminants Research serves as a local support for residents in the community if they have questions. Some remediation was conducted in summer of 2011 and more work is expected for summer of 2012. The Northern Contaminants Researcher was also heavily involved in a dietary survey that is being used to better understand risks to human health as a result of the contamination.

In order for Nunatsiavut Inuit to be informed about wise food choices the Northern Contaminants Researcher and Nain Research Centre coordinate efforts between Inuit Tapiriit Kanatami, NCP, the Department of Health and Social Development within the Nunatsiavut Government, Universities and government researchers and our communities. Following the objectives of the Northern Contaminants Program, the Northern Contaminants Researcher acts as a key resource person and provides contaminant-related information to the population in a culturally relevant and plain language manner while promoting country foods across the region.

Activities and Results

This year the Nunatsiavut Governments Northern Contaminant Researcher:

- informed residents of Nunatsiavut about the benefits of country/traditional foods through:

– the development of posters distributed to communities;

– traditional/country food events promoting the richness of wild food, and;

– the Avativut Newsletter.

- Traveled to Nunatsiavut communities with members of the Nunatsiavut Health and Environment Research Committee to bring Labrador Inuit information about research, health, contaminants, and environmental issues that affect their daily lives, so that they can make informed decisions.

- Assisted in managing the Nain Research Centre and programs directly and indirectly related to food security and contaminants, including the Nain Community Freezer program and affiliated youth outreach programs.

- Served on the Nunatsiavut Government Interim Research Advisory Committee which is responsible for reviewing proposals and ensuring research in the region follows guidelines set by the Nunatsiavut Government, is culturally sensitive, and has any permits required by the Nunatsiavut Government.

Figure 1. Country foods being served at a wild food celebration event (Nain Research Centre) in front of a backdrop highlighting some of the benefits of traditional foods.

- As part of her ongoing work on the issue of local contaminants sources at abandoned military sites, the NCR continues to be the first point of contact for Hopedale residents, ensuring they are well informed of the results of work in Hopedale.

- Assisted in the coordination of the Tukisimakatigennik ('understanding together') ringed seal knowledge (Inuit and science) project, including a workshop bringing together harvesters and scientists in Nunatsiavut, for research to be conducted in Nain, Nunatsiavut in the summer of 2012.

- Served as an active member on the Nunatsiavut Steering Committee for the Inuit Health Survey, providing both guidance and translation services for the contaminants portion of the IHS, the results of which are expected to be released and communicated to the public in summer 2012.

- Assisted and advised researchers who were conducting research in Nain and throughout Nunatsiavut.

Communications

Avativut Newsletter

The Avativut Newsletter is a quarterly newsletter that the Nain Research Center has developed and used to communicate the benefits and risks of country foods, contaminants and the Northern Contaminants Program. The

Figure 2. Nainimiuks celebrating country foods in the Nain Research Centre.

latest Avativut Newsletter that was published in January 2012, contained information on contaminants, health, environment, current research projects and upcoming activities for the Nunatsiavut region that are funded by the Northern Contmaminants Program. The newsletter is distributed to all Nunatsiavut communities.

Nunatsiavut Health and Environment Research Committee

|The Nunatsiavut Health and Environment Research Committee began in late 2007. The committee members come from various backgrounds. The Northern Contaminants Researcher is the Chairperson for the committee while the current co-chair is Ed Tuttauk (NG) from North West River (ULM). Other members include Tom Sheldon (Director of Environment – Nunatsiavut Government), Carla Pamak (Inuit Research Advisor – Nunatsiavut Government), Michele Wood (Researcher/Evaluator – Nunatsiavut Government), and Eric Loring (Senior Environmental Researcher – ITK).

The Northern Contaminants Researcher is responsible for securing funds for the committee and coordinating the committee activities, preparing for face to face meetings and teleconferences which include logistical planning, travel arrangements, orientation of new members, preparing minutes, disseminating proposals for review, collecting information, preparing documents and ensuring regional concerns are forwarded to the NCP. Terms of Reference for the NHERC have been developed.

Participation in Research Projects and Visiting Researchers

The Northern Contaminants Researcher continues to assist researchers coming to Nunatsiavut. Research has been ongoing in the Nunatsiavut communities, therefore the NCR is an important resource for communication between the researchers and the communities. Although there is some understanding of why research is important, it is necessary to continue to communicate research information and give explanations about it.

Discussion and Conclusions

The NCR continues to be an important part of the work of the Nunatsiavut Government, especially for residents who have concerns about contaminants. The Nain Research Centre is growing and trying to provide the people of Labrador with a better understanding of contaminants in their environment and traditional foods, and to be more aware of research and general environmental health issues.

Figure 3. Mary Sillitt and Katie Winters (L-R) in Hopedale just prior to an open house session with the Nunatsiavut Health and Environment Research Committee

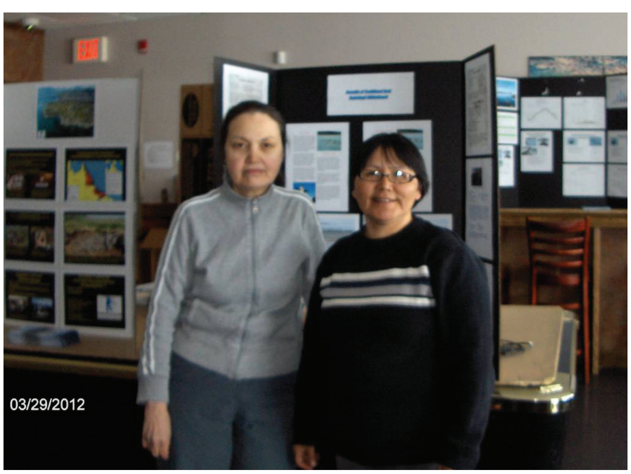

Figure 4. NHERC member Michele Wood with students at Amos Comenius Memorial School in Hopedale during the NHERC coastal tour.

The Nunatsiavut Government Contaminants Researcher continues to:

- Support the activities undertaken by NG and NCP in providing information on research about contaminants, their effects on wildlife and humans through consumption of wild foods which are based on the carried language and geographic needs of individuals and communities of Nunatsiavut and Upper Lake Melville.

- Enhance decision making abilities of Labrador Inuit through the delivery of information risks and benefits of contaminants and wild foods relevant to the region in an accurate, timely and accessible manner.

- Develop regionally relevant resource materials in consultation with the coastal communities and appropriate agencies (i.e. Department of Health and Social Development, AANDC-NCP, ITK etc.) These materials include educational materials such as a quarterly newsletter; all publications are produced in both Inuttitut and English.

- Use the research results from studies completed in the region to aid in effective delivery of information.

- Be a member of the NG Interim Advisory Committee, responsible for interacting with assisting outside researcher with community consultations. This assistance also includes negotiating research agreements between researchers and community organizations and reporting project results to communities in a timely and responsible manner. The Research Centre determines, in consultation with community representatives who is responsible for communication on contaminants as well as health and environment issues and which medium(s) best suit the information needs of the communities etc. This person will continue to assist in the development of a protocol and guidelines for research conducted in Nunatsiavut.

- Continue to act as Chair of the NHERC including the coordination of all logistical and administrative aspects of the committee.

- Take part in research projects and communication of research results when appropriate.

- Assist with the clean up on PCB contaminants and other pollutants in the community of Hopedale by sitting on the newly formed Hopedale Stakeholder Group.

Expected Project Completion Date

This Northern Contaminants Researcher position and program is an ongoing program.

References

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NCP Performance Indicators

Performance Indicator	Number	Details / Description
Number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	Approx. 260	– Nunatsiavut Health and Environment Research Committee open houses and school presentations in coastal communities. – Engaged in contaminants module for kANGDILUASUk Student Program. – Country food celebration events with contaminants/health information available to those attending. – Ringed seal knowledge study.
Number of project-related meetings/ workshops held in the North (April 1, 2011 – March 31, 2012)	19	– Ringed seal Study and TK with Local hunters and Scientists. – NHERC teleconferences, open houses and school presentations in coastal communities. – Country food celebration events with contaminants/health information available to those attending.
Number of students and post docs (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	35	– Co-op students from the Northern Natural Resource Technician Program. – kANGIDLUASUk Student Program – School visits during NHERC coastal tour.
Number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	0	The Avativut Newsletter is a quarterly publication that is distributed to the Nunatsiavut communities that contains information about the NCP, as well as the benefits and risks of contaminants and wildfoods.

Communication, Capacity, Outreach: Bridging the Cultural Divide in the Inuvialuit Settlement Region

Communications, capacité et sensibilisation : Par-delà les divisions culturelles dans la région désignée des Inuvialuit

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Abstract

In 2011-2012, the deliverables under by the Inuit Research Advisor (IRA) Program at Inuvialuit Regional Corporation (IRC) was carried out by three people; IRC researcher/previous IRA, Jennifer Johnston, interim IRA, Tamara Hansen and previous IRA Shannon O'Hara. In September 2011, IRC hired Shannon back into the position and she took over regular duties until the end of the fiscal year. This year's proposal included two projects; the first was the continuation of the Inuvialuit Research Newsletter and the second was the Regional tour of the Inuvialuit Settlement Region communities. Of the two proposed projects, the Management Committee approved the regional tour. However, with additional funding from ArcticNet and Nasivvik, the IRA was still able to produce one Inuvialuit Research Newsletter (winter 2011), complete the regional tour to the six Inuvialuit communities, and utilize additional funding to co-fund/sponsor and coordinate several Inuvialuit to take part in training, research and capacity building activities throughout the year. In summary, the IRA was able to fulfill all obligations under this year's proposal including attending the Annual Results Workshop, NWT Regional Contaminants

Résumé

En 2011-2012, les résultats attendus dans le cadre du programme de conseiller en recherche inuite (CRI) à la Société régionale inuvialuit (SRI) ont été pris en charge par trois personnes : Jennifer Johnston (chercheuse à la SRI/CRI précédente), Tamara Hansen (CRI par intérim) et Shannon O'Hara (CRI précédente). En septembre 2011, la SRI a de nouveau confié le poste à Shannon, qui a repris ses tâches habituelles jusqu'à la fin de l'exercice financier. La proposition de cette année comprend deux projets, soit la poursuite du bulletin d'information sur la recherche inuvialuite *(Inuvialuit Research Newsletter)* et la visite régionale des collectivités de la région désignée des Inuvialuit. Des deux projets proposés, le Comité de gestion a approuvé la visite régionale. Toutefois, grâce au financement supplémentaire d'ArcticNet et du Centre Nasivvik, le CRI a été en mesure de produire un bulletin d'information (hiver 2011), d'effectuer une visite régionale des six collectivités inuvialuites et d'utiliser le financement additionnel pour cofinancer/commanditer et coordonner les activités de formation, de recherche et de renforcement des capacités de plusieurs Inuvialuits durant l'année. En résumé, le CRI a été en mesure

Committee's Social and Cultural review and all other pertinent communication with the committee regarding contaminants messaging, researcher advice and literature reviews.

Specifically, in September 2011, with the limited resources available, the IRA was able to sponsor two high school students to attend the Youth Summit of Northern Climate Change in Yellowknife, NT. Also in September 2011, the IRA attended, co-funded and helped coordinate for two community members to attend the Nuts and Bolts of Research training course offered in Inuvik by Aurora College and University of Alberta. In January 2012, the IRA partially sponsored one student from Aurora College's Environmental and Natural Resource Technology Program to undertake the required fieldwork for his 2-year technical project. His project focused on interviewing s traditional land use holders who have cabins in Husky Lakes water shed to find out their perceptions and thoughts about the proposed Tuktoyaktuk to Inuvik Highway Project. Also in January, the IRA attended and helped coordinate a research workshop with Aurora Research Institute to bring in community members from each Inuvialuit community to share information and lessons learned about research approvals, applications and the new online POLAR database that is used in the NWT. In summary, the main message of this work is that given more resources to implement community-based approaches to capacity building, IRC and the IRA can accomplish this type of work in the next fiscal year with direct guidance from our regional communities.

de remplir l'ensemble de ses obligations dans le cadre de la proposition de cette année, y compris sa participation à l'atelier annuel sur les résultats et l'examen social et culturel du Comité régional des T.N.-O. sur les contaminants ainsi que toutes autres communications pertinentes avec le comité concernant les messages sur les contaminants, les conseils des chercheurs et les analyses documentaires.

Plus particulièrement, en septembre 2011, au moyen des ressources limitées dont il disposait, le CRI a été en mesure de commanditer deux élèves du secondaire pour qu'ils participent au sommet des jeunes leaders sur le changement climatique dans le Nord *(Young Leaders' Summit on Northern Climate Change)* à Yellowknife (T.N. O.). Également en septembre 2011, le CRI a participé à la formation « Nuts and Bolts of Research » offerte par le Collège Aurora et l'Université de l'Alberta, en offrant du financement et en coordonnant la participation de deux membres des collectivités. En janvier 2012, le CRI a commandité en partie un étudiant du programme de technologies des ressources naturelles et environnementales du Collège Aurora pour qu'il puisse entreprendre les travaux sur le terrain nécessaires à la réalisation de son projet technique de deux ans. Son projet visait à rencontrer des propriétaires pratiquant une utilisation traditionnelle des terres dont les chalets sont situés dans le bassin versant des lacs Husky, afin de recueillir leur point de vue et leurs commentaires au sujet du projet de route entre Tuktoyaktuk et Inuvik. Également en janvier, le CRI a participé à la tenue et à la coordination d'un atelier de recherche, en collaboration avec l'Institut de recherche Aurora, en invitant des membres de chaque collectivité inuvialuite à mettre en commun l'information et les leçons apprises au sujet des approbations de recherche, des demandes et de la nouvelle base de données en ligne, POLAR, utilisée dans les T.N. O. En résumé, s'ils disposaient d'un plus grand nombre de ressources pour mettre en œuvre les approches de renforcement des capacités fondées sur les collectivités, la SRI et le CRI pourraient accomplir ce type d'activités au cours du prochain exercice en comptant sur les conseils directs des collectivités régionales.

Key Messages

- The new format of the newsletter was well received in the region. People stated liking the Inuvialuktun translations, how the newsletter informs them of research, and how it has become more interactive with the addition of word finds, country food recipes, articles from community members and true and false questions on contaminants.
- The community tours went very well. The IRA informed people of new changes to the IRA program, the community informed the IRA of training and capacity-building gaps in communities, and the IRA gave information on research licensing and approvals and gave some context into community based research funding programs and processes.
- The NWT RCC meetings went well with climate change programs also in attendance, it gave a lot of emphasis to support communities take the lead in research.
- The focus of IRC in the next few years will be on community-based research, capacity building initiatives, training, and the expansion of the research department within the organization to better support communities take the lead in directing research priorities.

