Aboriginal Affairs and
Northern Development Canada

Affaires autochtones et
Développement du Nord Canada

Synopsis of Research
Conducted under the 2012–2013 Northern Contaminants Program

Résumé de recherche
effectuées en 2012–2013 dans le cadre du
Programme de lutte contre les contaminants dans le Nord

Canada

Bilingual Colopon page (MISSING)

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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 2012-2013 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.science.gc.ca/ncp

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 2012-2013 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.science.gc.ca/plcn

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 based on an understanding of the species

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.

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 cellesci 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 abouti à la signature de

The NCP is directed by a management committee that 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 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.

Blueprints were developed for each of the four main NCP subprograms: i) Human Health, ii) Environmental Monitoring and Research,

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 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 récolte recueillies dans le cadre du Programme. Le Guide comporte aussi des renseignements

iii) Community Based Monitoring, and iv) Communications, Capacity and Outreach. 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 2012-2013. It is a compilation of reports submitted by project teams, emphasizing the results of research and related activities that took place during the 2012-2013 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 Knowledge Integration; and Communication, Capacity, and Outreach.

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 sousprogrammes 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 2012-2013 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 2012-2013. 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 communication, sensibilisation et consultation.

Human Health

Santé humaine

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 relationship between esterase paraoxonase (PON1), a major component of high-density lipoprotein (HDL), and the intake of traditional food and body burden of contaminants, (2) the communications activities of the contaminant results, and (3) progress of the risk perception study conducted in Nunavut. PON1 activity and metal concentrations were measured in blood collected from 2172 healthy participants. Sociodemographic, anthropometric

Résumé

Cette 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 liens entre l'activité estérasique de la paraoxonase (PON1), un élément important des lipoprotéines de haute densité (HDL), l'ingestion d'aliments traditionnels et les charges corporelles de contaminants, 2) les activités de communications des résultats concernant les

and lifestyle variables were also assessed. The associations between PON1 activity and blood metal concentrations, age, sex, body mass index (BMI), and lifestyle habits (eg. smoking and alcohol consumption) were explored via multiple linear regression. PON1 activity was positively associated with Se blood concentration and n-3 fatty acids in the red blood cells but was negatively associated with Cd blood concentration. No association was observed between PON1 activity and Hg or Pb blood concentrations. Our results suggest that: PON1 activity is modulated by metal exposure, and Inuit traditional foods may confer health benefit by increasing PON1 activity via higher Se and n-3 fatty acids intake rates. These findings underline the importance of considering the nutritional benefits conferred by traditional foods when developing food consumption advisories to limit people's intake of contaminants. Key results/messages from this study were presented in 3 regional reports published and released in June 2012 and a dietary advisory was issued in Nunavut. The perception of contaminants was assessed by interviewing 545 participants in 3 communities in Nunavut in February/March 2013. Results of the study will provide useful information to assist health professionals and policy makers at the regional, provincial, territorial, national, and international levels in developing environmental health policies and aid Inuit in making informed dietary choices.

contaminants et 3) l'état d'avancement de l'étude sur la perception du risque menée au Nunavut. L'activité du gène PON1 et les concentrations de métaux ont été mesurées dans des échantillons sanguins prélevés chez 2172 participants en santé. On a également évalué diverses variables sociodémographiques, anthropométriques et du style de vie. On a étudié les associations entre l'activité du gène PON1, les concentrations de métaux dans le sang, l'âge, le sexe, l'indice de masse corporelle (IMC) et les habitudes de vie (p. ex., tabagisme et consommation d'alcool) au moyen de la régression linéaire multiple. L'activité du gène PON1 a été associée positivement à la concentration de Se dans le sang et les acides gras n-3 dans les globules rouges, mais a été associée négativement à la concentration de Cd dans le sang. Aucune association n'a été observée entre l'activité du gène PON1 les concentrations de Hg ou de Pb dans le sang. Nos résultats donnent à penser que l'activité du gène PON1 est modulée par l'exposition aux métaux et que les nourritures traditionnelles des Inuits peuvent être bénéfiques pour la santé puisqu'elles rehaussent l'activité du gène PON1 grâce à la consommation de Se et d'acides gras n-3. Ces résultats soulignent l'importance de tenir compte des avantages nutritionnels des aliments traditionnels dans l'établissement des avis sur la consommation alimentaire visant à limiter l'absorption de contaminants. Les principaux résultats/messages émanant de cette étude ont été présentés dans trois rapports régionaux publiés et diffusés en juin 2012, et un avis alimentaire a été émis au Nunavut. On a évalué le niveau de perception des contaminants en interviewant 545 participants dans trois collectivités du Nunavut en février et mars 2013. Les résultats de l'étude permettront de disposer de renseignements utiles pour aider les spécialistes de la santé et les décideurs à l'échelle régionale, provinciale, territoriale, nationale et internationale à élaborer des politiques sur la salubrité de l'environnement de même que pour aider les Inuits à faire des choix éclairés quant à leur régime alimentaire.

Keys messages

- Country foods provide many essential nutrients that can lower the risk of chronic diseases.
- Generally, the benefits of eating country foods outweigh the risks from contaminant exposure.
- Inuit women of child-bearing age in Nunavut who may become pregnant, are planning to get pregnant, or are pregnant should avoid eating ringed seal liver due to its high mercury content. Instead, ringed seal meat is a great and healthy alternative.
- Smoking is a major problem for many reasons. One such reason is that smoking exposes Inuit to high levels of cadmium.

Messages clés

- Les aliments traditionnels contiennent de nombreux nutriments essentiels qui peuvent réduire le risque de maladies chroniques.
- De façon générale, les avantages liés à la consommation d'aliments traditionnels sont plus importants que les risques associés à l'exposition aux contaminants.
- Les femmes inuites en âge de procréer au Nunavut qui pourraient devenir enceintes, qui songent à avoir un enfant ou qui sont enceintes devraient éviter de consommé du foie de phoque annelé en raison de sa forte teneur en mercure. Par contre, la viande de phoque annelé constitue un excellent choix pour la santé.
- Le tabagisme est un grave problème pour de nombreuses raisons, notamment les fumeurs sont exposés à des niveaux élevés de cadmium.

Objectives

a. Investigate the interactive effects between dietary nutrients such as selenium, and fatty acids with POPs and metals on health status of the participants

b. 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, inflammation, neurotoxicity and bone mineral density

c. Support the regions, as needed, to develop health prevention and health promotion policies for contaminants in partnership with the regional Inuit organizations and regional health authorities that will inform policy.

d. Develop, pre-test, adapt and deliver the key public health messages in Nunavut

e. Assess risk perception after the implementation of the communication plan in Nunavut to evaluate the impact of the public health messages in 3 Nunavut communities.

Introduction

The Inuit Health Survey is a comprehensive study that included 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 (Saudny et al. 2012). 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.

The enzyme paraoxonase-1 (PON1) is mainly found in the blood bound to high-density lipoprotein (HDL) (Furlong 2008) where it limits low-density lipoprotein (LDL) oxidation (Aviram et al. 1998), and protects against atherosclerosis (Getz and Reardon 2004). Previous studies have shown that higher levels of circulating HDL are associated with higher serum PON1 activity (Ayotte et al. 2011; Hernández et al. 2009; Li et al. 2006). Additionally, it is has been shown that improved nutrient status of selenium (Se) and omega-3 fatty acids (n-3 FA) can result in increased circulating levels of PON1 (Ayotte et al. 2011). The importance of PON1 to health is underlined by the association between serum PON1 activity and numerous human diseases (e.g. cardiovascular disease, Alzheimer's disease, chronic renal failure, and chronic liver impairment) (Marsillach et al. 2008). Further, polymorphisms of the PON1 gene are the primary determinant of serum PON1 activity; these polymorphisms are strongly related to atherosclerosis susceptibility (Sorenson et al. 1999) as well as cardiovascular disease risk (Bhattacharyya et al. 2008). PON1 activity in humans may also be governed by exposure to chemical stressors (Hernández et al. 2009; Li et al. 2006). For example, occupational lead (Pb) exposure is associated with decreased PON1 activity (Li et al. 2006) and cross-sectional studies have shown PON1 activity to be negatively associated with blood cadmium (Hernández et al. 2009).