Messages clés

- Le nouveau format du bulletin d'information a été bien accueilli dans la région. Les gens ont aimé les traductions en inuvialuktun, l'information sur la recherche contenue dans le bulletin et les nouvelles sections interactives, soit les mots cachés, les recettes d'aliments traditionnels, les articles écrits par des membres des collectivités et les questionnaires sur les contaminants.
- Les visites des collectivités se sont très bien déroulées. Le CRI a informé la population des nouveaux changements au programme de CRI, les membres des collectivités ont informé le CRI des lacunes en matière de formation et de renforcement des capacités, et le CRI a diffusé de l'information sur les permis et les approbations de recherche, en plus de préciser le contexte des programmes et des processus de financement de la recherche fondés sur les collectivités.
- Les réunions du Comité régional des T.N.-O. sur les contaminants se sont bien déroulées, et des membres des programmes sur le changement climatique y ont aussi pris part. L'accent a été mis sur l'appui offert aux collectivités pour qu'elles prennent les devants dans les activités de recherche.
- Les activités du CRI au cours des prochaines années seront centrées sur la recherche fondée sur les collectivités, les projets de renforcement des capacités, la formation et l'expansion du département de la recherche au sein de l'organisation de façon à mieux soutenir les collectivités pour qu'elles prennent les devants dans les activités de recherche.

Objectives

Continue the bi-annual production of the Inuvialuit Research Newsletter (translated in three dialects of the Western Arctic; Siglitun, Inuinnaqtun and Uummarmiutun on a rotational basis

- Continue with annual Regional Tour to communities to offer training and to receive feedback and program direction on capacity building and training.
- Continue on NWT RCC/ NCP Committees

- Work on getting newsletter and other communication materials online on IRC's revamped website late 2012 or early 2013. Information would include newsletters (past and current editions), IRA guide, fact sheets, etc.

Introduction

Background Information

IRC has been submitting proposals to the NCP for over 20 years. The research focus between government departments and Inuvialuit Regional Corporation has evolved over time towards better representation of the needs of Inuvialuit. Over the past 5-years, collaboration has moved from strictly contaminants work to include a broader approach of research. In the early and late 1990's, the NCP position within IRC was called the Regional Contaminants Coordinator that only undertook contaminants related communication and involvement. In early 2000-2004, IRC took a new approach to this position and began a Student Mentoring Program, which later led the position to be renamed Health and Environment Research Coordinator. This position allowed for an easier transition from student to employee by including dollars to network with the Aurora College. However, in 2004, when ArcticNet and Nasivvik became involved and began co-funding the position to move beyond only contaminants research to include all fields of research, this approach opened up the position to many more responsibilities and roles to the larger scientific community. This transition then led to creation of a new position in all Inuit regions in Canada called the Inuit Research Advisor.

Context

Inuvialuit Research Newsletters (2010-2012)

The Inuvialuit Research newsletter has served as a way the IRA can communicate research occurring in the Inuvialuit region with a larger audience that includes Inuvialuit beneficiaries inside and outside the ISR, as well as organizations at territorial, national and even international levels. The newsletter feature short articles written in both English and Inuvialuktun to accommodate both languages spoken in the region. The newsletter informs people about the various programs that the IRA runs, those that partner organizations are undertaking, but also about current research initiatives taking place in the region from other research programs such as the Health Canada Climate Change and Health Adaptation Program for First Nations and Inuit Communities or the Cumulative Impacts Monitoring Program (NWT).

It is also a place for communities to submit their work for feedback from these various groups. A good example of this is during the Inuit Health Survey or the h. Pylori project where community representatives submitted articles about their involvement. In addition, the newsletter has become more interactive and assertive in its delivery of contaminants messaging through the introduction of true and false questions on contaminants, arctic word finds and country food recipes. All of which engages the reader and informs them about the impacts of contaminants and how a warming climate is a contributing factor to contaminant release and distribution in the Arctic. To date, this Inuvialuit Research Newsletter has been successful in Inuvialuit communities. People are happy to see that they can get up to date information on research and know in which ways IRC is handling research on a daily basis via the development of a research department within the Community Development Division and the establishment of research policies and research agenda within the organization. People have much more trust that they can have a meaningful part in research through directing research priorities from the community level while also doing their own research through establishing partnerships with academia

Regional community tours

Community visits are one of the most effective and important aspects of working in the Inuvialuit region. Largely because the ISR only encompasses six communities, IRC believes it is imperative that staff conducting community programs visit communities every year to consult and update them on the progression and on-goings of Community Development Division programs. Each year, the IRA visits all six Inuvialuit communities for four specific reasons,

1) To gauge research interests in old, on-going projects or new projects while also promoting community based monitoring research

2) To offer and ask for feedback on current projects and training

3) To provide available updates on current and future projects from academia who the IRA is assisting

4) To answer any questions they may have about research pertaining to a specific project in their communities, in the region or on a specific researcher. This process proves to be the best way to get the feedback we require to tweak or add on to already existing initiatives such as the Inuvialuit Research Newsletter.

Website

Although this project was not fully (financially) supported by the Management Committee, the Inuvialuit IRA found ways to make this project possible. The IRA was able to utilize ArcticNet funding to pay a web host to work on developing an IRA page for the IRC website where IRA information and files could be stored and updated for general public use. This project was first proposed when no IRA funding organizations had an online portal or website where the IRA's were officially acknowledged by the funders or programs. The website was created but was not as functional as expected and did not go much further than being a place for general information. Since there was no money to update it, the project was dropped from the agenda. Currently, the idea of the website is getting new life as IRC has internally hired a new communications advisors that will be working on not only re-vamping the IRA page but also the entire IRC website which will be underway this year. Today, it should be noted that ArcticNet, Nasivvik and NCP have included small sections in their websites where researchers could find information on IRA's. However, the Inuvialuit IRA still believes more work and emphasis should be given to online communication to ensure the IRA position is recognized as the "first point of contact" or "go to" people for researchers who are coming into Inuit regions. This recognition has gradually slowed down over the past few years due to a combination of IRA turn over and less communication of the position overall via alternative communication mediums like pamphlets, fact sheets, etc.

Scope

The nature of the projects that IRC undertakes is under the Northern Contaminants Program's Educations and Communications blueprint. The IRA undertake projects that inform Inuvialuit of current NCP contaminants research, research our other funding partners are doing, while also building capacity through training and outreach based on direction from community members

Rationale

IRC would like to continue work under the Education and Communications blueprint of the Program to continue to produce a media that informs our people of contaminants and other related research of importance to them. In addition, we want to continue to utilize our communities to increase capacity to be involved and lead research in our region. We believe the work we are doing now will pave the way for a more community driven approach to research and training in the future. We want more training courses, communication materials and meetings/workshops that bring people together from all six communities in the ISR to begin to plan research priorities and initiatives but also deal with current issues such as continuing to monitor contaminants in our fish, whales and caribou.

Relation to prior work related to or relevant to this year's activities

The work completed by each individual IRA has varied greatly among Inuit regions. In the Inuvialuit region, where the Student Mentoring took place most, more training and involvement took place. For example, in 2004-2006, the IRA was deeply involved in an NCP Human Health research project called Monitoring our Mothers Survey (MOMS) through monthly NWT ECC teleconferences, surveys and orientation to office procedure. Then, in 2005-06, the student submitted a Complimentary-funding proposal to Nasivvik to continue in the SMP for travel to communities to collect additional samples and conduct food frequency questionnaires. In 2006, the IRA position was created and work with MOMS now focused on communication of results back to the region in 2007-08 via Inuvialuit Healthy Living Cookbooks and results summaries. In 2008, the IRA took on the position solo for the first time and began undertaking projects that fit under the NCP education and communications rather than human health blueprint. This enabled the IRA to take the lead to design and undertake projects of importance to Inuvialuit at the time, including; the 2nd edition of the Inuvialuit Healthy Living Cookbook (with a contaminants and nutrition focus) and the first editions of the Inuvialuit Health and Environment Newsletter (which later evolved into the Inuvialuit Research Newsletter as it is known today).

Activities in 2011-2012

What

- IRA wrote one Inuvialuit Research Newsletter from November 2011-January 2012. The Newsletter was produced and shipped up north in mid-January and was distributed in the ISR in February 2012.

- IRA completed one annual regional community tour from January-March 2012 to all six Inuvialuit communities.

- IRA took part in all other mandatory NCP deliverables, NCP Annual Results Workshop, NWT RCC Social and Cultural review and the submission of the Synopsis report.

Outside of the NCP blueprint, the IRA took part in the following activities:

- Submitted and presented a poster presentation to the IPY Conference, did a panel presentation and did an interview with Arctic Journal about research in the ISR

- Contributed to reviewing the forthcoming IRA Guide with ITK

- Promoted Nasivvik scholarships and post secondary initiatives in newsletter and through e-mail

- Took on an ITK Inuit Health Guides Working group and engaged other Inuvialuit to come to meeting as knowledge holders

- Gave IRA presentation, assisted with technical reports and co-funded one student from the ENRT Program at Aurora College

- Attended Beaufort Sea Partnership meetings as part of the Social, Cultural and Economic working group

- Assisted and helped coordinate research training with researchers from University of Alberta,

- Assisted Inuvik and Paulatuk Hunters and Trapper's Committee's apply to the Health Canada Climate Change and Health Adaptation Program for First Nations and Inuit

- Completed and promoted Niqiit online contaminants course

- Attended IKC research meeting in Ottawa, submitted proposal to NCP for 2012-2013 year

- Wrote and submitted a capacity building and training proposal to Health Canada on behalf of Inuvialuit Regional Corporation

- Attended ARI Community Research Workshop

- Sponsored 2 youth, one from Tuktoyaktuk, one from Ulukhaktok to attend Youth Summit on Northern Climate Change conference in Yellowknife

- Sponsored one college student to complete field work for 2 year technical report

- Co-sponsored two community people from Sachs Harbour to attend Nuts and Bolts of research training in Inuvik

- Sat on the Health Canada Inuit Selection Committee

- Attended and presented at IPY 2012 in Montreal

- Submitted website creation strategy to IRC's new communications advisor as IRC is revamping their website in 2012.

When & Who?

Inuvialuit Research Newsletter: The IRA developed the content for the newsletter from September-December 2011. Work with the Inuvialuktun translator took about two months going over content and activities to ensure accuracy. In January, the IRA worked back and forth with the designer to finalize the newsletter. In February, the newsletter was shipped to community organization not directly to beneficiaries due to budget cuts.

Community tours: The IRA community tours ran from the beginning of February until the end of March 2012. The tour began in Aklavik from February 1-3, Tuktoyaktuk on February 8-10, Inuvik on February 17, Ulukhaktok from March 5-7, Paulatuk from March 20-22 and Sachs Harbour from March 26-27. During each event, the IRA is responsible for all elements of planning. First, the IRA, like a researcher, must consult with the community to see when the best time to have a meeting is for them. Once this is established, the IRA can send out advertisements in each community organization that has bulletin boards, makes radio announcements and sends faxes to Inuvialuit organizations. Next, the IRA then books the caterer, accommodations and travel arrangements. Once all those are done, the IRA then books the meeting venue and makes any other arrangements with community members. Once all initial planning is completed, then the IRA purchases food and prizes for the consultation, this year the gifts were food and gas vouchers bought at Inuvialuit owned or operated businesses.

Aklavik: February 1-3, 2012

Venue: Hamlet Chambers
Number of participants: 25
Community involvement: 3: Diane Dillon (Aklavik HTC), Michelle Gruben (caterer), Brenda Archie (B & B)
Facilitators: Shannon O'Hara and Billy Turner

Tuktoyaktuk: February 8-10, 2012

Venue: Hamlet Chambers
Number of participants: 18
Community involvement: 6: Susie Keevik (caterer), Nancy Gruben (caterer's helper), Louisa Gruben (caterers helper), Preston Carpenter (facilitator helper, participant), Jocelyn Noksana (Tuk HTC), Stanton Distributing (Tuk Manager)
Facilitators: Shannon O'Hara

Inuvik, February 17, 2012

Venue: Midnight Sun Recreation Complex
Number of participants: 28
Community Involvement: 2: Mabel Sharpe (caterer), Preston Carpenter (facilitator helper/participant), Stanton Distributing (food),
Esso (gas)
Facilitator: Shannon O'Hara,
Billy Turner, Sarah Camsell

Ulukhaktok, March 5-7, 2012

Venue: Community Hall
Number of participants: 54
Community involvement: 5: Agnes and Robert Kuptana (translators, participants), Josh Oliktoak (handi-bus and taxi driver), Co-op Manager (food and gas vouchers), helper
Facilitator: Shannon O'Hara

Paulatuk, March 20-22, 2012
Venue: Angik School
Number of participants: 12
Community involvement: 4: Elsie Klengenberg (caterer), John Kudlak (Paulatuk HTC), Northern Store Manager (food), and Richard Ruben (gas)
Facilitator: Shannon O'Hara

Sachs Harbour, March 26-27, 2012

Venue: Family Centre
Number of participants: 12
Community involvement: 5: Donna Keogak (Sachs Community Corporation, caterer's helper and participant), Brenda Lucas (caterer, participant), Roger and his wife Kuptana (B & B, vehicle rental, participant), Angela Keogak (Co-op acting manager, food and gas)
Facilitator: Shannon O'Hara

Where

The majority of work took place in Inuvik, with only brief visits in each of the other five communities in the Inuvialuit Settlement Region. Other work took place in Yellowknife, Ottawa and Montreal.

The Inuvialuit Research Newsletter was produced in Inuvik with only the design components done in Edmonton by a company called RR Donnelley.

The Regional Community Tour took place in each of the six Inuvialuit communities at community halls and hamlet offices.

Who did the work?

The Inuit Research Advisor did all work independently, with the exception of the community visits where other CDD staff and community members assisted with the meetings and the Newsletter where the translator and designer did their parts in the process.

How

All projects were made possible through funding provided by NCP, ArcticNet, and Nasivvik and through other organizations such as National Aboriginal Health Organization (NAHO) and Inuit Tapiriit Kanatami (ITK) on a per project basis.

Inuvialuit Research newsletter

The IRA is the project leader in every Inuvialuit Research newsletter. The IRA develops all the content including articles, activities, and pictures. The IRA then works with local translators in the region and gets all materials converted into Inuvialuktun. The IRA likes to work with different translators in every edition to give the readers a sample of each of the three Inuvialuit dialects, Siglitun, Inuinnaqtun, and Uummarmiutun. Then, the newsletter is then sent back for approval where the IRA has it peer reviewed by other IRC staff then it is sent out for finalizing. Once completed, the newsletters are shipped to the regions via by air or by road, depending on the time of year. Lastly, the IRA then labels and packs the newsletters and mails them out the beneficiaries inside and outside the ISR. One thing that the IRA will be striving for in the near future is developing a large mailing list so that the Inuvialuit Research Newsletter can be shared with a larger audience. Once this is established the newsletter will reach a vast audience in other provinces and territories in Canada but also to a International audience.