The understandings and perceptions of risk among people are much richer and more complex than originally thought, and they reflect legitimate concerns that are often omitted from formal risk assessment processes. Assessments of the response to risk communication (e.g., health advisories) indicate that individuals who adapt and respond to environmental or other health advisories within the context of limited socio-economic resources demonstrate more passive strategies or are less inclined to comply with advice (Vaughan, 1995). Similar relationships exist with response or compliance and traditions associated with the performance of the exposure behaviour (Diana et al., 1993). This is very important in the context of compliance or reaction to advisories or advice around contaminants in country foods in the Arctic where limited resources or alternatives to minimize risk sometimes exist. It is important to not only understand individual or population perceptions of contaminant risks in the North but also their relationship to attitudes about country foods and a number of socio-demographic factors that may influence the ability of community members to respond or take action (Burger, 2004). For these reasons, the perceptions of those involved and affected by a hazard must be considered as they directly influence the effectiveness of any risk management decisions and actions (including communications) taken to minimize risks and maximize the benefits. Risk perception has been shown to be influenced by a variety of factors including age, gender, education, occupation, language, world view, and culture (Slovic and Peters, 1995; Myers and Furgal, 2006; Jardine and Furgal, 2007). Prior work in the Canadian North has reported issues with the message reception, recall and comprehension of messages focused on invisible 'chemical' contaminants (Myers and Furgal, 2006).

Activities in 2012-2013

1. Analysis of biomarker, contaminant and dietary nutrient interactions

Of the 2595 individuals participated in IHS, 2172 provided blood samples for the measurement of whole blood metal concentrations and plasma PON1 activity. The survey assessed household overcrowding, food insecurity, biochemical endpoints, chronic disease risk, diet and nutrition, physical activity, mental health and blood concentrations of contaminants; the work described herein focuses exclusively on the contaminant and biochemical data.

All data were analyzed with SAS 9.2 (SAS Institute Inc., Cary, North Carolina, USA) and R 2.11.1 statistical software. The distributions of PON1 activity, blood metal concentrations, and other continuous variables were characterized by measures of their centrality and variability. Normality of covariates distribution was assessed graphically and checked using the Kolmogorov-Smirnov normality test. All continuous variables were logarithmically transformed to normalize their distributions and stabilize their variances. The magnitude of correlation between PON1 and blood metal concentration, as well as age, BMI, sex, smoking status, and alcohol consumption was assessed by the Spearman correlation test. PON1 activity was subjected to simple and multiple linear regression analyses to evaluate the contribution of individual risk factors and metals in unadjusted and adjusted equations on PON1. In all analyses, blood metal concentrations, age, and BMI were all regarded as continuous variables whereas sex, smoking status, and alcohol drinking were regarded as categorical variables. For all tests, results were considered statistically significant when P value was less than 0.05 for a two-tailed test. To determine whether multicollinearity was a problem among the covariates in any multiple linear regression analysis, we ran a variance inflation factor (VIF) analysis on all multiple linear regression analyses. VIF did not exceed 3 in any of the analyses.

2. Delivery and Evaluation of Results Communication

Results of contaminant related data collected by the Inuit Health Survey were published in 3 regional reports in June 2012. The Steering Committee in each region designed the communication plan in each region.

For example, in Nunavut, a meeting with the press was held in Iqaluit in June 38, 2012 (http://www.cbc.ca/news/canada/north/story/2012/06/28/north-nunavut-ringed-seal-liver-warning.html). We collaborated with the communication teams at the Government of Nunavut (GN) and NTI to develop various materials to be distributed to all communities in Nunavut including:

a. A 1-page information sheet (in English, Inuktitut, Inuinnaqtun and French) on: 1) cadmium and smoking; 2) mercury in ringed seal liver; 3) benefits of country food.

b. A public service announcement (video and audio) to be used for community broadcast.

c. A 3-page PowerPoint presentation to be broadcasted in the LCD panels at the community health centres.

In ISR, a 1.5-day workshop was held in Inuvik, NWT, Canada, in July 2012. This regional workshop gathered researchers from Canadian Universities, Inuit community representatives, local and Northwest Territories government representatives and discussed the results and implications of food safety and food security studies results. The group developed a vision for future research and intervention, which is to empower communities to promote health, well being and environmental sustainability in the ISR. Missions and programs for the region that address the following issues: (i) capacity building within communities; (ii) promotion of the use of traditional foods to address food security; (iii) research to better understand the linkages between diseases and contaminants in traditional foods, market foods and lifestyle choices; (iv) and promotion of affordable housing, were identified.

3. Evaluation of Impacts on Risk/Benefit Perception

Drawing upon previous perception survey tools conducted in Nunavut, Nunatsiavut and Nunavik, we developed a questionnaire to assess the perception of risk and benefit of country food after the release of contaminant results. Research ethics approvals were obtained at the University of Ottawa and Trent University. Community members of the following 3 communities: Arviat, Cambridge Bay and Iqaluit were invited to participate in community feasts in February and March 2013. Local interviewers were hired and trained to conduct the interviews. At each gathering, we explained the project and invited community members to participate in the study in the following week. The participation exceeded our target of 100 per communities. We collected a total of 545 questionnaires from the 3 communities and the data are being analyzed. We expect to conduct the same interview in the fall of 2013 to gauge the temporal change of perception after 6 months.

Results

Table 1 details the descriptive statistics of the study variables for the 2172 individuals for whom blood measurements were conducted. Notably, the study population was predominately female (Male: 38 %; Female: 62%) with a mean age of 42 years. It should also be noted that smoking is a major health concern for Inuit, with 94% of participants self-identifying as ever-smokers (i.e., current or former smokers), 69% identifying as current smokers, and 29% smoking more than 10 cigarettes per day. Blood concentrations of all metals were markedly skewed to the right.

Spearman correlation analysis indicated that PON1 activity tended to be higher for females than males and increased with increasing BMI (Table 2). In contrast, the other three co-variables (i.e., age, smoking status, and alcohol consumption) were not significantly correlated with PON1 activity in this study population. Crude linear associations, as quantified by their simple regression ß coefficients, showed the same trends between PON1 activity and sex ($ß = 0.021$, $P < 0.05$) and BMI ($ß = 0.10$, $P < 0.05$). Each of the other covariables were not related to PON1 ($P > 0.05$). However, when these co-variables were included in adjusted multiple regression analyses for each of the four metals (Table 3), a slightly different picture emerged. For example, increased alcohol consumption was consistently associated with higher PON1 activity in each of the four multiple regression models (Table 3). As observed in the correlation analysis, female sex was consistently associated ($P < 0.001$) with increased PON1 activity for each of the metals. However, in stark contrast to the correlation and simple regression analyses, BMI was only weakly associated with PON1 activity in the multiple regression models of Hg, Pb, and Se and showed no association with PON1 activity in the Cd model.

Blood concentrations of Hg, Pb, and Se all increased with increasing age while Cd blood concentrations decreased with increasing age (Table 2). This correlation analysis also showed that participants with higher BMI values tended to have lower Cd and Pb blood concentrations, while levels of Hg and Pb were significantly higher in males than females. Ever-smokers tended to have higher blood concentrations of Cd and Pb than never-smokers (Table 2). Finally, alcohol consumption was negatively correlated with Hg, Pb, and Se blood concentrations but demonstrated a positive and significant association with Cd blood concentration (Table 2).

We found small but significant positive correlations between PON1 activity and the blood concentrations of Hg and Se (Table 2). In contrast, PON1 activity showed a significant negative correlation with blood Cd concentration and no correlation with blood Pb concentration. When the associations between PON1 activity and metal concentration are adjusted for covariables (e.g., age, BMI, sex, smoking status, and alcohol consumption) using multiple linear regression, the results are remarkably consistent with the crude regression models. For example, the strongest association between PON1 activity and blood metal concentration occurs with selenium, both before and after adjustment for the co-variables (Table 3). Also, after adjustment for covariables, Pb remains the only metal that is not associated with PON1 activity, while Cd remains the only metal negatively associated with PON1 activity (Table 3). Notably, Hg is significantly and positively associated with PON1 activity before and after covariable adjustment (Table 3).

Caution must be taken when interpreting the positive associations between PON1 activity and Hg and Se when each metal is considered separately given the strong correlation between Hg and Se blood concentrations (Table 3). Consequently, a stepwise regression was performed to investigate the association between PON1 activity and Hg and Se together, with adjustment for HDL blood concentration, omega-3 fatty acid blood levels, age, sex, BMI, smoking status, and alcohol consumption. Most importantly, this stepwise regression demonstrated that the positive association between PON1 and Hg blood concentration was strictly driven by the covariation between Hg and Se (Table 4). As such, when Hg and Se were considered together in the multiple regression model, it became clear that PON1 activity was positively associated with Se blood concentration but was independent of Hg blood concentration. It is also notable that alcohol consumption was dropped during the stepwise iterations (Table 4) even though it was significantly associated with PON1 activity when Hg and Se were considered separately (Table 3).

Discussion and Conclusions

This cross-sectional study was undertaken to examine whether concentrations of metals in the blood of Inuit are associated with PON1 activity. It was found that Cd exposure was negatively associated with PON1 activity, whereas Pb blood concentration was not associated with PON1 activity. Additionally, Hg and Se were positively associated with PON1 activity when considered separately. However, after the correlation between Hg and Se was accounted for, it became evident that this positive association between PON1 activity and metal concentration was driven strictly by Se and not Hg. As a whole, these results demonstrate that current environmental exposures to metals have the potential to modulate PON1 activity in the blood of Inuit.

The interactions between PON1 and metals have been reported in in vitro studies (e.g. Cole et al., 2002) and in human populations (Ayotte et al., 2011; Hernández et al., 2009; Li et al., 2005). Occupational exposure to Pb was associated with decreased PON1 activity in serum, with this inhibitory effect being most pronounced for subjects carrying two R alleles (Li et al., 2006). The mechanism for PON1 inhibition may be that Pb, like other divalent metal ions, binds to the free thiol group of PON1 located at residue 284 (Cys 284). However, according to the crystal structure of PON1, this cysteine is buried and thus unlikely to play a functional role (Harel et al., 2004). An alternative explanation is that Pb interferes with Cu utilization and it is Cu deficiency that decreases PON1 activity (Klevay, 2004, 2006). Similar Pb blood concentrations (average = 1.3 mM) in an occupationally-exposed cohort also resulted in PON1 inhibition. At much lower blood Pb concentrations (0.19 mM), Pb can be positively associated with PON1 activity (Hernández et al., 2009). This may suggest that Pb stimulates PON1 activity at low exposures but diminishes PON1 activity at higher exposures. Although Pb blood concentrations of participants in the Inuit Health Survey (approximately 0.17 mM) were similar to those reported by Hernández et al. (2009), no relationship was observed between Pb and PON1 activity in the Inuit study population. Therefore, differences between the results reported herein and previous publications are likely driven in part by differences in the study populations (e.g. PON1 genotype, nutrition, smoking status).

The negative association between Cd blood concentrations and PON1 activity reported for the Inuit population (Table 3) is consistent with results reported for residents of Andalusia, Spain (Hernández et al., 2009). Smoking is the single largest source of Cd exposure for both the Inuit in this study and residents of Andalusia (Hernández et al., 2009). In contrast, there was no association between PON1 activity and Cd concentration in the blood of non-smoking Inuit. Given the important role PON1 plays in protection from atherosclerosis, the negative relationship between Cd and PON1 activity poses a legitimate public health concern and may explain, in part, the well-established link between smoking and coronary heart disease. Therefore, the long term effects of Cd should be addressed through the strengthening of ongoing efforts to decrease smoking rates among Inuit in the Arctic.

Through stepwise multiple regression, we showed that higher Hg blood concentrations are not associated with PON1 after adjustment for Se co-exposure (Table 4). This is in agreement with in vivo rodent data that showed no relationship between Hg and PON1 activity (Cole et al., 2002). In contrast, Ayotte et al. (2011) reported an inverse association between blood Hg and PON1 activity for Inuit living in Nunavik, QC, Canada. One possible explanation for the inconsistency between our results and those of Ayotte et al. (2011) is that our model did not include PON1 genotype, whereas PON1 genotype data was included in the multiple regression of the Nunavik dataset. This hypothesis is supported by the fact that both the Inuit Health Survey and Nunavik studies showed significant and positive correlations between Hg and Se blood concentrations and PON1 activity (Table 2). Similarly, Hernández et al. (2009) showed a significant and positive association between Hg blood concentration and PON1 activity without adjustment for Se co-exposure and PON1 genotype.

As observed for Inuit living in Nunavik (Ayotte et al., 2011), higher Se blood concentrations were associated with higher PON1 activity (Table 3, Table 4). Selenium, an essential micronutrient that is a component of the amino acids selenocysteine and selenomethionine, functions as a cofactor for the reduction of antioxidant enzymes involved in redox regulation (Carvalho et al., 2011). It has the ability to catalyze certain reactions that remove reactive oxygen species such as hydrogen peroxide and organic hydroperoxides. It also plays a role in thyroid gland function and in every thyroid hormone-using cell, by acting as a cofactor for thyroid hormone deiodinases while activating then deactivating various thyroid hormones and their metabolites (Berry and Larsen, 1992). Inuit traditional foods, including ringed seal liver, beluga muktuk, and Arctic char, provide a rich source of Se. The consumption of these traditional foods provide Inuit higher blood concentrations of Se than observed in the general Canadian population (Health Canada, 2010). Therefore, the well-documented dietary transition away from Se-rich foods could lead to lower PON1 activity and result in increased risk of atherosclerosis and heart disease (Ayotte et al., 2011). This result highlights the need to consider the health benefits of traditional foods when deriving food consumption advisories to reduce contaminant exposure for Inuit in the Canadian Arctic.

In summary, the results of this cross-sectional study highlight the interactions between metal exposure and PON1 activity in the blood of Inuit living in the regions of Inuvialuit Settlement Region, Nunavut, and Nunatsiavut. Considering the important defensive role this enzyme plays in protection against atherosclerosis, these results should be heavily weighed within the effects assessment component of biomonitoring initiatives. The significant negative association between Cd and PON1 activity in the blood of Inuit provides further support for the ongoing efforts to lower smoking rates in the Arctic. Additionally, this work shows the importance of jointly considering the effects of Hg and Se on biochemical endpoints when conducting epidemiological studies. Future work is needed to elucidate the molecular mechanisms by which Se is able to augment PON1 activity and to identify whether or not these biochemical effects translate into clinical benefits for Inuit.

Expected Project Completion Date

March 2014

Acknowledgments

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Table 1. Descriptive statistics of the demographic study variables, PON1 and metals concentrations in participants (n=2595) of the International Polar Year Inuit Health Survey 2007-2008.

Covariates	n	Range	Geometric Mean (95% CI)	Mean ± SD	Median (IQR)
Age (y)	2595	18 – 100	39.4 (38.9 – 40.0)	42.1 ± 15.2	41.0 (30.0 – 52.0)
BMI (kg/m^2)	2178	16.2 – 62.6	27.7 (27.4 – 27.9)	28.3 ± 6.5	27.4 (23.3 – 32.3)
Sex[a] (% female)	2595	0 – 1	NA	61.5 ± 48.6	1 (0 - 1)
Smoking[b] (% yes)	2206	0 – 1	NA	94.3 ± 23.1	1 (0 – 1)
Alcohol[c] (% yes)	2035	0 – 1	NA	61.4 ± 48.6	1 (0 – 1)
HDL (mmol/L)	2200	0.39 – 4.8	1.43 (1.41 – 1.45)	1.5 ± 0.5	1.4 (1.2 – 1.8)
Omega-3 (% fatty acid)	2201	0.14 – 22.2	4.6 (4.4 – 4.7)	5.8 ± 3.4	5.4 (3.3 – 7.7)
PON1 (U/L)	2214	1290 – 35400	10900 (10800 – 11000)	11300 ± 2960	11100 (9330 – 13000)
Mercury (μg/L)	2172	0.09 – 130	7.0 (6.6 – 7.3)	12.6 ± 14.0	7.8 (3.2 -17)
Cadmium (μg/L)	2172	0.039 – 11	1.6 (1.5 – 1.7)	2.6 ± 2.0	2.5 (0.69 – 3.8)
Lead (μg/L)	2172	4.5 – 400	35 (34 – 36)	46.8 ± 39.6	35 (20 – 61)
Selenium (μg/L)	2172	85 – 2800	319 (312 – 327)	381 ± 281	280 (210 – 450)

[a] Dichotomous variable: 0 = Male; 1 = Female
[b] Dichotomous variable: 0 = Never-smoker; 1 = Ever-Smoker
[c] Dichotomous variable: 0 = No alcohol consumption in past 12 months; 1= Alcohol consumption in past 12 months

Table 2. Spearman (ρ) correlation coefficients between plasma PON1 activity, circulating HDL, erythrocyte omega-3 fatty acids, demographic variables, and metals in whole blood for participants of the International Polar Year Inuit Health Survey 2007-2008[a].