Regional Community Tour

The Regional community tour is always a huge undertaking each year. It takes a lot of planning and preparing to make sure all runs smoothly. First off, the IRA needs to consult the community to see if we can negotiate the best time to hold a meeting. Once a good time has been established, the IRA can then begin to advertise the meeting via radio, rolling channels, public bulletin boards, bingo channels, etc. Next, the IRA will contact local community members to take part in the work. The first person the IRA contacts is a caterer. Community Corporations direct these preparations as they hold caterers lists and can help the IRA to identify who will be able to prepare a meal for the meeting. Next, the IRA has to book the venue in a community, which is booked through the Hamlet offices as they manage many of the community halls and other venues in communities. Once the meeting is set up, then the IRA can begin to book hotels or Bed and Breakfasts for accommodations, airfare and make other arrangements. The final planning stage is hiring a local interpreter or translator to facilitate the meeting. Some of the other pre-trip preparation s include, developing a meeting agenda, preparing information materials and activities, submitting paperwork to IRC for payment of the meeting bookings and people, and securing transportation including (taxis, elder's handi-bus) to get interested elders to the meeting. All of this planning takes a lot of time, but it ensures that the community meeting is successful. This process has proven to work, as this year the IRA was been able of get a minimum of 12 people, and a maximum of 54 participants to each event.

Capacity building

As is very clear throughout this report, capacity building and training is at the forefront of Inuvialuit and IRA research priorities. Various activities directed by Inuvialuit communities have led to a community-based approach to educate and certify our beneficiaries in a ways that is regionally specific.

Traditional knowledge integration

Traditional knowledge (TK) is integral to the work Inuvialuit are doing at many levels within the organization. For this project specifically, the IRA's involvement with community based monitoring and research will ensure that TK is documented and shared among our regional communities by with other northern communities and organizations. Currently, there are a total four community-based research projects underway for the next fiscal year (2012-2013). These include the continuation of the h. Pylori project which originated in Aklavik, to be expanded into all other Inuvialuit communities, Paulatuk and Inuvik Hunters and Trapper's Committee's (HTC's) are launching TK and science climate change field camps and workshops this summer and the beluga monitoring project on Hendrickson Island will be continuing again this year. The combination of these projects will ensure that traditional knowledge is incorporated, respected and utilized in our work.

Results

To date, the IRA has been able to establish a good working relationship with all Inuvialuit community. People are aware of and appreciate the Inuvialuit Research Newsletter as it informs them of research information that they were not always privy to in the past. Communities have also shown that they enjoy the Annual community tours as it gives them an opportunity to come to the meetings to discuss and learn about current research initiatives of IRC, as well as bring forward any issues that of importance to them when been involved in research. Both of these projects are successful in the region, and now with direction from these discussions, the IRA is now aware of the gaps that exist in communities that need to address in areas of capacity building and training. One of the main points that the IRA informed community members on it the new direction IRC is taking with research, especially research approvals. The IRA informed communities that they have the right to decline research if they do not see at least three benefits to their communities in either the short or the long term. In addition, communities informed the IRA of the training needs they see as most important. These include, proposal writing, project management, keeping certification up to date for already existing wildlife/ice monitors, guides, safety courses for travel, elders and youth programming, and general research skills such as surveying, interviewing, and data management.

Discussion and Conclusions

One of the results that have seen from the work the IRA does in the region is an increased

NCP Performance Indicators

Performance Indicator	Number	Details / Description
Number of Northerners engaged in your project (April 1, 2011-March 31, 2012)	170 Plus number of people who read the newsletter unknown	Aklavik: 3 community workers, 21 meeting participants=24 Inuvik: 2 community workers, 28 meeting participants=30 Sachs: 5 community workers, 12 meeting participants=17 Ulukhaktok: 5 community workers, 54 meeting participants=59 Tuktoyaktuk: 6 community workers, 18 meeting participants=24 Paulatuk: 4 community planners, 12 meeting participants=16
Number of project related meetings/ workshops held in the north	8	6 Community meetings for regional tour 1 Nuts and Bolts of Research training course 1 Research workshop with Aurora Research Institute (ARI)
Number of students (both northern and southern) involved in your NCP work	10	2 youth to climate change summit 8 students from ENTRP program
Number of citable publications	2011: 0 2012: 0	None

understanding of the community role in research. Today the role of the community is not only a facilitator, subject, or logistical help but now is participatory, directing and managing research. The Inuvialuit IRA wants to see more of this in the future, therefore has begun to plan out activities for the next fiscal year that will be giving communities in the region what they asked for in terms of what they identify as needs to help prepare them to take the leading role in research. While the IRA would like to continue with newsletter, annual regional community tours, and complete all NCP deliverables, the IRA would also like to begin to implement the training courses and capacity-building exercises that are needed to allow communities to begin to apply for their own funding and carry out their own projects in years to come. This movement from community participatory research to community led and based research will change the perceptions people have in our communities, of the way things used to be when communities were the last to know about research projects, to having local people community people are familiar with voice these results and messages to them in way they can appreciate.

Expected Project Completion Date

March 31, 2012

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References

None

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Abstract

The Inuit Research Advisor (IRA) program continues to serve as the first step in a more coordinated approach to community involvement and coordination of Arctic science in Nunatsiavut. Nunatsiavut Government (NG) encourages researchers to consult/meet with Inuit Community Governments and NG Departments/Divisions in developing their proposals. Comprehensive reviews of proposals are initiated involving appropriate NG departments, Inuit Community Government(s)/Corporation(s).

Together with IRAs in the other Inuit regions of Canada, the Nunatsiavut IRA works towards achieving a new way of knowledge sharing and engagement of Inuit in Arctic science in the region. In addition to NCP support, the program is co-funded by ArcticNet and the Nasivvik Centre for Inuit Health and Changing Environments. In 2011-12, the IRA in Nunatsiavut was critical to the successful launch of the Nain Research Centre, the only Inuit operated research facility in a Nunatsiavut community.

Résumé

Le programme de conseiller en recherche inuite (CRI) continue à constituer le premier palier d’une approche mieux coordonnée visant à favoriser la participation des collectivités et à coordonner les sciences de l’Arctique au Nunatsiavut. Le gouvernement du Nunatsiavut encourage les chercheurs à consulter et à rencontrer les administrations des collectivités inuites et les ministères et divisions du gouvernement lorsqu’ils élaborent leurs propositions. L’examen complet des propositions est effectué par les ministères concernés, les administrations des collectivités inuites et les sociétés communautaires inuites.

De concert avec les CRI des autres régions inuites du Canada, le CRI du Nunatsiavut s’efforce de promouvoir une nouvelle façon de diffuser les connaissances et de mobiliser les Inuit en ce qui concerne les sciences de l’Arctique dans la région. Le financement des activités est conjointement assuré par le Programme de lutte contre les contaminants dans le Nord (PLCN), ArcticNet et le Centre Nasivvik pour la santé des Inuit et les changements environnementaux. En 2011 2012, le CRI du Nunatsiavut a joué un rôle essentiel en vue de l’ouverture du Centre de recherche de Nain, la seule installation de recherche entièrement exploitée par des Inuit dans une collectivité du Nunatsiavut.

Key Messages

- The current IRA was hired on November 21, 2011.
- In 2011-12 the IRA undertook various tasks to liaise with the Northern Contaminants Program (NCP), ArcticNet, Nasivvik Centre, and Nunatsiavut Government (NG) in the areas of research promotion and coordination, public education and information. The IRA distributes all promotional items, notices etc. from the three funding agencies to all of the NG Assembly and employees.
- The IRA has also served as a liaison for partners such as Inuit Tapiriit Kanatami (ITK), Inuit Circumpolar Council (ICC) Canada, Nunatsiavut Inuit Community Governments/ Corporations, International Polar Year (IPY), researchers, students, and other organizations.
- The IRA was instrumental in the development and launch of the newly developed Nain Research Centre, serving as the first point of contact for all researchers conducting work in Nunatsiavut and requiring contact with or assistance from the Nunatsiavut Government.
- The IRA is the Chair and administrator of the Nunatsiavut Government Research Advisory Committee (NGRAC). The IRA has communicated with 18 primary investigators and their research teams from 21st November 2011 to 31st March 2011.
- The IRA served as liaison, contact and assistant to research projects taking place in Nunatsiavut. This assistance ranged from linking the researchers with appropriate individuals and/or organizations such as NG departments and Inuit Community Governments in Nunatsiavut to providing input on research proposals and plans to actually executing community-based research programs in the region.

Messages clés

- Le CRI actuel a été embauché le 21 novembre 2011.
- En 2011 2012, le CRI a exécuté diverses tâches en collaboration avec le PLCN, ArcticNet, le Centre Nasivvik et le gouvernement du Nunatsiavut dans les secteurs de la promotion et de la coordination de la recherche, de l’éducation du public et de l’information. Le CRI diffuse tous les articles de promotion, avis, etc., provenant des trois organismes de financement à l’ensemble de l’Assemblée du gouvernement du Nunatsiavut et aux employés.
- Le CRI assure également la liaison avec des partenaires comme l’Inuit Tapirit Kanatami (ITK), le Conseil circumpolaire inuit (CCI), les administrations des collectivités inuites et les sociétés communautaires inuites du Nunatsiavut, l’Année polaire internationale (API), les chercheurs, les étudiants et divers organismes.
- Le CRI a grandement contribué à l’établissement et à l’ouverture du Centre de recherche de Nain, en faisant office de point de contact initial pour tous les chercheurs effectuant des travaux au Nunatsiavut et ayant besoin de communiquer avec le gouvernement du Nunatsiavut ou d’obtenir son aide.
- Le CRI est le président et l’administrateur du comité consultatif de la recherche du Nunatsiavut. Entre le 21 novembre 2011 et le 31 mars 2011, le CRI a communiqué avec 18 chercheurs principaux et leurs équipes.
- Il a aussi joué le rôle d’agent de liaison, de contact et d’assistant pour ce qui est des projets de recherche menés au Nunatsiavut. Entre autres, il a mis les chercheurs en lien avec les personnes ou organisations pertinentes, par exemple les ministères du gouvernement et les administrations des collectivités inuites du Nunatsiavut.

- The IRA is a member of the NCP funded Nunatsiavut Contaminants Committee called the Nunatsiavut Health and Environment Research Committee (NHERC). As a member of this committee the IRA reviewed all proposals that were submitted to the NCP associated with the Nunatsiavut Region.

- The IRA along with other members of the NHERC visited communities along the Nunatsiavut coast to communicate contaminants related research programs to Nunavimmiut in addition to other ongoing research programs.

- The IRA has undertaken diverse tasks for the host organization Nunatsiavut Government (NG) ranging from attending NG researcher workshops and collaborating with many researchers and organizations.

Il a également fait des suggestions quant aux propositions et plans de recherche, et a participé à l'exécution de programmes communautaires de recherche dans la région.

- Le CRI fait partie du Comité des contaminants du Nunatsiavut, financé par le PLCN et désormais appelé Comité d'examen de la santé et de l'environnement du Nunatsiavut (Nunatsiavut Health and Environment Review Committee). À titre de membre de ce comité, le CRI a passé en revue toutes les propositions qui ont été présentées au PLCN en ce qui a trait à la région du Nunatsiavut.

- Le CRI ainsi que les autres membres du Comité d'examen ont visité des collectivités le long de la côte du Nunatsiavut pour faire connaître aux Nunavimmiut les différents programmes de recherche liés aux contaminants en plus des autres programmes de recherche en cours.

- Le CRI a accompli diverses tâches pour l'organisme d'accueil, le gouvernement du Nunatsiavut; il a entre autres assisté à des ateliers donnés par le gouvernement ou des chercheurs et a collaboré avec un grand nombre de chercheurs et d'organismes.

Objectives

- Provide liaison support for and promote research in Nunatsiavut. The IRA has communicated with 18 researchers.

- Promote more community-based research in the region. There have been more community led research projects such as the projects led by the Nunatsiavut Government's Environment Division as well as other programs led by the Inuit Community Governments of Nain and Rigolet and the Inuit Community Corporation in North West River.

- Assist in the development of local capacity for research in Nunatsiavut. The IRA has a list of research assistants and interpreters/ translators from each Inuit Community who are willing to work with researchers on their projects.

- Provide information regarding research in Nunatsiavut and opportunities for local involvement.

- Liaise with national organizations and other Inuit regions in matters related to Arctic science and research.

Activities in 2011-2012

- Managed the Nain Research Centre and served as Chair to the NG Research Advisory Committee, making contact with virtually all researchers, students and organizations visiting or wanting to conduct research in the Labrador Inuit Land Claims Area.

- Assisted in preparing for 'Sustainable Communities' workshops in each of the Nunatsiavut communities;

- Undertook socio-cultural review of NCP proposals through NHERC in February 2012.

- Attended Health Canada's, Health Adaptation and Climate Change proposal review in March 2012, March;

- Visited Nunatsiavut communities in March along with other NHERC members to present on research related initiatives in Nunatsiavut at public meetings and within the schools.

NCP Performance Indicators

Performance Indicator	Number	Details / Description
Number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	Approx. 260	– Nunatsiavut Health and Environment Research Committee open houses and school presentations in coastal communities. – Engaged in contaminants and climate change modules for kANGDILUASUk Student Program. – Country food celebration events with contaminants/health information available to those attending. – Ringed seal knowledge study.
Number of project-related meetings/workshops held in the North (April 1, 2011 – March 31, 2012)	19	– Ringed seal Study and TK with Local hunters and Scientists. – NHERC teleconferences, open houses and school presentations in coastal communities. – Country food celebration events with contaminants/health information available to those attending.
Number of students and post docs (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	25	– Co-op students from the Northern Natural Resource Technician Program. – School visits during NHERC coastal tour.
Number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	0	– Preparation was conducted to begin publishing an annual Nunatsiavut research compendium in 2013.

- Participated in teleconferences with other regional IRA's.
- Attended IPY 2012 in Montreal in April.
- Kept Nunatsiavut Government Assembly, Staff and Research Advisory Committee informed of all NCP, ArcticNet and Nasivvik activities and opportunities.
- Promoted NCP, ArcticNet, Nasivvik activities and opportunities at the Nunatsiavut community and regional level through word of mouth and the distribution of promotional materials.
- Assisted in the preparation of the Nunatsiavut NCP Newsletter (Avativut)
- See attached Research Contact list for all contacts the current IRA made with researchers during the 2011-12 fiscal year.

Results

The IRA program in Nunatsiavut continues to provide a coordinated process by which Inuit and researchers can become connected for more effective and meaningful research in the disciplines of environmental science, contaminants and human health. The Nain Research Centre is quickly becoming a hub for locally-owned research that is being conducted with outside partners, where necessary. Programs that operated from the research centre and for which the IRA played a critical role included (but, are not limited to) a community freezer program (along with an associated youth outreach program), a ringed seal IK-science program, and a sustainable community development initiative.

Expected Project Completion Date

This is an ongoing project.