	Age	BMI	Sex	Smoking	Alcohol	Mercury	Cadmium	Lead	Selenium	HDL	Omega-3
PON1	0.031	0.082*	0.095**	-0.034	0.034	0.093**	-0.116**	0.017	0.102**	0.210**	0.117**
Age	-	0.182**	-0.054*	-0.051*	-0.301**	0.436**	-0.230**	0.517**	0.315**	0.121**	0.424**
BMI	-	-	0.132**	-0.073*	-0.061*	0.036	-0.298**	-0.087**	0.079*	-0.338**	0.028
Sex	-	-	-	-0.004	-0.081*	-0.096**	0.008	-0.265**	-0.041	0.159**	-0.034
Smoking	-	-	-	-	0.119**	0.041	0.317**	0.035	0.048	-0.0003	-0.042
Alcohol	-	-	-	-	-	-0.178**	0.165**	-0.152**	-0.124**	-0.016	-0.094
Mercury	-	-	-	-	-	-	0.014	0.486**	0.827**	0.131**	0.501**
Cadmium	-	-	-	-	-	-	-	0.123**	0.029	0.021	-0.082*
Lead	-	-	-	-	-	-	-	-	0.390**	0.0172**	0.319**
Selenium	-	-	-	-	-	-	-	-	-	0.063*	0.403**
HDL	-	-	-	-	-	-	-	-	-	-	0.182**

[a] continuous variables were logarithmically transformed.
*significant correlation at level 0.05 > p > 0.0001.
**significant correlation at level p ≤ 0.0001.

Table 3. Crude and adjusted regression analysis of log10-transformed PON1 activity as a function of metal blood concentrations and background covariables for participants (n=2172) of the International Polar Year Inuit Health Survey 2007-2008.

	Mercury		Cadmium		Selenium		Lead	
	β ± SE	P-value	β ± SE	P-value	β ± SE	P-value	β ± SE	P-value
Metal[a]	0.020 ± 0.005	< 0.001	-0.024 ± 0.005	< 0.001	0.054 ± 0.011	< 0.001	0.0006 ± 0.007	0.93
Metal[b]	0.029 ± 0.005	< 0.001	-0.031 ± 0.006	< 0.001	0.069 ± 0.012	< 0.001	0.016 ± 0.01	0.092
Age	-0.0003 ± 0.0002	0.13	-0.00001 ± 0.0002	0.95	-0.0002 ± 0.0002	0.30	-0.00007 ± 0.0002	0.76
BMI	0.001 ± 0.0004	0.016	0.0003 ± 0.0004	0.41	0.0009 ± 0.0005	0.038	0.001 ± 0.0004	0.01
Sex	0.024 ± 0.005	< 0.001	0.020 ± 0.005	< 0.001	0.022 ± 0.006	< 0.001	0.023 ± 0.005	< 0.001
Smoking	-0.017 ± 0.011	0.13	0.008 ± 0.012	0.47	-0.017 ± 0.011	0.13	-0.024 ± 0.011	0.21
Alcohol	0.014 ± 0.005	0.017	0.015 ± 0.006	0.01	0.014 ± 0.006	0.021	0.012 ± 0.005	0.032

[a] crude relationship.

[b] adjusted relationship.

Table 4. Stepwise multiple regression analysis of log10-transformed PON1 activity on Hg and Se blood concentrations with adjustment for background co-variablesa.

	β ± SE	P-value
Mercury[b]	0.0007 ± 0.0084	0.937
Selenium[b]	0.047 ± 0.018	0.008
HDL	0.061 ± 0.006	< 0.0001
Omega-3	0.0027 ± 0.0010	0.005
Age	-0.0009 ± 0.0002	< 0.0001
BMI	0.0026 ± 0.0005	< 0.0001
Sex	0.0117 ± 0.0057	0.039

[a] Background co-variables inputted stepwise in the model included HDL, Omega-3, age, sex, BMI, smoking status, and alcohol consumption.

[b] Blood metal concentrations constrained in the model.

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

Étude sur une cohorte d'enfants du Nunavik : suivi en fin d'adolescence

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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 20 years: monitoring of prenatal exposure from cord blood sampling, an effect study with infants up to 12 months of age, and an effect study at preschool age. In 2010, we completed the follow-

Résumé

L'exposition prénatale aux biphényles polychlorés (BPC) et au mercure a été associée à des effets sur la croissance et le développement cognitif des enfants. Les Inuits du Nunavik comptent parmi les populations les plus exposées à ces polluants environnementaux en raison du fait qu'ils consomment des poissons et des mammifères marins qui accumulent ces polluants dans leurs tissus. Toutefois, les poissons et les mammifères marins fournissent aussi des nutriments tels que les acides gras oméga-3, lesquels favorisent le développement du cerveau en bas âge. Au cours des 20 dernières années, nous avons mené quatre études au Nunavik : surveillance de l'exposition prénatale à l'aide d'échantillons de sang de cordon, et effets sur les nourrissons de 12 mois et

up of 294 11 year-old children and, during the years 2010 and 2011, we analyzed most of the 11-year data. In fall 2011, study results were presented to the Nunavik population and public health recommendations were provided by the Public Health Director of Nunavik. Summary of study results and public health recommendations can be found at http://www.rrsss17.gouv.qc.ca. During the years 2011 and 2012, we completed the knowledge transfer activities, communicated the final study results to the Nunavik population and stakeholders and completed the analyses of the 11-year data. In 2012-2013, we launched the follow-up of the cohort at adolescence. We successfully pre-tested the research procedures and selected tests/instruments, and recruited and tested 61 adolescents aged between 16 and 19 years old living in communities located in Ungava Bay Coast. For 2013-2014, we are proposing to continue this work and recruit 66 additional adolescents living in communities from the Hudson Bay Coast.

moins et sur les enfants d'âge préscolaire. En 2010, nous avons achevé le suivi de 294 enfants de 11 ans et, en 2010 et en 2011, nous avons analysé la plupart des données relatives à ces enfants. À l'automne 2011, les résultats de l'étude ont été présentés à la population du Nunavik et des recommandations en matière de santé publique ont été formulées par le directeur de la santé publique du Nunavik. Un résumé des résultats d'études et des recommandations en matière de santé publique est publié à l'adresse suivante : http://www.rrsss17.gouv.qc.ca. En 2011–2012, nous avons mené à bonne fin le transfert des connaissances, communiqué les résultats finals de l'étude à la population et aux parties intéressées du Nunavik et achevé l'analyse des données concernant les enfants de 11 ans. En 20122013, nous avons amorcé le suivi de la cohorte à l'adolescence. Nous avons mis à l'essai de façon préalable, et avec succès, les procédures de recherche, avons choisi les tests et instruments et avons recruté et soumis à des tests 61 adolescents âgés de 16 à 19 ans vivant dans des communautés situées sur les côtes de la baie d'Ungava. Pour 20132014, nous proposons de poursuivre ces travaux et de recruter 66 autres adolescents dans les communautés établies le long des côtes de la baie d'Hudson.

Key Messages

- The first data collection trip was completed in Kuujjuaq (Jan 25 to Feb 22 2013) with 61 participants successfully tested.
- We obtain additional support from these Nunavik organizations: Nunavik Nutrition and Health Committee; Board of the Kativik Regional Government; Inuit Circumpolar Council –Canada Office; Municipal council of Kuujjuaq; Executive Board of the Nunavik Regional Board of Health and Social Services; Director of Tulattavik Health Center.
- We obtained an additional grant for funding the research activities to be held during 2012/2013 from the Canadian Institutes of Health Research.

Messages clés

- La première campagne de collecte de données (du 25 janvier au 22 février 2013) a eu lieu à Kuujjuaq, où nous avons réussi à recueillir les données de 61 participants.
- Nous avons obtenu un soutien additionnel de la part des organismes du Nunavik suivants : Comité de la nutrition et de la santé du Nunavik, Conseil de l'Administration régionale Kativik, Conseil circumpolaire inuit (bureau du Canada), conseil municipal de Kuujjuaq, conseil d'administration de la Régie régionale de la santé et des services sociaux Nunavik, Centre de santé Tulattavik (directrice).
- Les Instituts de recherche en santé du Canada nous ont accordé une subvention additionnelle pour les activités de recherche prévues en 2012–2013.