Attachment

2011-12 Nunatsiavut IRA Researcher Contact List

1. Gail Baikie, Indigenous Social Work Praxes in-between worldviews: Researching in a 'Good Way'
2. Gail Baikie, Petrina Beals, Claiming Our Place: Women's Relationship with Rivers
3. Jennifer Mitchell, Polar Bear Inuit Qaujimajatuqangit/Traditional Ecological Knowledge
4. Nathaniel Pollock, Working together to prevent suicide in Labrador
5. Gary Mallach, Hopedale Indoor Air Quality Study
6. Atanu Sarkar, Assessment of environmental Health Risks Due to Radiation Exposure at Makkovik, Labrador and Understanding Population Perspectives
7. Sherilee Harper, Climate Change, Water, and Scenario Planning in Rigolet, Nunatsiavut
8. Edward C. Allen, The Seasonality of Suicide in Nunatsiavut: Interpreting Data with Inuit Knowledge.
9. Bjartmar Sveinbjörnsson, Controls on Performance of Contrasting Tree Functional Types across Polar Treelines in Labrador, Canada and Tierra del Fuego, Argentina
10. Emilie C. Thomassot, Differentiation and Environmental Surface condition of the early Earth: Isotopic Constraints from the Hadean Rock Record
11. J. Brian Dempson, Milton Shears, Research and Assessment of Arctic Char in North Labrador
12. Julie Whalen, Snow Crab Surveys in NAFO division 2J 2012

13. Myrtle Blanford,Community planning for women's economic security in Nunatsiavut

14. Vincent Brodeur, Shannon Crowley, George River Herd Monitoring Program (GRHMP)

15. Lindsay Swinarton, Environmental Archaeology and Household Subsistence at Dog Island

16. Julie Whalen, Exploratory Greenland Halibut (Turbot) Fishing Survey 2012

17. Dr. Darroch Whitaker, Dr. Fiona F. Hunter, Developing a Mosquito and biting fly monitoring program for the Torngat Mountains

18. Patricia Nash, Working with Marine Resource Users and Coastal Communities to Recover Marine Species at Risk (MSAR) in Newfoundland and Labrador

The Nunavik Inuit Research Advisor: Building Health and Environment Research Capacity in Kativik Regional Government (KRG)

Conseiller en recherche inuite au Nunavik : renforcer la capacité de recherche en santé et en environnement au sein de l'administration régionale Kativik

♦ Program Leaders:

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♦ Project Team:

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Abstract

The Nunavik Inuit Research Advisor (IRA) continues to serve as the first step in a more coordinated approach to community involvement and coordination of Arctic science in Nunavik. The IRA position is housed within the Renewable Resources Department of the Kativik Regional Government (KRG) and works closely with the Nunavik Nutrition Health Committee (NNHC) and the Makivik Research Center. The objective of the IRA position in Nunavik is to help facilitate research both at the program level, assisting researchers from the Northern Contaminants Program (NCP), ArcticNet and Nasivvik, as well as preparing communities in advance of research. Together, with IRAs in the other Inuit regions of Canada, the Nunavik IRA works towards achieving a new way of knowledge sharing and engagement of

Résumé

Le conseiller en recherche inuite (CRI) au Nunavik est toujours la première étape d'une approche plus concertée en matière de participation communautaire et de coordination des sciences arctiques au Nunavik. Le CRI travaille à l'administration régionale Kativik (Ressources renouvelables, Environnement et Aménagement des terres) et collabore étroitement avec le Comité de la nutrition et de la santé du Nunavik et le Centre de recherche du Nunavik de la Société Makivik. Le CRI au Nunavik est chargé de faciliter les recherches dans le cadre du programme en aidant les chercheurs du Programme de lutte contre les contaminants dans le Nord (PLCN), d'ArcticNet et de Nasivvik, ainsi qu'en préparant les collectivités aux recherches. Avec les CRI d'autres régions inuites du Canada, le CRI

Inuit in Arctic science and research. In addition to ArcticNet support, the Nunavik IRA position is co-funded by NCP and the Nasivvik Centre for Inuit Health and Changing Environments.

du Nunavik cherche un nouveau moyen de mettre en commun les connaissances et de faire participer les Inuit aux activités scientifiques et aux recherches dans l'Arctique. En plus de l'appui d'ArcticNet, le travail du CRI du Nunavik est cofinancé par le PLCN et le Centre Nasivvik pour la santé des Inuit et les changements environnementaux.

Keys Messages

- Providing input and direction to three major Arctic Research Programs (NCP, Nasivvik and ArcticNet).
- Helping researchers and communities coordinate and communicate information using various strategies that would attract future participation from the region in collaboration with research teams.
- The IRA is developing to be a first point of contact for all researchers conducting work in Nunavik.
- The IRA sits on the Nunavik Nutrition and Health Committee providing a voice in the NCP proposal process and communication of NCP health information to Nunavik communities.
- The IRA undertook a number of diverse tasks for KRG ranging from attending workshops/meetings and focus groups to collaborating and networking with researchers.
- The IRA also undertook a number of tasks for both ArcticNet and Nasivvik, helping to create linkages and avoid overlap in research activities.

Messages clés

- Le CRI offre des commentaires et une orientation dans le cadre de trois grands programmes de recherche dans l'Arctique (PLCN, Nasivvik et ArcticNet).
- Le CRI aide les chercheurs et les collectivités à coordonner et à communiquer l'information au moyen de diverses stratégies visant à favoriser la participation d'une région en collaboration avec des équipes de recherche.
- Le CRI est le premier point de contact pour tous les chercheurs qui mènent des recherches au Nunavik.
- Le CRI est membre du Comité de la nutrition et de la santé du Nunavik. Il fournit son point de vue concernant le processus de propositions du PLCN et la communication de l'information sur la santé aux collectivités du Nunavik.
- Le CRI a entrepris diverses tâches pour l'administration régionale Kativik. Il a entre autres assisté à des ateliers et à des groupes de discussion et a collaboré avec des chercheurs et établi des liens avec eux.
- Le CRI a aussi entrepris certaines tâches pour les programmes ArcticNet et Nasivvik. Il a contribué à créer des liens et à éviter les chevauchements dans les activités de recherche.

Objectives

Nunavik IRA will

Short Term Objectives

- Act as a liaison between ArcticNet researchers and communities to facilitate research and the development of effective partnerships;
- Offer guidance in the production of promotion and communication materials and the distribution of these materials in each region for both the research program and individual projects;
- Offer guidance and, where appropriate, assist with communicating research results of individual projects to relevant communities and regional organizations;
- Identify interests, needs, concerns and priorities of northerners, communities, and regional organizations, and promote these to NCP researchers;
- Identify where potential community or regional partnerships could be made with an existing project, or Inuit-led project proposals that could apply for ArcticNet funding;
- Identify both northern students and youth interested in participating in research activities and connecting these students with appropriate research projects and training initiatives;
- Provide information on non-ArcticNet research activities occurring in each of the regions.
- Facilitate and foster more community-based research
- Assist in the development of local research capacity
- Provide information regarding research in Nunavik and opportunities for local involvement
- Liaise with national and international organizations and other Inuit regional organizations in matters related to Arctic science and research
- Provide support and advice to communities (e.g. review and provide advice on the adjudication of proposals) on research from the ArcticNet.
- Provide support and direction for researchers coming to work in Nunavik and help with communicating the results back (e.g. to communities, policy makers, local decision makers) in a responsible and collective manner.
- Identify opportunities for youth to become engaged in ArcticNet research and science.
- Continued membership on the Nunavik Nutrition and Health Committee (NNHC)
- Collaborating with Makivik Research Center on licensing research permit for the Nunavik region.

Long Term Objectives:

- Communicate with, and inform, the Nunavik population about contaminants research and the results of research studies.
- Develop long term capacity for research needs in Nunavik;
- Develop a research mentorship program for KRG and Nunavik;
- Provide information to the ITK Research Team and Inuit Nipingit: the National
- Inuit Committee on Ethics and Research (NICER);
- Provide information and direction to the Inuit Qaujisarvingat:

- The Inuit Knowledge Centre;
- Develop more community-based researchers and research;
- Develop and be a part of a larger community-regional-national-international research network.

Introduction

When the media is used as a source of communication, the communication department of KRG must give a consent form before the results are published or announced for the region by the IRA. Other methods for communication by the NNHC are carefully prepared before releasing human health research results to the Nunavimmiut, the Public Health Director of Nunavik Regional Health and Social Services facilitates the communication plan for human health research with the NNHC. The Nunavik IRA is a member of NNHC and has meetings with the committee four times a year. NNHC communication protocol differs from other regions; therefore the IRA alone may not freely communicate the research results without discussing the accuracy and terminology of research with the NNHC. To avoid any misunderstandings about the research results, the regional population receives the information before it is released by the media. Human health research is very sensitive case for Indigenous peoples on country food diet, therefore human health research results is handled in Nunavik with much sensitivity.

Activities in 2011-2012

Louisa Thomassie works as the Nunavik IRA. Working closely with various research bodies and Inuit Organizations of the region, from meetings to workshops and working groups, the challenge of Nunavik during the year 2011 in the field of research was to build a better streamline for licensing permit for all research being carried out in the region.

The following list provides a summary of activities for the 2011-2012 fiscal year:

- Searching eatable vegetation of Nunavik, seafood and other country food finding the right terminology in both Inuktitut and English before finalizing the survey questions.
- Networking with Kativik School Board
- Introducing and discussing scientific projects taking place in the Arctic of Canada
- Helping students apply for scientific projects, ex: Students on ice, and Kangirsujuaq science camp.
- Defining basic English and scientific terms with high school student before discussing the scientific projects taking place in the four arctic regions under the land claim agreement.
- Discussing the importance of using the right source for information to gain accurate new knowledge.
- Reviewing document on Inuit Nutrition Program NNHC, April 2011
- Attending the public consultation concerning the protected areas in Nunavik, April 2011
- Discussion on highlighted land mass for protected land claims also to review which land mass are vulnerable for economic development for mining exploration.
- Two IAC teleconference with IRA from Nunavut, Nunatsiavut, Inuvialuit and Meghan Mckenna, May 2011
- Participated at the NNHC meeting held in Kuujjuaq, June 2011
- Updating the evaluation grid for NNHC
- Installation of earthquake monitoring in three communities throughout Nunavik

- Assisting the research team on finding source for the internet signal to send the data to be directed to Ottawa earthquake monitoring capacity building. Seeking community resource for researcher to manually install the equipment.
- Workshop on integration of Indigenous knowledge, Paris, June 2011.
  - Discussing various needs and challenges of Indigenous people
  - Sharing the science policies for our countries.
  - Searching and preparing innovative ways to integrate Indigenous traditional knowledge into scientific reports.
  - Presenting on Inuit terminologies and the importance of understanding the concept of words from certain cultures
- Reviewing the human health monitoring research questionnaire before the research interviews the Inuit participants, July 2011
- Drafting up activity report for the Renewable Resource Department of KRG, August 2011
- Attending the NCP 19th Annual meeting held in Victoria BC, September 2011
- Project Review food security NNHC, September 2011
- Participated at the IAC teleconference, October 2011
- Attended the public health message for Nunavimmiut on the final results of Child Cohort Study Kuujjuaq, October 2011.
- Harvesting survey Nunavik with Makivik research center, scheduling a workshop with hunter support coordinators, October-November December 2011.
- Attending the NNHC meeting held in Nunavik, November 2011
- Attending and participating at the first CARLI working group meeting in Nunavik Kuujjuaq, November 2011.
- Updating and editing IRA handbook with Kendra Tagoona and other IRAs
- Planning proposal and reviewing with researcher submitting to AANDC
- Sharing research results and proposal with Makivik Research center to help draft up the CARLI Nunavik project.
- January 2012, assisting the earthquake monitoring system with the internet modem, by resetting the system manually at Kangirsuk airport, the data is send to science lab in Ottawa.
- January 18, 2012, teleconference with the IRA from the four regions, discussing the NCP proposal and questions about the blueprint. (Conference facilitated by Kendra Tagoona) planning the next IRA face to face meeting.
- January 30, 2012 reviewing human health research proposals before the Nunavik Nutritional Health Committee meeting, editing the evaluation criteria for NNHC.
- February 2012, harvesting workshop survey with hunter support coordinators from three communities, held in Quartaq. Task was to inform the importance and purpose of the survey soon to be carried out in three communities in Nunavik, three communities will continues the harvesting survey every year in the region until all the fourteen communities have participated, hiring only Inuit researchers, the results may not be shared with non-beneficiaries.
- February 2012, reviewing the RMC agenda as Inuit Advisory Committee with other IRAS from four regions under the land claims agreement.

- February 2012, selecting Nunavik Regional choice for International Polar Year meeting soon to be held in April, 2012.

- March 2012, resetting the transmission from the Kangirsuk seismograph (earthquake monitor) assisting a researcher located in Ottawa by manually resetting the system at Kangirsuk airport.

- March 2012, discussing a meeting that would take place in France about mining impact research in Indigenous communities for a global observation. Seeking Nunavik representatives.

- March 2012, IAC teleconference to discuss the IRIS with the IRAs.

- Preparing a trip to Inukjuaq to give a workshop about the harvesting survey, unable to attend the workshop in the end, conflicting with the videoconference with Makivik Research staff and the fourteen communities.

Expected Project Completion Date

The IRA position in Nunavik is on-going.

Acknowledgments

Inuit environmental and health concerns have been well funded and supported by Northern Contaminant Program research projects in Nunavik. The strategies are well thought out, and effective.

NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	25-50	
number of project-related meetings/ workshops held in the North (April 1, 2011 – March 31, 2012)	8-10	
number of students (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	60	
number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	2011: n/a 2012: n/a	

kANGIDLUASUk Student Program: A Cornerstone for Connecting Inuit Youth with Science Through Experiential Education and Outreach

Le programme étudiant kANGIDLUASUk : la pierre d'angle pour associer les jeunes Inuits et la science au moyen d'un enseignement fondé sur l'expérience et d'une sensibilisation

♦ Program Leaders:

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♦ Project Team:

Mary Denniston, Northern Contaminants Researcher, Nunatsiavut Government
Katie Winters, Northern Contaminants Researcher, Nunatsiavut Government
Carla Pamak, Inuit Research Advisor, Nunatsiavut Government
Joey Angnatok, Longliner owner/operator, Nain, NL
Darroch Whitaker, Monitoring Ecologist, Parks Canada, Western Newfoundland and Labrador Field Unit.
Donna Dicker, Nunatsiavut Rising Youth Council President and TMNP Summer Student.
Jason Dicker, kANGIDLUASUk Student Program 2010 alumni
Carol Luttmer, Environmental Sciences Group, Royal Military College of Canada
Tanya Brown, Environmental Sciences Group, Royal Military College of Canada
Chris Furgal, Associate Professor, Trent University

Abstract

The kANGIDLUASUk Student Program is a non-profit organization that coordinates and delivers an experiential work and learning program at the Torngat Mountains Base Camp and Research Station in northern Nunatsiavut. Through a multi-faceted four week summer internship, ten Inuit youth form Nunatsiavut and Nunavik lived, learned, and worked together with some of Canada's top Arctic researchers, Parks Canada staff, international visitors, and local Inuit leaders, elders, and entrepreneurs. They contributed to real fieldwork, research and monitoring programs, visitor experience

Résumé

Le programme étudiant kANGIDLUASUk est une organisation à but non lucratif qui coordonne et applique un programme de travail et d'apprentissage fondés sur l'expérience au camp de base et station de recherche des monts Torngat, dans le Nord du Nunatsiavut. Dix jeunes Inuits de Nunatsiavut et Nunavik y ont suivi des stages d'été multiformes de quatre semaines, où ils ont vécu, appris et travaillé côte à côte avec quelques-uns des meilleurs chercheurs arctiques du Canada, des employés de Parcs Canada, des visiteurs internationaux, et des dirigeants, aînés et entrepreneurs inuits

initiatives, and remote base camp operations. Interns also experienced traditional Inuit practices, values, and customs, and explored the Torngat Mountains as an Inuit homeland. Interns acquired practical work experience, built respect, self-confidence and other leadership skills while supporting each other to discover areas of personal interest, skill, and capacity they might not have valued or known about.

In 2011-12, the kANGIDLUASUk Student Program coordinated and delivered a multidisciplinary contaminants field unit within the four week kANGIDLUASUk Student Internship at the Torngat Mountains Base Camp and Research Station. In partnership with related research projects and Inuit harvesters and elders, the field unit engaged Inuit youth in contaminants research, and created opportunities to learn about contaminants and connections to regional Inuit Knowledge, values, observations, and perceptions through a combination of presentations, activities, projects, discussions, storytelling, and hands-on fieldwork. Through their participation in the field unit and the four week internship, students also increased their understanding and awareness of the education and acquisition of skills required for future employment in front line positions related to contaminants, and had positive and meaningful experiences that may inspire such pursuits.

locaux. Ils ont pris part à des programmes de travail sur le terrain, de recherche et de surveillance véritables, à des initiatives axées sur l'expérience du visiteur et à des activités tenues à des camps de base éloignés. Les internes ont également fait l'expérience des pratiques, valeurs et coutumes inuites traditionnelles, en plus d'explorer les monts Torngat, qui sont l'un des foyers des Inuits. Ils ont acquis une expérience pratique, bâti le respect et la confiance en soi et développé des compétences en leadership, tout en s'entraidant à découvrir les domaines d'intérêt, de compétence et de capacité personnels que peut être ils ignoraient ou jugeaient sans valeur.

En 2011-2012, ce Programme a coordonné et dirigé une unité de campagne pluridisciplinaire sur les contaminants au camp de base et station de recherche des monts Torngat, au cours des quatre semaines des stages étudiants de kANGIDLUASUk. Combinant des présentations, activités, projets, discussions, narrations et travaux sur place, cette unité a fait participer les jeunes Inuits à de la recherche sur les contaminants, en même temps qu'à des projets de recherche connexes et à des partenariats avec des récolteurs et aînés inuits. Les participants ont eu l'occasion d'en apprendre au sujet des contaminants et d'avoir accès au savoir, aux valeurs, aux observations et aux perceptions régionaux des Inuits. Le travail dans l'unité de campagne, et les quatre semaines de stage, ont permis en outre aux étudiants de mieux comprendre et saisir l'éducation et les compétences qu'il faut acquérir en vue d'emplois futurs de première ligne dans le domaine des contaminants, et d'acquérir ainsi une bonne expérience utile de nature à nourrir de telles ambitions.

Keys Messages

- A contaminants module for Inuit students, intended to be delivered in an outdoor, experiential education context at the Torngat Mountains Base Camp and Research Station was further developed, refined and implemented as part of the kANGIDLUASUk Student Program

Messages clés

- Un module sur les contaminants destiné aux étudiants inuits, qui devait être dispensé dans un contexte d'enseignement en plein air, axé sur l'expérience, au camp de base et station de recherche des monts Torngat a été élaboré, peaufiné et mis en œuvre dans le cadre du programme kANGIDLUASUk pour étudiants.

- Ten students from Nunatsiavut and Nunavik participated in the kANGIDLUASUk Student Program, including the contaminants field unit.

- Delivery of the contaminants field unit is highly flexible, allowing the incorporation of other related programs operating at base camp

- The contaminants field unit includes seven modules and incorporates pre-assessment/ introduction, exploration of concepts, and extension phases as students work their way through the seven modules.

- At the end of the program, students completed a comprehensive assessment and evaluation form for their entire summer experience, on which aspects of their participation in the contaminants unit is reflected. On a scale of 0-5 for overall impressions and enjoyment of the contaminants field unit, the average rating of all participants was 4.6. In addition, on a scale of 0-10, mean self-rated student knowledge levels on contaminants also increased from 2.2 before the program to 7.5 after the program.

- Outcomes of this program indicate that outdoor, experiential education programs designed specifically for northerners may be valuable to pursue in order to build further capacity in the North (including capacity related to contaminants).

- Dix étudiants de Nunatsiavut et du Nunavik ont participé au programme kANGIDLUASUk pour étudiants, y compris à l’unité de campagne sur les contaminants.

- L’unité de campagne sur les contaminants a un fonctionnement très flexible, qui permet d’y intégrer d’autres programmes connexes donnés au camp de base.

- L’unité de campagne sur les contaminants comprend sept modules. À mesure que les étudiants exécutent ces modules, l’unité intègre les étapes d’évaluation préalable et d’introduction, d’exploration des concepts, et d’extension.

- À la conclusion du programme, les étudiants ont rempli un formulaire d’appréciation et d’évaluation globale de l’ensemble de leur expérience d’été, faisant état de certains aspects de leur participation à l’unité des contaminants. Sur une échelle de 0 à 5, les participants ont accordé une cote moyenne de 4,6, dénotant leur impression et appréciation globales de l’unité de campagne sur les contaminants. De plus, les niveaux de connaissance moyens sur les contaminants ont été évalués par les étudiants, passant de 2,2 avant le programme à 7,5 à sa conclusion, sur une échelle de 0 à 10.

- Les résultats de ce programme donnent à penser qu’il vaut sans doute la peine de poursuivre des programmes d’éducation fondés sur l’expérience en plein air, conçus expressément pour les résidants du Nord, afin de renforcer la capacité (y compris sur les contaminants) dans le Nord.

Objectives

Following pilot project and module development in 2010-2011 through NCP funding, the kANGIDLUASUk Student Program aimed to further refine and develop resources to coordinate and deliver a multidisciplinary contaminants field unit within the four week kANGIDLUASUk Student internship at the Torngat Mountains Base Camp and Research Station in 2011-12. In partnership with related research projects, Inuit harvesters and elders, and other base camp programming where appropriate, objectives of the field unit were to:

1) Create opportunities for Nunatsiavut and Nunavik Inuit youth to increase their understanding of:

    - contaminants, contaminant pathways, processes, issues, and effects that contaminants may have on wildlife and humans in the north.
    - the Northern Contaminants Program.
    - the development and implementation of global agreements to reduce and/or eliminate the production, use, and release of contaminating substances into the environment.
    - nutritional information and health benefits of consuming country foods.
    - connections or linkages between Inuit Knowledge, values, observations, and perceptions and the scientific understanding of contaminants, contaminant issues and trends.

2) Explore contaminant concepts and key messages of the Northern Contaminants Program (NCP) through a variety of hands-on and exploratory-based activities using context and examples familiar to Nunatsiavut and Nunavik youth.

3) Create experiences that will have a positive and meaningful impact on the attitudes and behaviours of young Inuit towards science and research.

4) Provide students with more than just knowledge of facts, and create opportunities for youth to learn through investigation, to develop critical thinking, and then allow students to connect that understanding to their own lives and the world around them.

5) Develop leadership, employability, and traditional skills consistent with the vision and goals of the kANGIDLUASUk Student Program.

Introduction

The 2011 kANGIDLUASUk Student Program was based out of the Torngat Mountains Base Camp and Research Station in kangidluasuk (St. John's Harbour). Ten Inuit students from Nunatsiavut and Nunavik communities participated in the program. The activities included a blend of science, culture and adventure, and the overall program was designed to contextualize each activity and foster a sense of connection and relevance to the scientific programs taking place.

This year, a focus of the program was the delivery and refined development of a contaminants field unit. The field unit was adapted and built from many sources, including the Niqiit course, and included a variety of flexible modules covering a range of contaminant concepts and issues for delivery and integration within overarching themes, programs, and inter-disciplinary research projects at the base camp. Field unit content was delivered through a range of presentations, activities, projects, discussions, storytelling, and hands-on field work with contaminant-related research projects. Students also explored linkages between contaminant issues and concepts and Inuit Knowledge, values, observations and perceptions with Inuit harvesters and elders.

As part of the program, students completed evaluations on their enjoyment of the contaminants field unit as well as their perceptions of their level of knowledge prior to and after delivery of the program. The results speak to the value of outdoor, experiential learning opportunities designed specifically for a northern and Inuit context and delivered in Inuit homelands.

Activities and Results

Seven contaminant modules within the field unit were refined and further developed, with each module building on the content and skills within the previous one. At a high level, they include:

i) Country foods and you

- Set context
- Explore current relationship with country foods and their importance

ii) What do you think?

- Introduction to key concepts, NCP, vocabulary
- Assess baseline knowledge

iii) Types of contaminants

- Characteristics
- Sources
- Local context

iv) Contaminants in ecosystems

- Food Webs
- Bioaccumulation
- Biomagnification

v) Where did it come from?

- Long-range transport and local sources
- Relate concepts to technology, society and the environment

vi) Global action

- Contaminant trends
- Think globally, act locally

vii) Health and country foods

- Explore all factors that can affect health
- Nutrient comparisons
- Traditional food preparation

Modules 1 and 2 were designed for pre-assessment/introduction (eg. what do students already know? Have they heard the word contaminants before?). Modules 3-5 were designed to allow the exploration of contaminant concepts and information through experiential inquiry and learning. Modules 6-7 were designed to extend and incorporate skills and concepts learned into other areas and activities at base camp and in the student's lives beyond base camp.

The modules were built to be extremely flexible, as they can be delivered over consecutive days or spread throughout the four-week program, one module at a time. Cross-curricular programming was integrated into the modules, as the facilitator can draw on the resources at the base camp and integrate the contaminants field unit activities with other KSP program (i.e. marine module, Parks Canada/IPY field unit). This creates synergies within the various programs being run within KSP. In addition, if there are any experts in a particular area that is explored in the Field Unit at base camp, they are invited to teach or expand on certain topics. For example, in 2011, marine mammal toxicology and food web experts were engaged to expand on their work for the delivery of the contaminants in ecosystems module.

Each module within the field unit has three facets built in: i) Knowledge, ii) Skills acquired, and iii) Activities. For example, the contaminants in ecosystems module includes the following:

i) Knowledge

- Marine and terrestrial food webs
- Biomagnification
- Bioaccumulation

ii) Skills

- Communication
- Adaptability
- Working with others
- Observation and recording
- Working safely
- Critical thinking
- Formulating hypotheses/questions
- Analysing and interpreting
- Collection and identification of marine species
- Marine navigation
- Traditional harvesting

iii) Activities

- Survival biomagnification game
- Marine module investigations onboard the MV What's Happening

Communications

An annual program report was published and provided to all project partners following the 2011 summer Student Program. Presentations by past students and/or program staff were given at schools and at the Nunatsiavut Youth Symposium. An oral presentation was also provided at the annual NCP results workshop in Victoria that spoke about KSP generally and the contaminants field unit specifically. A poster presentation on KSP was also given at the IPY conference in spring 2012. Radio interviews were conducted with the OKalaKatiget Society before and after the 2011 program.

Discussion/Conclusions/ Capacity Building

At the end of the program, students completed a comprehensive assessment and evaluation form for their entire summer experience, on which aspects of their participation in the contaminants unit is reflected upon. First and more generally, on a scale of 0-5 for overall impressions and enjoyment of the Arctic

Figure 1. Predators chase prey during survival biomagnification round

Figure 2. KSP student helps lead a survival biomagnification debrief after a round of play.

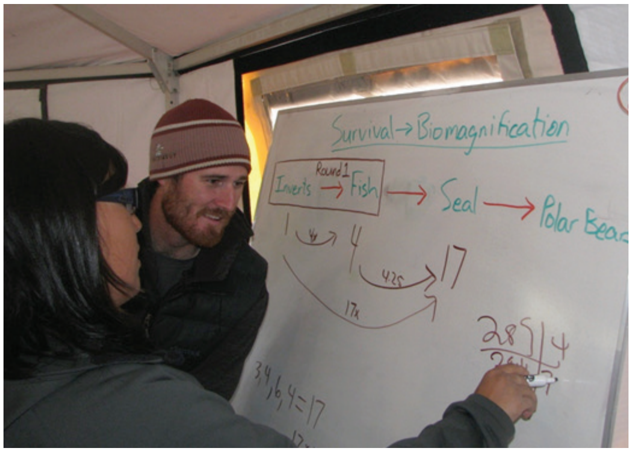


Figure 3. KSP student explores contaminants and related concepts through an inquiry based module onboard the Inuit owned *MV What's Happening*

Figure 4. KSP students complete an activity i n Contaminants field unit module 5 – Where did it come from?

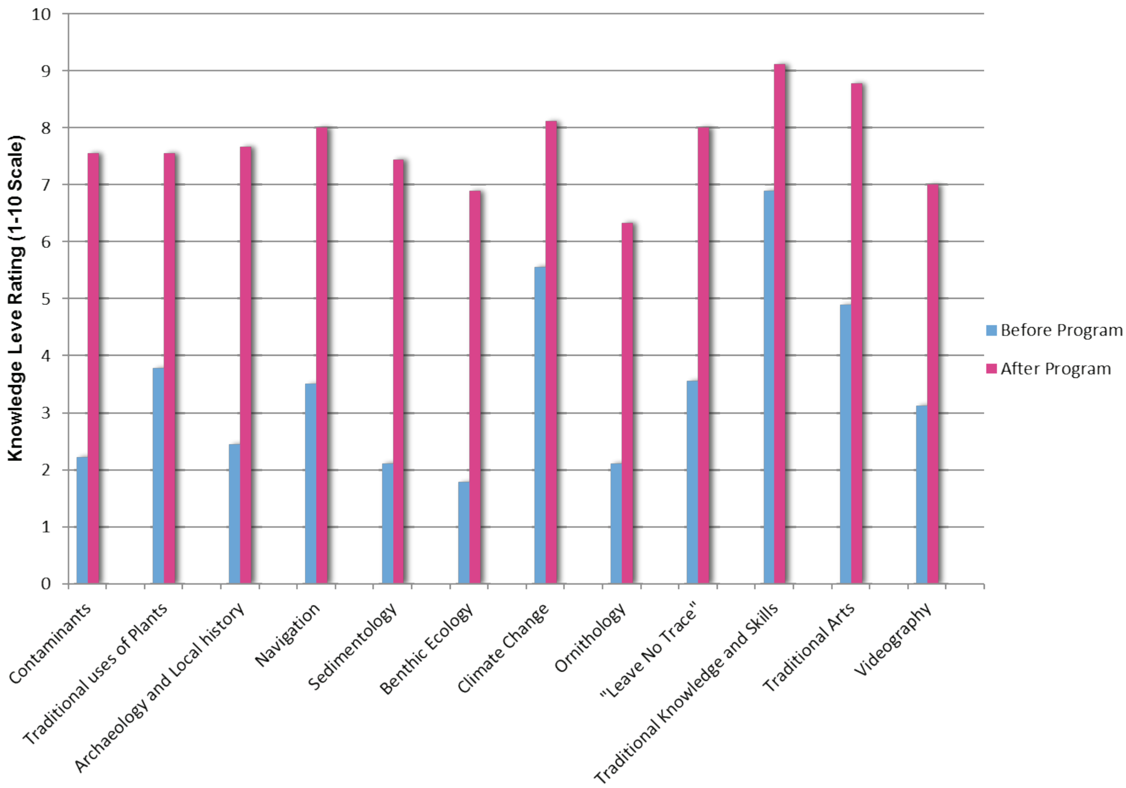
Contaminants Activities, the average rating of all participants was 4.6 (so, they seem to be enjoying learning about contaminants in this experiential, outdoor setting!). Again in 2011, we also asked KSP students to evaluate the impact of the program on them as individuals (both in terms of knowledge and skills acquired). Generally, the students indicated they learned a lot and further developed skills both directly and indirectly related to contaminants. It is our belief, based on student feedback, that there is tremendous capacity development through KSP, including the contaminants field unit.

Going forward, our plan is to have the contaminants field unit undergo further peer review (by Inuit, including the regional contaminant committees, educators and scientists). We have met with the Development Specialist for Aboriginal Education with the Labrador School Board are exploring the possibility of using the contaminants field unit as a basis for building a locally developed course or schools and finding the best fit with Labrador and Nunavik curriculum. We plan to further refine and formalize materials, including a Module Overview Document, Facilitator Guide, graphics and design. We also plan to share the contaminants field unit with other field programs and schools. Finally, we expect that the field unit will continue to be re-worked on an ongoing basis as KSP evolves and takes new directions.

Expected Project Completion Date

Although funding for this program is now over, the Contaminants module within the KSP will continually be refined, adapted and implemented moving forward.

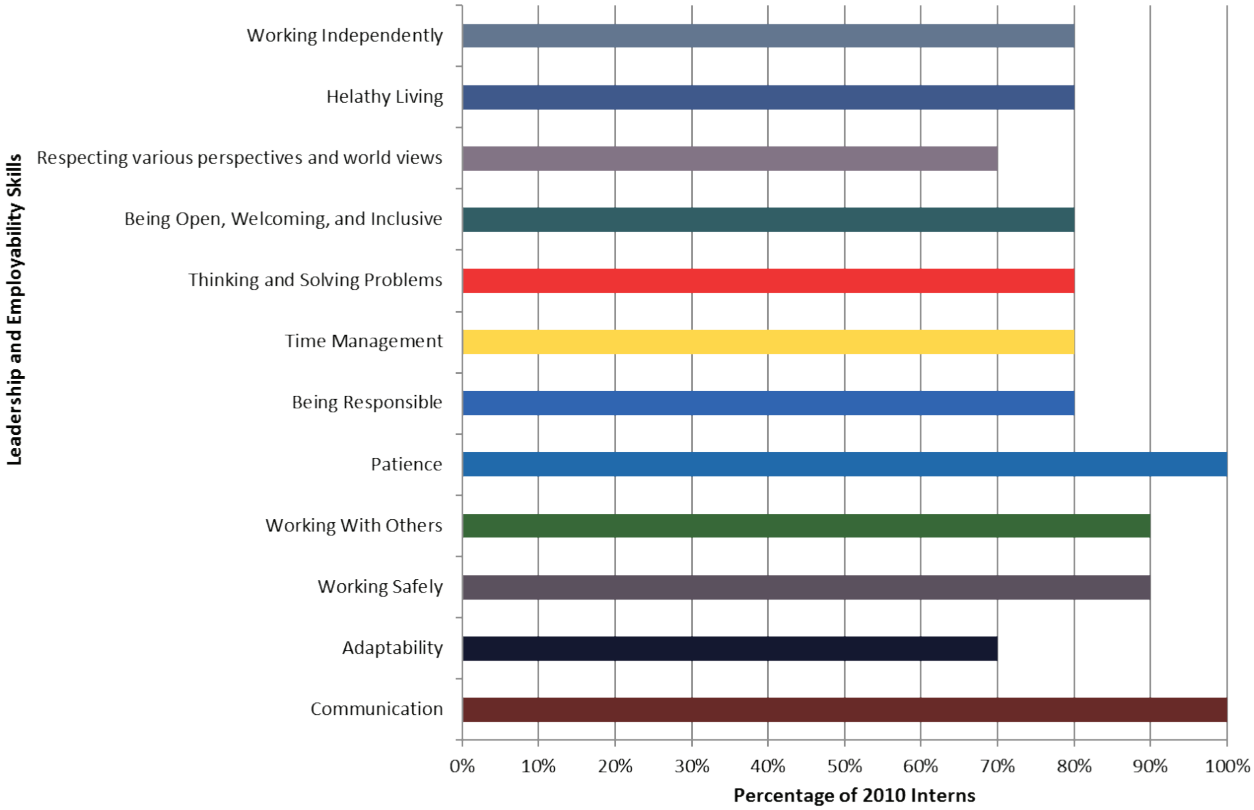
Figure 5. Mean self-rated student knowledge levels on various program components before and after participating in the 2011 program (contaminants highlighted on far left).



NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	18	10 students directly in KSP program. 8 northerners helping prepare and execute the program
number of project-related meetings/ workshops held in the North (April 1, 2011 – March 31, 2012)	0	NA
Number of students and post docs (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	Approx. 80	We have made a deliberate decision to emphasize quality over quantity. Each student in KSP (10) has a 650 hour learning experience, which includes a substantial contaminants component. KSP also gave presentations in schools in Nain, Hopedale, Rigolet, Makkovik, Postville and Kagiqsuallujuaq.
Number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	0	The annual KSP report has been published.

Figure 6. The percentage of 2011 interns who identified having developed and/or improved a variety of leadership and employability skills throughout the summer field program.



Building Capacity in Knowledge Translation of Northern Contaminants: Phase II

Renforcement des capacités dans l'application des connaissances relatives aux contaminants dans le Nord : phase II

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Abstract

Environmental contaminants in Northern Canada are becoming more of a concern to residents. It is important that contaminant data is kept current; this requires continual monitoring and evaluation. The Government of the Northwest Territories (GNWT) relies on this up to date information given their responsibility to provide generic advice on the consumption and safe handling of country foods in the Northwest Territories. Traditional food harvesting plays an important role in the way of life for aboriginal people in the Northwest Territories (NWT). It is therefore expected that plain language messaging around contaminants and communication of important information be dispersed to communities in a timely manner, along with informing community leaders of pertinent information so that knowledgeable decisions can be made.

Résumé

Les contaminants environnementaux dans le Nord du Canada préoccupent de plus en plus les habitants de la région. Il importe donc que les données sur les contaminants soient tenues à jour, ce qui nécessite des activités soutenues de surveillance et d'évaluation. Le gouvernement des Territoires du Nord Ouest (GTNO) utilise cette information mise à jour, compte tenu de son mandat consistant à fournir des conseils génériques sur la consommation et la manipulation sécuritaires des aliments traditionnels dans les Territoires du Nord Ouest. La récolte des aliments traditionnels joue un rôle important dans le mode de vie des peuples autochtones dans les Territoires du Nord Ouest; c'est pourquoi on s'attend à ce que des messages en langage clair et l'information importante sur les contaminants soient diffusés rapidement au sein des collectivités. Les leaders des collectivités

In 2011-2012, a Contaminants Researcher was hired through GNWT and AANDC co-funding in order to respond to concerns pertaining to contaminant related issues within the GNWT Department of Health and Social Services (HSS). In addition, communication and database activities around contaminants were greatly strengthened. Numerous activities were conducted in 2011-2012 which aided in the dispersion of contaminant related information. This increased public knowledge to help in understanding why contaminants are in the environment and what people can do as a healthy approach to traditional food consumption. The intern actively sought relevant data to complete a comprehensive database on mercury levels in fish in lakes that were tested in the early 1970s to present. These data sources expanded past NCP funded projects and included data from mines as well as other federal departments. This data was also mapped by the GNWT Centre for Geomatics. Links to general fish consumption guidelines, a map of lakes with public health advisories on fish consumption and contaminant fact sheets were added to the GNWT-HSS website. Through this detailed research, other associated information came to light, including old health advisories that have not been retested for almost two decades. As a result, new proposals were successfully submitted for funding in 2012-2013 to retest lakes with standing advisories, and to develop visual pathways using ArcGIS to determine lakes with elevated mercury concentrations.

doivent aussi disposer de toute l'information pertinente à la prise de décisions éclairées.

En 2011-2012, un agent de recherche sur les contaminants a été embauché dans le cadre d'un cofinancement GTNO-AADNC afin de répondre aux préoccupations que soulèvent les questions liées aux contaminants au sein du ministère de la Santé et des Services sociaux (MSS) du gouvernement des Territoires du Nord-Ouest. De plus, les activités de communication et de mise à jour des bases de données sur les contaminants ont été grandement renforcées. Bon nombre d'activités réalisées en 2011-2012 ont favorisé la diffusion de l'information relative aux contaminants. Ces activités ont permis d'accroître les connaissances du public et ont aidé à comprendre pourquoi les contaminants se trouvaient dans l'environnement ainsi que les mesures que les membres des collectivités peuvent prendre pour consommer les aliments traditionnels de façon sécuritaire pour la santé. Le stagiaire a activement recueilli les données pertinentes à la mise sur pied d'une base de données complète sur les concentrations de mercure dans les poissons des lacs ayant fait l'objet d'analyses depuis le début des années 1970. Les sources de données dépassent la portée des projets financés par le Programme de lutte contre les contaminants dans le Nord (PLCN) et comprennent des données issues de l'exploitation minière et d'autres ministères fédéraux. Les données ont aussi été cartographiées par le Centre de géomatique du GTNO. Des liens vers des lignes directrices globales sur la consommation de poisson, une carte des lacs visés par des avis de santé publique concernant la consommation de poisson et des fiches d'information sur les contaminants ont été ajoutés au site Web du MSS-GTNO. Dans le cadre de cette recherche approfondie, d'autres renseignements connexes ont été recueillis, y compris d'anciens avis de santé publique n'ayant pas fait l'objet de nouvelles analyses depuis près de vingt ans. Par conséquent, de nouvelles propositions ont été présentées afin d'obtenir du financement en 2012-2013 pour effectuer de nouveaux échantillonnages dans les lacs associés à des avis en vigueur, ainsi que pour élaborer des tracés visuels dans ArcGIS dans le but de déterminer quels sont les lacs qui contiennent des concentrations élevées de mercure.

Key Messages

- It is the responsibility of the GNWT to provide generic advice on the consumption and safe handling of country foods that are important to Aboriginal people in the NWT. In order to fulfil this responsibility, pertinent and timely information on contaminants must be part of public health messages.
- Meaningful participation in the NWT Regional Contaminants Committee (NWT RCC) provides the GNWT with a forum for the two-way transfer of contaminant information that is relevant to the regions and builds capacity in key community representatives as they communicate specific health messaging on northern contaminants.
- Assessing what people already know about contaminants and whether or not contaminants messaging has been correctly received and understood is a main goal of this project. Part of this process is learning the best ways to communicate contaminant issues in the North, as well as building capacity of community leaders and local healthcare providers which help to provide timely health messages.
- Environmental Contaminants is an ongoing issue in the North, requiring up-to-date monitoring and analysis of data. Another main goal of this project is to ensure that this takes place in a timely manner and to get a step ahead of community concerns about contaminants as well as future concerns of elevated levels.

Messages clés

- Il incombe au GTNO de fournir des conseils génériques sur la consommation et la manipulation sécuritaire d'aliments traditionnels importants pour les peuples autochtones des Territoires du Nord Ouest. Afin de remplir ce mandat, des renseignements pertinents fournis en temps opportun doivent être inclus dans les messages de santé publique.
- La participation significative au Comité régional des T.N. O. sur les contaminants offre au GTNO un forum pour l'échange bidirectionnel de renseignements sur les contaminants pertinents aux régions, et permet de renforcer les capacités des principaux représentants communautaires à mesure que ceux ci communiquent des messages de santé publique spécifiques sur les contaminants du Nord.
- L'évaluation des connaissances actuelles de la population sur les contaminants ainsi que de la réception et de la compréhension des messages sur les contaminants constitue l'un des principaux objectifs du projet. Une partie de ce processus implique l'apprentissage des meilleures méthodes de communication des questions associées aux contaminants dans le Nord, ainsi que le renforcement des capacités des leaders communautaires et des intervenants de la santé locaux qui aident à transmettre rapidement les messages de santé publique.
- Les contaminants environnementaux constituent un enjeu permanent dans le Nord et nécessitent des activités de surveillance, d'analyse et de mise à jour des données. Un autre des objectifs du projet consiste à veiller à ce que ce processus s'effectue rapidement ainsi qu'à obtenir une longueur d'avance sur les préoccupations des collectivités concernant les contaminants ainsi que sur les préoccupations futures liées à la hausse des concentrations.

Objectives

The main objectives of this project were to:

- Further synthesize historical contaminants information into a web format to allow timely access;
- Improve coordination and communication with federal departments around contaminants;
- Further develop the capacity of the NWT communities and continue knowledge translation activities that began during the previous year.

Introduction

The GNWT is responsible for delivering time sensitive health messaging from new data and ongoing monitoring of environmental contaminants that have a potential to pose health concerns to the people of the NWT. Because of challenges encountered in previous years, a new tool was developed.

With issues concerning the lack of communication within departments, programs and researchers regarding Public Health Advisories (PHA) on the consumption of fish, a different approach was sought out in order to deliver timely and appropriate health messaging. This entailed a user friendly format of information distribution which could be broadcast to the public as soon as new information pertaining to contaminant related concerns and issues becomes available. The first step involved accumulating, reviewing and synthesizing extensive contaminant information dating back to the early 1970's. This was completed in 2011 as a part of Phase 1 of this project. Phase 2 of the project required further refining and maintaining of the current long-range contaminant data in order to keep it up to date. The GNWT will now be able to provide up to date generic health messaging on contaminants to the public, and prepare community leaders and local healthcare providers to communicate contaminant information effectively and appropriately (Kandola 2011).