Objectives

1. Consultation meetings with Inuit youth representatives.
2. Consultation meetings with Nunavik stakeholders.
3. Pilot research procedures and instruments.
4. Enrollment and testing of the first 60 participants.

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 ammunition.

The first phase of the study was initiated in 1996. We investigated the role of 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 Public Health Director (PHD) of Nunavik.

We decided to continue the study with children at 11 years old to observe if adverse effects found during infancy would impact on child development at school age. Between September 2005 and February 2010, 294 children and their mothers from all 14 Nunavik communities participated in the follow-up. 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). Results and implications from the second phase of this study, when infants were examined at 11 years of age, were communicated to the Nunavik population by the researchers and public health officials in 2011-2012. Public health recommendations were also provided to the population by the PHD. In order to document the long term effects of exposure to environmental contaminants, we decided to follow the cohort at 16-19 years of age. The final sample should consist of approximately 200 adolescents from the 14 Nunavik communities, which corresponds to 72% of the eligible children seen at age 11 years.

Activities in 2012/2013

1. **G Muckle met with the NNHC in November 2012 to update the committee members with regard to the study procedures. She also obtained additional support from the following Nunavik stakeholders and representatives:**
    - Inuit Circumpolar Council –Canada Office;
    - Municipal council of Kuujjuaq;
    - Executive Board of the Nunavik Regional Board of Health and Social Services;
    - Board, Kativik Regional Government;
    - Director of Tulattavik Health Center.

2. **Research activities completed prior to the data collection are:**
    - Consultation with the Nasivvik Inuit research advisor on study procedures and instruments;
    - Selection of the tests and questionnaires to be use with adolescents;
    - Purchase of research equipment and tests;
    - Development of the consent forms (6 versions: minor child French, English, Inuktituk; major child, French, English, Inuktituk);
    - Development of an invitation letter, a study pamphlet to be provided to participants, and the study poster to be posted in public places in Nunavik;
    - Ethical review process at the CHUQ Research Center;
    - Development of operational procedures for manipulations of biological specimens with the collaborating laboratories;
    - Development of operational procedures for blood and sampling;
    - Completion of working agreements with hospital authorities and staff from Kuujjuaq;
    - Hiring and training all the research personnel: the Inuit research professional, the research nurse, the youth interviewer, the youth tester;
    - Search for and renting of a working place for the team to do the data collection;
    - Shipment the study material and equipment to Kuujjuaq;

3. **The study procedures and the selected tests/instruments were pre-tested during the first week of the field work in Kuujjuaq.**

4. **Between January 25 and February 22 2013, we successfully recruited and tested 61 participants from Ungava Bay in Kuujjuaq. Participants were contacted by phone, were provided with information about the study protocol, and were invited to participate in Kuujjuaq. Participants from other communities**

located in Ungava Bay coast were transported by plane to to Kuujjuaq.

5. **We obtained one grant outside the NCP for co-funding the study: Canadian Institutes of Health Research (CIHR), 10/2012 to 03/2013, 100 000$. A new grant proposal was submitted to the CIHR March 1st 2013 for co-funding the follow-up at adolescence during the next 4 years.**

Capacity Building

During the previous phase of the study each child was evaluated by four examiners and two of these evaluators were Inuit. We have trained two Inuit women for child testing; they tested all children seen at age 11years. They received a high level of training and their involvement in this study makes them very skilled and sought-after for work with school and hospital specialists on child psychology, psychiatry, pediatrics and learning disabilities. Furthermore, we have always worked with one and sometimes two interpreters when conducting the field work. A total of 5-6 interpreters have been trained previously to do maternal interviews. For this current phase, we are hiring one Inuit women as a research professional. This person has previously worked with us as an interpreter but her new responsibilities fall far beyond interpretation and include: recruitment and consent, scheduling appointments, arranging local transportation and coordinating flight and lodging arrangements for out of town participants and interpreting when needed.

Communications

During the data collection trip in January 2013, study posters have been posted in communities (e.g. municipal offices, nursing stations, school, youth house, groceries). The fact sheet presenting the main results of the 11-year follow-up and the public health recommendations provided to the population in 2011 has been given to each participating adolescent along with our study pamphlet. Participants were also informed that we created a Facebook page for them. This Facebook page was designed to share progress and results from the current and previous phases of the study, and to provide information relevant for youths.

Traditional Knowledge Integration

Pure traditional knowledge was not integrated in the research protocol and methods but better understanding of traditional knowledge will be particularly important in examination of emotional development of adolescents. Consultation activities conducted in 2012 provided us access to the Inuit perspective with regard to adolescent development and adaptation. Based on our previous experience, intensive field work will provide opportunities for very informative discussions with Inuit that are likely to strengthen our understanding of the adolescent period in a culturally relevant way.

Results

We are currently conducting the data entry of results from biological samples and of child assessments collected in January 2013. Therefore, we do not have results to provide at this step of the data collection at adolescence. Below are the abstract of the most recent and relevant publications with regard to results from the previous phases of the study.

Boucher, O., Jacobson, S.W., Plusquellec, P., Dewailly, E., Ayotte, P., Forget-Dubois, N., Jacobson, J.L., & Muckle, G. (2012). Prenatal methylmercury and postnatal lead exposure: risk factors for attention deficit hyperactivity disorder among Inuit children in Arctic Quebec. Environmental Health Perspectives, 120(10): 1456-1461.

Background: Prenatal exposure to methylmercury (MeHg) and polychlorinated biphenyls (PCBs) has been associated with impaired performance on attention tasks in previous studies, but the extent to which these cognitive deficits translate into behavioral problems in the classroom and attention deficit hyperactivity disorder (ADHD) remains unknown. By contrast, lead (Pb) exposure in childhood has been associated with increased risk of ADHD and disruptive behaviors in several studies. Objectives: This study examined the relation of developmental exposure to MeHg, PCBs, and Pb to behavioral problems at school age in Inuit children exposed from their traditional diet. Methods: In a prospective longitudinal study conducted in the Canadian Arctic, exposure to contaminants was measured at birth and at school age. An assessment of child behavior (N = 279; mean age = 11.3 years) was obtained from the child's classroom teacher on the Teacher Report Form (TRF) from the Child Behavior Checklist, and the Disruptive Behavior Disorders Rating Scale (DBD). Results: Cord blood mercury concentrations were associated with higher TRF symptom scores for attention problems and scores consistent with ADHD diagnoses on the DBD. Current blood Pb concentrations were associated with higher TRF symptom scores for externalizing problems and with ADHD (hyperactive-impulsive type) on the DBD. Conclusions: This study is the first to identify prenatal MeHg exposure as a risk factor for ADHD symptomatology in childhood and, to our knowledge, is also the first to replicate previously reported associations between low-level childhood Pb exposure and ADHD in a population exposed primarily from dietary sources.

Dallaire, R., Dewailly, É., Ayotte, P., Forget-Dubois, N., Jacobson, S.W., Jacobson J.L., Muckle, G. (2013). Effects of exposure to persistent organic pollutants and mercury through fish and marine mammal consumption on growth and gestation of Inuit newborns. *Environmental International*, 54: 85-91. doi: 10.1016/j.envint.2013.01.013

Background: Effects of polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB) and mercury (Hg) on duration of gestation and foetal growth in fish eating populations, and docosahexaenoic acid (DHA) from seafood intake has been shown to have beneficial effects on pregnancy outcomes and foetal growth. So far, it remains unclear, however, if the effects of those environmental contaminants (ECs) on growth are direct or mediated through their impact on duration of gestation and the degree to which DHA intake during pregnancy attenuates the adverse effect of ECs on fetal growth.

Objectives: To investigate direct and indirect associations of *in utero* exposure to ECs with foetal growth and pregnancy duration while taking into account the possible beneficial effects of DHA.

Methods: Pregnant Inuit women ($N = 248$) from Arctic Quebec were recruited and cord blood samples were analyzed for PCBs, HCB, Hg and DHA. Anthropometric measurements were assessed at birth. Path models were used to evaluate direct and indirect effects.