Since 2007, twelve (12) PHA's on the consumption of fish within the NWT have been implemented by the GNWT Office of the Chief Public Health Officer (OCPHO). Ten (10) of these twelve (12) have been implemented in the past two years. The concerns for safe levels of contaminants in fish are steadily growing and the issue is not going away anytime soon. It is imperative that up-to-date monitoring and analysis of current data is conducted. It is also crucial for new studies to be performed with the gathering of data in new areas (lakes/rivers) that are within closer proximity to communities where people consume fish on a regular basis, where no baseline studies/data has even been executed.

Mark Wasiuta, a Bachelor of Science graduate majoring in Environmental Science with related fish and wildlife experience, was hired as a Contaminants Researcher under an internship for one year in order to help the GNWT-HSS achieve their goals.

Activities

Capacity Building
In September 2011, data was mapped to show the sample locations around the NWT and was presented during the poster presentation at the NCP Results Workshop in Victoria BC.

Messaging pertaining to general fish consumption guidelines for the NWT has been included in the 2012-2013 NWT Sport Fishing Regulations Guide (http://www.enr.gov.nt.ca/_live/pages/wpPages/sport_fishing_regulations_guide.aspx). Messaging for moose organ consumption advisory will be included in the 2012-2013 NWT Hunting Regulations (http://www.enr.gov.nt.ca/_live/pages/wpPages/hunting_regulations.aspx).

Workshops and conferences were attended throughout the year as part of this project. These include the 2011 Geo-Science Forum, a Department of Fisheries and Oceans (DFO) results workshop, and an information session from the Canadian Nuclear Safety Commission. In January 2012, an information session on Oil and Gas Exploration and Production Drilling Techniques related to Unconventional Oil and Gas Deposits. All of these meetings took place in Yellowknife, NWT. In April 2012, GNWT-HSS attended a results presentation of a community based mercury levels in fish project in the community of Behchoko, NWT.

In January 2012, the GNWT-HSS submitted a 2012-2013 NCP proposal and also submitted a 2012-2013 NWT Cumulative Impact Monitoring Program (CIMP) proposal in February 2012. The feedback on the NCP proposal from the 2012 Social Cultural Review was highly supportive. The proposal was approved for funding by the NCP Management Committee, and the plan is to update old PHA's for the consumption of fish.

Further update, synthesis and compilation of the NWT fish muscle mercury data was an ongoing process throughout the year with new data always being presented. Once this data had been validated it then formed the basis of a comprehensive web-map database, with the help of the GNWT Centre for Geomatics based in Yellowknife, NWT. The web-map database consists of 554 mean concentrations of mercury representing a sample size of 7,838 fish in 116 study locations, of which 85 sample groups of fish (1,295 fish) were over 0.5 µg/g of mercury. The web-map involves numerous layers of data which will help to create criteria for potential future sample locations, lakes that would be a priority to the communities and lakes that have the potential of inhibiting fish with elevated levels of mercury. Once the analysis is proven it will enable for trend analysis. The first step of this project lays the foundation for the work involved in the CIMP proposal entitled "Visual analysis of predictors for increased mercury levels in predatory fish in NWT lakes" that was submitted for FY 2012-13 and successfully funded in whole.

With the help of Norm Mair (G.I.S. Specialist with GNWT-Informatics Department in Yellowknife, NWT), an interactive web-map was also composed and made available to the public which displays public health advisory messaging for the consumption of fish from lakes in the NWT. This featured map was linked to the GNWT-HSS website (http://www.hlthss.gov.nt.ca/english/services/environmental_health/food_safety/contaminants/mercury/default.htm) in April 2012 and shows all the lakes in the Northwest Territories that currently have fish consumption advisories implemented.

In March 2012, video clips were produced to help with the promotion of eating fish in the Dehcho, with the help of George Low, Dehcho AAROM Coordinator and with the intent to post on the GNWT-HSS website. Due to a request by the Dehcho Nation, the videos were respectively not posted and would be discussed at a later date.

Communications

As a part of funding requirements, either the GNWT Acting Chief Public Health Officer, environmental health officer or contaminants intern actively participated in the following NCP meetings: Northern Contaminants Program (NCP) Results Workshop in Victoria, BC in September 2011; Social Cultural Review in Yellowknife, NWT in February 2012; and Managers Meetings in Iqaluit, NU in October 2011 and Ottawa, ON in April 2012.

In the 2011-2012 fiscal year, six (6) Public Health Advisories for the consumption of fish pertaining to elevated levels of mercury were implemented in the NWT by the GNWT-HSS and put on the HSS website (http://www.hlthss.gov.nt.ca/english/services/environmental_health/food_safety/contaminants/mercury/default.htm). On June 28th,2011, two (2) PHA's were implemented in the Akaitcho region on the consumption of Lake Trout (*Salvelinus namaycush*) for Stark Lake and Nonacho Lake. On August 19th,2011, three (3) PHA's were implemented in the Dehcho region on the consumption of fish for McGill, Deep and Fish Lake. Deep and McGill Lake, the advisory is for Northern Pike (*Esox lucius*) and Walleye (*Sander vitreus*), while for Fish Lake, the advisory is for lake trout, northern pike and walleye. On February 9th, 2012, another PHA was implemented in the Dehcho region on the consumption of northern pike and walleye for Ekali Lake.

The former Chief Public Health Officer, Dr Lorne Clearsky also visited the communities of Lutsel'ke (accompanied by Lorna Skinner, local NCP Secretariat) and Jean Marie River and Wrigley to deliver the respective June and August 2011 public health advisories. In the most recent public health advisory on Ekali lake, the GNWT Office of the Chief Public Health Officer worked with George Low, Dehcho AAROM Coordinator on communications with Jean Marie River and Norman Well aboriginal leaders and community members. There was media publicity on the release of these public health advisories. There is a growing concern related to whether mercury levels are in fact increasing across the territory and whether climate change is the causative factor.

Signs indicating fish consumption advisories were given to authorities in order for them to be placed at sites on lakes commonly used as access points in 3 languages - English, French and the local Traditional Language. Most of the signs have an image of the elevated fish species that depicts the actual size of the safe limit for fish length; while others have an image of a deck of cards that depicts the actual amount (75 grams) of the safe limit of the fish muscle for consumption. Flyers/posters had accompanied signage only upon request from the local band or community.

The Contaminants Researcher has reproduced plain language contaminant fact sheets which after the required approval process, will be linked to the GNWT-HSS website (http://www.hlthss.gov.nt.ca/english/services/environmental_health/default.htm) These 18 fact sheets were created anew or updated from older fact sheets that originated from the Aboriginal Affairs and Northern Development Canada (AANDC). These fact sheets cover important information pertaining to contaminant issues and concerns in the NWT as well as current PHA's. The fact sheets include informative topics on contaminants in traditional foods such as Moose, Caribou, Beaver and Muskrat, Fish, Beluga Whale, Ptarmigan and Grouse, Ringed Seal, Muskoxen, Dall Sheep and Mountain Goat, Wood Bison, Berries and Waterfowl. Other topics educate the reader on specific contaminants including DDT, Heavy Metals, Dioxins and Furans, PCB's, POP's and Radionuclides. The GNWT-HSS is planning to add more contaminant fact sheets, such as contaminants in mushrooms, to this arsenal but only as time and resources permit.

Meetings and planning events were engaged with stakeholders such as AANDC-AADNC, Health Canada, Environment Canada, GNWT Department of Environment and Natural Resources (ENR), RCC, DFO, Akaitcho Dene, NWT Metis Nation, Dehcho First Nations, community members and other local agencies in the Dehcho.

Traditional Knowledge Integration

The distribution of Fish Harvest Surveys were attempted at a results presentation in Behchoko, NWT but denied due to a respectful request that was asked at the time.

Results

The NWT mercury in fish data has finished the final stages of preparation and incorporates 2 web-maps; a web-map of the NWT showing lakes with current fish muscle consumption PHA's and a web-map that encompasses all the lakes with mercury in fish muscle data in the NWT, which allows the user to query the data with straightforward interactions. These web-maps will also allow for visualization of contaminants data in a comprehensive and longitudinal format.

Multiple over-the-phone and in-person meetings with federal contacts and researchers have occurred and will continue to occur. This has helped in the process of seeking out information for various contaminant-related activities including research proposals, preparation of contaminant fact sheets and future plans pertaining to contaminants in the NWT, to name a few. As a result of this concrete coordination and communication, a smoother road has been paved for key stakeholders and researchers when it comes to issues and concerns regarding contaminants in the NWT.

Other additional activities by the Contaminants Researcher included helping with the logistics and processing of wildlife samples for the GNWT-ENR and primarily assisting the OCPHO for the GWNT-HSS in contaminant related issues from other professionals, the public and communities.

Discussion and Conclusions

The appointed Contaminants Researcher has helped to increase the capacity of the NWT communities regarding contaminants and help adapt contaminant related health messages within the communities. The individual has worked with key stakeholders and local healthcare providers in the affected regions to determine the appropriate level of activity on contaminants communication and education which will maximize behavioural change in the communities. Communities have become familiar with accessing the GNWT-HSS website as a source of valid and relevant information. Most communication was done via conference calls and in-person meetings in Yellowknife, NWT. Visits to communities were dependent on additional funding and reflecting on the low number of community visits. However, five contaminant-related community visits were done by the Office of the Chief Public Health Officer during this period (Wrigley, Jean Marie River, Behchoko, Lutselke and Hay River). Meetings and conference calls aided with the collaboration of key stakeholders to assist in the coordination and lines of communication around contaminants issues with multi-stakeholders.

The individual helped in the development and delivery of health promotion and communication activities involving communities that were impacted by contaminants that had reached levels of concern. In the event that messaging was needed, the individual also took part in the development and distribution of community-specific northern contaminant messages to the affected communities.

While reviewing old reports and compiling data, numerous related information pertaining to past PHA's, which had been in place from 1990's for the consumption of fish in lakes, had no current PHA's and after further review, had no data since the old advisories had been implemented. The updating of these out-dated PHA's thus became a high priority and a proposal was then submitted to the NCP that specifically aimed to test the fish in these lakes in order to possibly lift the old PHA's depending on the data collected. Six lakes were proposed to be tested for mercury levels in fish muscle and among those six lakes; five had last been tested around 20 years ago. This NCP proposal has received partial funding for FY 2012-13.

The web-map repository for all mercury fish data allows future analysis of numerous layers of data which will help to create criteria for potential future sample locations, lakes that would be a priority to the communities and lakes that have the potential of inhibiting fish with elevated levels of mercury. A CIMP proposal entitled "Visual analysis of predictors for increased mercury levels in predatory fish in NWT lakes" was submitted for FY 2012-13 and successfully funded in whole

Enhanced work on contaminant related issues done by GNWT OCPHO in the past two years has been made possible through NCP funding. It has also allowed for the successful submission of two strategic proposals. A dedicated contaminants website is now being developed jointly by GNWT HSS Communications and the Contaminants Researcher to allow sustainable access to current knowledge on NWT contaminants issues. This would benefit a greater audience outside of NWT communities such as the other territories, NCP and the circumpolar communities internationally.

In conclusion, the GNWT-HSS is now able to show support with meaningful participation in the NCP and will continue to play a major part in the NWT RCC.

Expected Project Completion Date

This was the final year of the project and the date of completion was March 31st, 2012.

Acknowledgments

We wish to acknowledge the following individuals for their support:

- Lorna Skinner, Planning and Reporting Coordinator Indian and Northern Affairs former Contaminants and Remediation Directorate
- Norm Mair, G.I.S. Specialist, GNWT Informatics, Shared Services, Environment & Natural Resources/ Industry, Tourism & Investment.
- Daniel Gibson, Enterprise G.I.S. Administrator, GNWT Informatics, Shared Services, Environment & Natural Resources/ Industry, Tourism & Investment.
- Myrna Matheson, Enhanced Surveillance Projects Officer, GNWT Health and Social Services.

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NCP Performance Indicators

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	–	All participants involved in this project are from the North; GNWT-HSS/ENR/Informatics, AANDC-AADNC, Dehcho First Nations
number of project-related meetings/ workshops held in the North (April 1, 2011 – March 31, 2012)		All project based meetings took place in the North
Number of students and post docs (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)		The Contaminants Researcher would be considered an early scientist. He is also cofunded within by GNWT as an intern.
Number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	2011:1 2012:1	The resources will be made available on GNWT-HSS Contaminants Website as well as presented at the RESULTS workshop.

Beluga Communication Package for Inuvialuit Settlement Region (ISR): A Social Component

Trousse de communication sur le béluga pour la région désignée des Inuvialuit : composante sociale

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Abstract

The traditional hunt for belugas is an important cultural event in the Inuvialuit Settlement Region (ISR). The beluga whale remains an important part of healthy diets for many Inuvialuit. The Hendrickson Island Beluga Study near Tuktoyaktuk, NT within the ISR, has been monitoring beluga whales and contaminants over the last decade. In recent years, members of the monitoring team have collaborated with local representatives to develop a holistic approach to studying beluga whale health and incorporate perspectives from both scientific information and local knowledge. One of the tangible outputs from these efforts of bringing the two knowledge systems together was a contextualized communication package for the community. As we moved forward on this initiative, it was important to bring together knowledge and respect from both perspectives and values. This year we supported a Traditional Ecological Knowledge (TEK) youth program, based out of Tuktoyaktuk, that focused on traditional food preparation. It engaged many community members in a wrap-up communication event. The community

Résumé

La chasse traditionnelle au béluga représente un événement culturel important dans la région désignée des Inuvialuit. En outre, le béluga demeure un élément important d'un régime alimentaire sain de bon nombre d'Inuvialuits. Une surveillance des bélugas et des contaminants a été effectuée au cours des dix dernières années à proximité de Tuktoyaktuk (T.N. O), à l'intérieur de la région désignée des Inuvialuit, dans le cadre de l'étude sur les bélugas sur l'île Hendrickson. Dans les dernières années, les membres de l'équipe de surveillance ont collaboré avec des représentants locaux pour élaborer une approche holistique en matière d'étude de la santé des bélugas et pour intégrer à celle ci différents points de vue issus de l'information scientifique et des connaissances locales. L'un des résultats tangibles de ces activités visant à rassembler les deux systèmes de connaissances a été une trousse de communication adaptée au contexte de la collectivité. À mesure que le projet allait de l'avant, il importait de rassembler les connaissances et de respecter les deux points de vue et les deux systèmes de valeurs.

representatives guided us in the development of an appropriate communication forum and package. With guidance and input from the community, we are currently completing our final report in book format.