Results: Path models revealed that all the associations of ECs with reduced foetal growth were mediated through their relationships with shorter pregnancy duration. Cord DHA was indirectly related to greater growth parameters through its positive association with gestation duration.

Conclusion: Prenatal exposure to ECs was associated with reduced pregnancy duration, which adversely affected foetal growth in a fish eating population. DHA intake during pregnancy appeared to have independent and beneficial effects by prolonging gestational length.

Discussion and Conclusions

The follow-up at age 11 years 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. Activities planned for the current year were successfully conducted, without significant changes, and in accordance the expected timeline. The current phase of this prospective longitudinal mother-child cohort successfully started in 2013 with the recruitment of 61 participants for the follow-up of the cohort at the adolescence period. For the next year, we aim to recruit 66 participants, and by 2017, we aim to recruit 200 participants.

Publications in peer-reviewed journals

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Dallaire, R., Dewailly, É., Ayotte, P., Forget-Dubois, N., Jacobson, S.W., Jacobson J.L., Muckle, G. (2013). Effects of exposure to persistent organic pollutants and mercury through fish and marine mammal consumption on growth and gestation of Inuit newborns. *Environmental International*, 54: 85-91.

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Expected Project Completion Date

End of data collection 03/2017

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

Étude sur une cohorte d’enfants du Nunavik : étude complémentaire de suivi auprès d’adolescents – comportements et stress observés

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Abstract

Prenatal exposure to lead, PCBs and mercury were associated to behavioural impairments in children. In the last three cohort studies conducted in Nunavik (1 year-old, 5 years-old, 11-years-old), we have assessed behavioural development and found subtle effects of lead on attention, activity, impulsivity, but also of PCBs on emotional outcomes. For year 2012/2013, we have proposed an add-on study to the main follow-up of children at age 17 proposed by

Résumé

L’exposition prénatale au plomb, aux biphényles polychlorés (BPC) et au mercure a été associée à des troubles du comportement chez les enfants. Dans le cadre des trois dernières études de cohortes que nous avons menées au Nunavik (sujets âgés de 1 an, de 5 ans et de 11 ans), nous avons évalué le développement sur le plan du comportement et constaté des effets discrets du plomb sur le niveau d’attention, d’activité et d’impulsivité,

G Muckle. Adolescence is thus a period at which mechanisms of hormone disruption by environmental contaminants become obvious, and at which emotional development is particularly at risk. Our project focuses on the assessment of observational data on attention, activity and emotional reactivity obtained from coding of videotapes since those data have been shown to be highly sensitive to environmental contaminants exposure. Furthermore, this project focus on the assessment of the endocrine stress system through a self-report questionnaire, saliva samples and hair sample to assess reactive glucocorticoids levels following the testing situation, and chronic stress. This focus on the stress system is based on recent scientific results showing that exposure to environmental contaminants may impair this endocrine system, and thus impact behavioural outcomes. Data collection on Inuit adolescents from 17 year-olds was realised during Winter 2013. Therefore, results are not yet available for these participants because behavioural observations as well as environmental contaminants and glucocorticoids levels are currently under analysis. Nonetheless, we pursue our analysis of children cohorts. In the 11 year-old children, results showed that postnatal exposure to Pb was still associated with increased activity and increased inattention, and also that prenatal exposure to PCBs was still related to increased negative affect during the blood test situation. In addition, we begin the analysis of the Nunavik Inuit Health Survey involving Inuit adults. Preliminary results suggest significant associations between increased exposure to 3 toxic metals (Pb, Hg, Cd) or 8 persistent organic pollutants (PCB 153, p,p'-DDE, trans-nonachlor, oxchlordane, PBDE 47, PFOS, PCP and toxaphene) and allostatic load, a validated indicator of chronic stress. These results indicate that exposure to environmental contaminants may trigger the chronic stress that leads to behavioural and psychological outcomes, as hypothesized.

mais aussi des effets des BPC sur le plan affectif. Pour l'année 2012-2013, nous avons proposé une étude qui complèterait l'étude principale de suivi des enfants ayant atteint l'âge de 17 ans proposée par G. Muckle. L'adolescence est une période où les mécanismes de perturbation hormonale causée par les contaminants de l'environnement deviennent manifestes et où le développement affectif est particulièrement à risque. Notre projet consiste à évaluer les données d'observation relative à l'attention, à l'activité et à la réactivité émotionnelle issues du codage des comportements enregistrés sur bandes-vidéo, car un lien étroit a été établi entre les comportements étudiés et l'exposition aux contaminants de l'environnement. Il consiste également à évaluer le système endocrinien d'adaptation au stress en déterminant, à l'aide d'un questionnaire d'autoévaluation et d'échantillons de salive et de cheveux, les taux de glucocorticoïdes réactionnels des sujets après une séance de tests et en état de stress chronique. L'accent a été mis sur le système d'adaptation au stress en raison des résultats d'études scientifiques récentes indiquant que l'exposition aux contaminants de l'environnement peut perturber le système endocrinien et, par conséquent, affecter le comportement. Étant donné que la collecte de données auprès des adolescents inuits de 17 ans a été effectuée au cours de l'hiver 2013 et que l'analyse des observations comportementales ainsi que des taux de contaminants environnementaux et de glucocorticoïdes est toujours en cours, les résultats concernant ces participants ne sont pas encore accessibles. Nous poursuivons néanmoins notre analyse des cohortes d'enfants. Chez les enfants de 11 ans, les résultats indiquent que l'exposition postnatale au plomb était encore associée à un niveau élevé d'activité et d'inattention, et que l'exposition prénatale aux BPC était encore liée à une augmentation du nombre d'affects négatifs observés au moment de la prise de sang. Nous avons en outre commencé l'analyse des données de l'Enquête de santé auprès des Inuits du Nunavik à laquelle ont participé des Inuits adultes. Les résultats préliminaires laissent croire à l'existence de relations significatives entre une exposition accrue à trois métaux toxiques (plomb, mercure et cadmium) ou à huit polluants organiques persistants (PCB 153, p,p'-DDE, trans-nonachlore, oxychlordane, PBDE 47, PFOS, PCP et toxaphène) et la charge allostatique, un indicateur validé de stress chronique. Ces résultats révèlent que l'exposition aux contaminants environnementaux peut déclencher un stress chronique entraînant des effets comportementaux et psychologiques, conformément à l'hypothèse posée.

Key Messages

- Associations found between environmental contaminants and behavioral development are subclinical. It means that it does not impact the day to day functioning of Inuit children, but it prevents Inuit children from expressing their full potential of behavioral development. Those adverse associations were still measurable at 11 years of age.
- In Inuit adults, preliminary results suggested that increased exposure to 3 toxic metals (Pb, Hg, Cd) or 8 persistent organic pollutants (PCB 153, p,p'-DDE, trans-nonachlor, oxchlordane, PBDE 47, PFOS, PCP and toxaphene) may be significantly associated with chronic stress.
- The data collection for the ongoing study has been launched in February 2013 and to date, 58 Nunavik teenagers have been successfully tested at 17 years of age.

Messages clés

- Les relations mises en évidence entre les contaminants environnementaux et le développement sur le plan du comportement sont de nature sous-clinique, ce qui signifie que les effets n'altèrent pas le fonctionnement au quotidien des enfants inuits, mais ils empêchent l'expression du plein potentiel de développement de ces enfants sur le plan comportemental. Ces relations néfastes étaient encore mesurables à l'âge de 11 ans.
- Chez les Inuits adultes, les résultats préliminaires semblent indiquer qu'une exposition accrue à trois métaux toxiques (plomb, mercure et cadmium) ou à huit polluants organiques persistants (PCB 153, p,p'-DDE, trans-nonachlore, oxychlordane, PBDE 47, PFOS, PCP et toxaphène) peut être associée de façon significative à l'état de stress chronique.
- La collecte de données dans le cadre de l'étude en cours a commencé en février 2013 et, jusqu'ici, nous avons obtenu la participation de 58 adolescents de 17 ans du Nunavik.

Objectives

Adolescence is a critical period of development at which great changes in the body occur that are orchestrated by hormonal changes. Environmental contaminants are known to disrupt these hormonal changes. We thus plan to characterize these disruptions and their consequences for Inuit adolescents' emotional and behavioural development.