Cette année, nous avons soutenu un projet sur les connaissances écologiques traditionnelles destiné à la jeunesse qui s'est déroulé à l'extérieur de Tuktoyaktuk et qui était centré sur la préparation des aliments traditionnels. Ce projet a rassemblé bon nombre de membres de la collectivité dans le cadre d'une activité de communication récapitulative. À cet égard, les représentants communautaires nous ont orientés dans l'élaboration d'un forum et d'une trousse de communication appropriés. Grâce aux conseils et aux commentaires de la collectivité, nous en sommes à la réalisation de notre rapport final en format livre.

Key Messages

- This year our program focused on communicating the findings of several beluga research and monitoring programs that have been based out of Hendrickson Island.
- A communication event was held in Tuktoyaktuk March 6-8th ,2012. It was open to the community of Tuktoyaktuk and shared with several Hunters and Trappers Committees in the ISR.
- The event was a venue for the exchange of knowledge between scientists and community members, and it increased dialogue about the direction of beluga research in the ISR.
- The new TEK program taught youth the traditional ways of harvesting and preparing beluga and fish for subsistence. This was lead by C. Pokiak and I. Thrasher.
- Members of the project team presented the Hendrickson Island program at the recent IPY conference.

Messages clés

- Cette année, notre programme a été centré sur la communication des résultats de plusieurs programmes de recherche et de surveillance sur le béluga qui ont été réalisés à proximité de l'île Hendrickson.
- Une activité de communication a été tenue à Tuktoyaktuk, du 6 au 8 mars 2012. Elle était ouverte à la collectivité de Tuktoyaktuk et partagée avec plusieurs comités de chasseurs et de trappeurs de la région désignée des Inuvialuit.
- L'activité a tenu lieu de forum pour l'échange de connaissances entre les scientifiques et les membres de la collectivité, et elle a alimenté le dialogue sur la direction de la recherche sur les bélugas dans la région désignée des Inuvialuit.
- Le nouveau projet sur les connaissances écologiques traditionnelles a enseigné aux jeunes les méthodes traditionnelles de récolte et de préparation de bélugas et de poissons à des fins de subsistance. Ce projet a été mené par C. Pokiak et I. Thrasher.
- Les membres de l'équipe du projet ont présenté le programme d'étude sur l'île Hendrickson à la dernière conférence de l'API.

Objectives

a) Continue to work with beluga research scientists (DFO, NCP, ArcticNet) to develop an integrated scientific package of beluga whale information for communication.

b) Continue the collection of traditional knowledge surrounding beluga health and associated topics with community members to incorporate local insight and community knowledge on the health and well being of beluga whales alongside western science.

c) Communicate program and findings to other ISR communities outside of Tuktoyaktuk and begin to initiate similar local knowledge collection in those communities led by those communities.

Introduction

Beluga whale research taking place in the Inuvialuit Settlement Region (ISR) provides an excellent opportunity to bring scientists and community members together in the development of a comprehensive communication package that includes contaminant data and local insights about the overall health of the beluga whale, such as behaviour, timing of migration, and qualitative characteristics of muktuk, meat and organs. This communication effort is partnered and conducted with northern residents. The long-term presence of local participants in the community provides the opportunity for insight from elders and youth into the scientific data being collected on belugas.

Researchers in Inuit communities are all encouraged to have a strong communication strategy, incorporate traditional knowledge and build capacity with local community members. To reduce community fatigue in communication of many different science projects in relation to beluga whales, the community of Tuktoyaktuk has requested that these beluga research projects be communicated in a unified communication strategy/ package. Thus, all beluga programs would be presented together to enhance the clarity of the progress being made on beluga research. There are a large number of research programs related to beluga health, taking place at Hendrickson Island (hunting area for community of Tuktoyaktuk). These programs have coordinated their reporting and licence applications with the Tuktoyaktuk Hunters and Trappers Committee and other ISR agencies since 2008. The next phase of these coordinated efforts has been to work with local partners to create a holistic communication package (that includes TK) that summarizes all beluga related research.

Scientists have studied population dynamics and trends in contaminants of the eastern Beaufort Sea beluga population for the past two decades (e.g. NCP funded beluga monitoring), while Inuvialuit have been studying and learning about belugas for thousands of years. Our goal is to find new ways to bring together all knowledge-holders to improve our understanding of beluga whale health. This project has provided opportunities for local knowledge and increased participation of community members in various aspects of the beluga health program. In 2011/2012 more community members were involved in the communication/knowledge collection and sharing components of the program, which built a collective community around the research program.

Activities 2011/2012

Youth Traditional Knowledge Program: Learning how to prepare beluga and dry fish

To continue a traditional knowledge component to the program, we hired Charles Pokiak and Ida Thrasher to take several youth out for one week (July 16-22) to learn how to harvest and process beluga and fish. A total of five youth from the ages of 11 to 13 participated in the program. These youth were selected based on interest, as well as representing youth who may not have the opportunity to go out whaling with a family member. C. Pokiak and L. Pokiak landed a whale for processing and mentoring the youth. The whale was butchered at Hendrickson Island and the muktuk and meat were brought to camp for

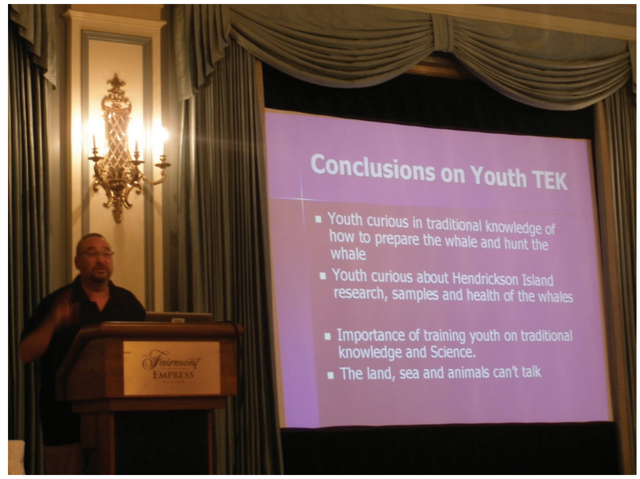
Photo: Youth that took part in Charles Pokiak's and Ida Thrashers Youth Beluga TEK program near Tuktoyaktuk NT, July 2012.

preparing. At the camp the youth learned how to cut and prepare the muktuk which included the cutting, hanging, boiling and storage. Beluga meat was also taken, cut and hung to smoke and dry. Youth learned about the proper driftwood to use for smoking meat in the smoke house and had to keep the fire going. During the same time fish nets were set out along the shore and youth were taught how to catch fish and cut them up for drying/smoking. All youth prepared a summary report of their experience for the program, and brought muktuk and dry meat home to share with their families.

NCP Annual Results Meeting: Sharing the program

Charles Pokiak participated in the fall NCP results workshop in Victoria BC. C. Pokiak and L. Loseto gave a joint talk about the summer's program that emphasized the importance of passing on knowledge to youth. Many youth have participated in programs based out of Hendrickson Island and knowledge transfer focused on science with some traditional knowledge, whereas this program was focused specifically on traditional knowledge and use of the beluga whale.

Photo: Charles Pokiak presenting on his youth Beluga TEK summer program a the NCP annual results workshop, Victoria BC 2012.



Communication Event: Tuktoyatktuk
March 6-8th 2012

The scientists from the Hendrickson Island Beluga Study communicated their research objectives and findings to the Tuktoyaktuk HTC, FJMC and Inuvialuit Game Council (IGC) throughout the study period (2008-2011). A team communication event about beluga health and our research was planned for the winter of 2012. The Communication Event titled 'Sharing Knowledge about Belugas' was organized to improve the exchange of knowledge between scientists, harvester and

Photo: Open house at the Tuktu B&B. Open for questions and discussion over tea.

residents of Tuktoyaktuk many of which do not sit on the boards we present to. The Science Team worked closely with three community research assistants and the Tuktoykatuk HTC to develop a communication event that would respond to community concerns and interests regarding beluga research. On March 7, the Science Team and Community Research Assistants met with Elders, harvesters and youth to discuss the Hendrickson Island Beluga Study. These gatherings were in peoples' homes, at Mangilaluk School, Kitty Hall (Rec Centre) and at the Bed and Breakfast. The intention was for the Science Team to present their research findings, provide a place to discuss and address any questions community members had about beluga health and our research, engage youth in learning about belugas and beluga research, discuss future ideas and the direction of beluga research/monitoring in the Inuvialuit Settlement Region.

Communication Event Itinerary: Tuktoyaktuk, NT

March 6:
- Meet with Community Research Assistants (RAs)
- Meet with youth from the Youth TK program
- Final preparations for Communication Event

March 7:
- Meet with Elders
- Presentation for Gr. 10 Science class
- Review presentations and agenda with community RAs
- Open House at the B&B
- Evening Feast Workshop

Workshop Agenda:
- 5:00 pm – 5:30 pm : Meet and greet, pick up registration packages
- 5:30 – 6:00 pm : Introduction to the Hendrickson Island Beluga Study
- 6:30 – 7:00 pm : Feast and slideshow from HIBS (S. Ostertag, N. Pokiak, L. Loseto, S. Raverty, M. Noel).
- 7:00 – 8:30 pm : Research presentations and Q&A
- 8:30 – 9:30 pm : Coffee and Sharing Circle

March 8:
- Open House at the B&B and follow up with the Tuktoyakuk HTC on the event and future planning.

Community Research Assistants

Verna Pokiak, Mikkel Panaktalok and Nellie Pokiak assisted in varying capacities in the preparation and implementation of the communication event. V. Pokiak and M. Panaktalok met with 41 beluga harvesters prior to the communication workshop. A questionnaire developed by the research team was used to provide community feedback prior to the workshop to assist in the design and implementation. The pre-meetings were also an opportunity for community members to communicate their questions, concerns and feedback to the Science Team. The RAs guided the Science Team as they prepared for the workshop; they provided advice about appropriate language for communicating research, arranged meetings with Elders, and encouraged the Science Team to learn about the ways of doing things in Tuktoyaktuk.

Workshop Event

Thirty five community members, including three former field assistants, representatives from the FJMC and IGC, children, youth, elders and harvesters, attended the workshop. The Beluga Research Team presented information about the history of the monitoring program on Hendrickson Island, the results from beluga research on Hendrickson Island, and the expansion of monitoring to other communities in the ISR. Talks were given by the science team that included Nellie Pokiak who described her and Franks role as beluga monitors. Following each talk hand outs that summarized each talk were provided to the community members with contact info for further questions. Following the talks was tea time and an opportunity for all members to share their thoughts, questions, concerns, stories, suggestions on future work.

Youth

The research team and community research assistants prepared a presentation and Beluga Trivia game for the Gr. 10 Science class at

Mangilaluk School. S. Ostertag, E. Choy and N. Pokiak presented information about the Hendrickson Island Beluga Study to the class. Youth were also invited to attend the Communication Event and several

Elders
M. Panaktalok took L. Loseto, M. Noel and S. Raverty to the Elder home to meet with elders and talk about our research and hear stories that elders may want to share. Following this M. Panaktalok arranged for the Science Team to visit Elders in their homes, to foster dialogue among knowledge holders. Elders also participated in the beluga workshop and shared stories from the past about harvesting belugas.

Tuktoyaktuk HTC
The Science Team communicated frequently with the HTC to ensure that the communication event would respond to community needs and would occur at a convenient time for community members. The HTC also provided essential support to the Science Team by posting the job application, assisting with communication with community RAs and providing other logistical support. Following the event L. Loseto and FJMC met with the Tuktoyaktuk HTC to review outcomes and discuss future planning.

Additional ISR HTCs (Inuvik and Paulatuk)
L. Loseto had the opportunity to meet with both the Inuvik and Paulakuk HTC's who both

Photo: Evening communication event on beluga health at Kitty Hall in the community of Tuktoyaktuk, NT, March 7 2012

were interested in upgrading beluga sampling programs to follow in the footsteps of the Hendrickson Island program. As a result of the communities drive and interest in monitoring and maintaining beluga health they have both obtained funding for beluga related monitoring and research programs for 2012. Efforts will be made to link all programs together and build a regional approach to ecosystem monitoring.

Results/Discussion

The communication event in Tuktoyaktuk succeeded in bringing together diverse knowledge-holders and stakeholders from the Hendrickson Island Beluga Study. The Science Team received important feedback from harvesters through the interviews that were carried out by V. Pokiak and M. Panaktalok. The workshop and gatherings provided the opportunities for the research team to answer many of the questions about belugas and beluga health that were raised during the interviews with V. Pokiak and M. Panaktalok. Questions were primarily about the safety of eating beluga, levels of contaminants in belugas, diet, calving grounds, state of beluga and population health, migration, industrial activity, details about the Marine Protected Area, and the future of the Hendrickson Island Research Program. The workshop participants were largely concerned about the safety of eating muktuk and dry meat from belugas, due to the presence of contaminants or infectious diseases.

In general, harvesters gave positive responses about the research taking place on Hendrickson Island. Recommendations for the researchers included: research has to be shared with the harvesters, research should be seen of an equal value if it comes from professional harvesters or academics, and all information should be shared both ways. Harvesters frequently stated that youth need to be taught about harvesting and preparing whale. Harvesters were interested in additional research being carried out to understand why the oksok was soft on some whales, why some whales were skinny, how does muktuk spoil, what is the impact of mining in the Yukon on the rivers and potential effects of Dew-line clean ups on belugas.

The communication event highlighted the importance of consistent and open communication among knowledge-holders. Furthermore, N. Pokiak highlighted the importance of communication among harvesters, to ensure that observations of unusual events and environmental change are documented. There was interest in developing a program to collect and document local and traditional knowledge about belugas. The Science Team and FJMC representatives were able to offer their support to community members who would like to lead future research in the ISR.

We look forward to bringing forward our findings and report book the upcoming results workshop where recommendations on communication and community partnerships will be made. We hope to have funding for our community research partners and projects to all attend the fall workshop.

Expected Project Completion Date

This was our final year and based outcomes will consider a new evolved proposal for 2013.

NCP Performance Indicators

The NCP is obligated to report on its performance on an annual basis, using the performance indicators listed below, as well as other measures. Please assist us by filling out the following table:

Performance Indicator	Number	Details / Description
number of Northerners engaged in your project (April 1, 2011 – March 31, 2012)	15	Leads (2) Youth Beluga TEK (8) RA's (3) HTC RP (1) FJMC reps (2)
number of project-related meetings/ workshops held in the North (April 1, 2011 – March 31, 2012)	3	Tuktoyaktuk, Inuvik, Paulatuk
Number of students and post docs (both northern and southern) involved in your NCP work (April 1, 2011 – March 31, 2012)	9	Sonja Ostertag, Marie Noel, Emily Choy, Mark Andrachuk and 5 youth in the beluga TEK program.
Number of citable publications (e.g., in domestic/international journals, conference presentations, book chapters, etc)	2011:1 2012:2	ArcticNet and IPY meetings. Currently working on a manuscript.

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