The objectives of the current project were:

- to conduct an add-on study with 17-year old children in order to test whether sub-clinical impairments observed in the previous study would persist in adolescence
- to conduct an add-on study with 17-year old children in order to test whether those sub-clinical impairments could be explained by the endocrine disrupting properties of environmental contaminants on the stress system

The current project addresses health effects priorities identified in the NCP Blueprints 2012/2013, under category 4.4 Human Health Effects Research and more specifically, "Studies examining NCP relevant endocrine disrupting contaminants including pathways, interactions and effects studies" but also "Research on NCP-relevant contaminants effects on immune, neurobehavioral, and cardiovascular systems function, pathways and effects."

Introduction

Adolescence is a period of great changes in the body functioning, and these changes are mainly orchestrated by hormones, called steroids, which are measurable in adolescents. Because steroids are known to be disrupted by low-level exposure to environmental toxins (*1-4*), it is critical to study the effects of environmental toxins on adolescents' steroids and the body and brain functions they impact on. From fetal life to adolescence, brain structures are developed and vital connections are established. These developmental processes create windows of great vulnerability to environmental toxins, in which even low levels of exposure can produce developmental impairments. Literature on child toxicology is extensive but literature on adolescent toxicology is scarce.(*5*) Yet, this time during the life course offers a unique opportunity to consider the mechanism by which environmental toxins influence development – through endocrine disrupting chemicals – and to better understand the effects associated with these disruptions. In this study, we focus on the corticosteroids, namely the endocrine stress system.

In Inuit from Nunavik, adolescence is a particular period of vulnerability for psychological well-being. For example, the 1992 Inuit Santé Quebec survey found that 38% of a sample aged 15-24 year-olds had suicidal ideation, 22% reported having attempted suicide in their lifetime, and 13% had attempted suicide in the year before the survey(*6*). These results have been replicated and are even more alarming in the 2004 Nunavik Inuit Health Survey. Young adults with suicide ideation in the past 12 months or a previous lifetime suicide attempt had higher levels of psychological distress, impulsivity, and boredom proneness, and lower levels of self-esteem compared to those without the given suicidal behaviour. In many studies, levels of psychological distress has been associated with the onset of puberty and its hormonal changes(*7, 8*), and environmental toxins have been related to impulsivity and psychological distress(*9, 10*).

Studies have shown that Inuits from Nunavik are significantly more exposed to Pb, PCBs and MeHg than the general population from Southern Quebec(*11*). These environmental toxins have been shown to impair behavioural development even at low doses of exposure. Importantly, little is known about the mechanism of action of environmental toxins in the developing human although more and more studies emphasized the endocrine disrupting properties of environmental toxins. Thus, the next generation of studies should have the ambition to understand how these common environmental toxins impair children's development and functioning in order to be able to precisely generate public health recommendations. Therefore, our aim was to address this research question by measuring in Inuit teenagers' levels of stress hormones, and behavioural/emotional outcomes.

Activities in 2012-2013

In direct relation with the objectives of the current project, we have prepared instruments for data collection, and this data collection on 58 seventeen year-old Inuit adolescents was realised from January 23rd to February 22nd 2013. Video recordings of different testing situations have been done, and behavioural dimensions are currently being extracted in our lab from those videos. Hair samples, and saliva samples collected to assess the levels of stress hormones have been sent to the biochemical lab, and are going to be analysed in a few weeks. Results are thus not yet available for 17 year-old Inuit adolescents. On the other hand, we pursue the analysis of the association between environmental contaminants and 11-year old children behavioural dimensions. We plan to publish these results in 2013. In addition, we started the investigation of the link between environmental contaminant exposure and stress in Inuit by performing analysis on the NUNAVIK INUIT HEALTH SURVEY involving 914 adults from 18 to 74 year-old.

Results

In the FOLLOW-UP study (11 year-old children), results showed that postnatal exposure to Pb was still associated with increased activity and increased inattention, and also that prenatal exposure to PCBs was still related to increased negative affect during the blood test situation. These results will be published in an international peer-reviewed journal.

With the NUNAVIK INUIT HEALTH SURVEY, preliminary results suggest that exposure to 3 toxic metals (Pb, Hg, Cd), 4 legacy persistent organic pollutants (PCB 153, *p,p'*-DDE, trans-nonachlor, oxchlordane) or 4 emerging persistent organic pollutants (PBDE 47, PFOS, PCP and toxaphene) may be significantly associated with allostatic load, a validated chronic stress indicator(*12, 13*).

Discussion and Conclusions

Results on the FOLLOW-UP STUDY confirmed that environmental contaminants may impair behavioural development in the long term, even if we should emphasize that this impairment are slight. Importantly, little is known about the mechanism of action of environmental contaminants in the developing human although more and more studies emphasized the endocrine disrupting properties of environmental contaminants. And focusing on adolescents, whose endocrine system is fully developed, may provide meaningful results to better understand how environmental contaminants have an impact on Inuit development.

In addition, we examined whether environmental contaminants exposure among the Inuit population is associated with altered stress endocrine system by looking at the allostatic load index. Allostatic load index is a validated measure of chronic stress representing multi-systemic physiological dysregulations in response to environmental demands (13, 14). Allostatic load index was calculated using 14 biomarkers representing neuroendocrine, immune, cardiovascular and metabolic systems (13). Preliminary analysis shows that increased exposure to ECs may be significantly associated with allostatic load in the adult Inuit population of Nunavik, thereby indicating that exposure to environmental contaminants may trigger the chronic stress that leads to behavioural and psychological outcomes, as hypothesized. We have done this preliminary analysis with 3 toxic metals, 4 legacy persistent organic pollutants and 4 emerging persistent organic pollutants relevant to NCP and identified as priority contaminants by the Nunavik Inuit Health Survey.

Those last results encourage our team to go further in the characterization of the stress system in the ongoing Inuit cohort, in order to better understand how environmental contaminants may play a role on adolescents behavioural development in Nunavik.

NCP Performance Indicators

Northerners are not directly engaged in the current project. But video recordings have been done during Gina Muckle's data collection which involved Northerners.

Transfer of knowledge has been ensured and will continue to be ensured through consultation with the Nunavik Nutrition and Health Committee (NNHC; 2007, in Quebec city; 2008, in Kujjuuaq; 2010 in Kujjuuaq; 2013 in Quebec city). A working group was created and was composed of key researchers, the Nunavik Public Health Director (PHD), members of Nunavik Nutrition and Health Committee (NNHC) and other community representatives, and was implemented in 2010 to develop a communication plan for dissemination of study results to frontline workers, organizations and communities. Press release was done in October 5, 2011 with updated recommendations for the Inuit Population concerning environmental contaminants but also nutrients. In an innovative way, YouTube capsules have been released (www.rrsss17.gouv.qc.ca), which present particularly the highlights of the research. An open line on local radio station was also offered to Nunavimmiut on October 6, 2011.

Since September 2012, a post-doctoral fellow is directly involved in this project. He coordinates the data collection held in January and February 2013. In addition, he performs the statistical analysis between environmental contaminants exposure and chronic stress in adult Inuits, and he is going to work to a communication plan related to the stress results when they will be available.

Four publications have been released in relation with the NCP work since 2011:

1. Saint-Amour, D., Ethier, A. A., Boucher, O., **Plusquellec, P.,** Bastien, C.H., Dewailly, E., Ayotte, P., Jacobson, S.W., & Jacobson, J.L. Muckle, G. Contribution des neurosciences cognitives pour l'étude de l'impact des contaminants environnementaux sur le développement des fonctions cérébrales. Revue de Neuropsychologie 2012, 3:163-173.

2. 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. Environ Health Perspect 2012, 120:1456-61.

3. Lanoix, D., **Plusquellec, P**. Social inequalities influencing allostatic load: Indigenous Peoples of North America. in: 3rd Neuropsychopathology handbook 2015. (in-press)

4. Lanoix, D., **Plusquellec, P**. Adverse effects of pollution on mental health: the stress hypothesis. Evidence-Based Medicine. Submitted.

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9. J. L. Jacobson, S. W. Jacobson, Prenatal exposure to polychlorinated biphenyls and attention at school age. *Journal of Pediatrics* **143**, 780 (2003).

10. P. Stewart *et al.*, Response inhibition at 8 and 9 1/2 years of age in children prenatally exposed to PCBs. *Neurotoxicology and Teratology* **27**, 771 (2005).

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

Surveillance des tendances spatiales et temporelles des concentrations de polluants environnementaux dans les échantillons de sang provenant de mères au Nunavik (année 2)

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Abstract

Previous studies conducted in Nunavik in the early 90's revealed that the Inuit population was exposed to a wide range of environmental contaminants through its traditional diet; this included several metals and persistent organic pollutants (POPs). Unfortunately, other studies revealed that prenatal exposure to mercury and some POPs was also associated with growth and effects on cognitive development in children. Hence, conducting monitoring activities seems

Résumé

Des études antérieures menées au début des années 1990 au Nunavik ont permis de constater que la population inuite était exposée à une vaste gamme de contaminants environnementaux par le biais de ses aliments traditionnels. On pense notamment à divers métaux et aux polluants organiques persistants (POP). Malheureusement, il est ressorti d'autres études que l'exposition prénatale au mercure et à certains POP était également

essential 1) to ensure that exposure of Inuit mothers to these contaminants do not exceed the threshold limit values recommended by Health Canada, and 2) to facilitate the implementation of prevention programs related to this issue. Over the last 20 years, contaminant blood levels in pregnant Inuit women were measured during two health surveys conducted in 1992 and 2004. The current project aimed to extend the monitoring of temporal trends of environmental contaminants in maternal blood to cover a 20-year period (1992-2012). This year, we completed the recruitment of 95 pregnant women and started data analysis. Preliminary results suggest that levels of toxic metals and most POPs (including PCBs, chlorinated pesticides, perfluorooctane sulfonate and polybrominated diphenylethers) significantly decreased in maternal blood over the last two decades. Only PBDE153 seems to have significantly increased over the last 8 years.

liée à la croissance et à divers effets sur le développement cognitif des enfants. Par conséquent, il semble essentiel d'entreprendre des activités de surveillance pour 1) s'assurer que l'exposition des mères inuites à ces contaminants ne dépasse pas les valeurs limites recommandées par Santé Canada et 2) faciliter la mise en œuvre de programmes de prévention à cet égard. Au cours des 20 dernières années, les niveaux de contaminants présents dans le sang des Inuites enceintes ont été mesurés lors de deux enquêtes sur la santé, l'une réalisée en 1992 et l'autre en 2004. Le projet actuel visait à élargir la surveillance des tendances temporelles concernant les contaminants environnementaux présents dans le sang des mères, et ce, de manière à couvrir une période de 20 ans (1992-2012). Cette année, nous avons terminé le recrutement de 95 femmes enceintes et commencé l'analyse des données. Les résultats préliminaires donnent à penser que les concentrations de métaux toxiques et de la plupart des POP (y compris les BPC, les pesticides chlorés, le sulfonate de perfluorooctane et les polybromobiphényléthers) dans le sang maternel ont diminué de façon marquée au cours des deux dernières décennies. Seul le PBDE153 semble avoir connu une augmentation importante au cours des huit dernières années.

Key Messages

- Levels of lead, mercury and several legacy POPs seem to have significantly decreased over the last 20 years in pregnant Inuit women.
- PBDE 153 exposure increased between 2004 and 2012.
- Few Inuit mothers seem to have heard about the communication campaign of the Nunavik Child Cohort Study and related dietary recommendations for pregnant women.

Principaux messages

- Les concentrations de plomb, de mercure et de plusieurs POP traditionnels présentes dans le sang des Inuites enceintes semblent avoir diminué de façon importante au cours des 20 dernières années.
- L'exposition au PBDE 153 a augmenté entre 2004 et 2012.
- Peu de mères inuites semblent avoir entendu parler de la campagne de communication de l'Étude sur une cohorte d'enfants du Nunavik et des recommandations alimentaires connexes à l'intention des femmes enceintes.

Objectives

The general objective of this project is 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 polybrominated diphenyl ethers (PBDEs). This project corresponds to point 4.3.2.2 on biomonitoring of the applicable NCP Blueprint for 2011-2012.

The specific objectives are:

- To follow temporal trends for contaminants, assess the effectiveness of the Stockholm convention and prepare to assist the future UNEP convention on mercury. At the same time, by establishing this monitoring activity, Canada will meet AMAP requirements.
- To follow temporal trend of key nutrients such as omega-3 polyunsaturated fatty acids (n-3 PUFAs) 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 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. 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 PUFAs 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 associated with high n-3 PUFA intake. The effects of prenatal exposure to emerging contaminants such as PBDEs and other BFRs, HPCs and PFOS have not yet been investigated.

In fall of 2004, pregnant women participating to the Nunavik Health Survey 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 at assessing exposure to environmental contaminants through maternal blood monitoring but it also proposed to examine n-3 PUFAs and selenium content in order to interpret any change in contaminant body burdens.

Activities in 2012-2013

Collecting data

The field work was prepared from the beginning of year 2012, as a research nurse was trained during summer time in Quebec City by the project coordinator. All supplies were provided to her in order to properly collect samples and data on site (vacutainers, vials, questionnaires, centrifuge, etc.), and to be as autonomous as possible during her field work in Nunavik. Pregnant Inuit women were invited to participate and once the eligibility criteria was verified, the research nurse explained the objectives of the project, the questionnaire, the sampling procedures, risks/benefits associated with their participation to the program and the need to collect data from their medical file. Informed consent was sought from all 95 participants. The research nurse was assisted by a local recruiter/interpreter in each community. Moreover, the research nurse collected the information requested from the medical file for the 17 participants from year 2011-2012. Two visits were done on site by the research nurse, the first one (from September 5th to October 6th 2012) in the communities of Kuujjuaq (n=21), Kangirsuk (n=3), Kangiqsujuaq (n=3), Salluit (n=11), Puvirnituq (n=18), Inukjuak (n=15), and Kuujjuraapik (n=9), and a second one (from November 26th to December 4h 2012) in the communities of Umiujaq (n=4), Akulivik (4) and Ivujivik (n=7). Letters were sent to participants with abnormal results concerning the following analytes: vitamins A and D, folic acid, mercury and lead. We considered it important to follow up on these specifics results during their pregnancy to improve the health status of the mother and foetus.

Preliminary Results and Discussion

Sociodemographic data

Sociodemographic data were collected using questionnaires administered to all 95 participants. This includes information on age, education, marital status, personal and familial incomes, cigarette, alcohol and drug consumptions of pregnant Inuit women. Results are shown in tables 1 and 2.

Age, education, marital status, personal familial incomes

In brief, mean age of the pregnant women recruited was 24.9 years in this sample; 65-% of them declared having completed elementary school or have stated some secondary school education. Regarding marital status, the rate of single mothers was 35-%; most of them lived with other family members (86-%). Almost half of the pregnant women (48.42-%) estimated their personal income below 20 000$/year. However, a significant proportion (19-%) of women recruited was not able to provide an approximate value of their personal earnings. The situation was worse for estimating familial incomes, with 66% declaring they do not know. The response rate to this question was 100-%.

Smoking, alcohol and drug consumption

91.6-% of the women declared having smoked cigarettes during the current pregnancy. The average number of cigarettes smoked per day was 9.21 ± 4.56 and a median was 9. However, these results should be interpreted with caution. For example, several women declared having reduced or stopped smoking after knowing they were pregnant. Further analyses of the answers reported in the questionnaire should allow us to refine our analysis of these sociodemographic data.

Contaminant temporal trends

Contaminant blood levels in Inuit pregnant women from Nunavik were previously measured in 1992 (Santé Québec Health Survey among the Inuit of Nunavik), and in 2004 (Qanuippitaa Health survey). Although the sample sizes were limited (respectively n=11 and n= 26 pregnant women in 1992 and 2004), these data were used to compare the maternal blood contaminant levels between 1992, 2004, and 2012, and assess temporal trends over the last 2 decades (Tables 3 and 4). Temporal trend analyses presented below were mainly performed by using linear regression models. The contaminant concentration was defined as the dependent variable and the year of sampling as the main independent variable. Because previous studies reported associations between age and metals or POPS blood levels, the models were adjusted for the age of the participant. Mean age of the pregnant women recruited in 1992, 2004 and 2012 were respectively 23.3 ± 4.8 years, 26.4 ± 5.6 years and 24.9 ± 5.6 years. We did not include data obtained from the 17 pregnant women recruited in 2011 (MTP phase I) in the temporal trend analyses presented below.

Metals

Mercury and lead: Statistical analyses suggest that maternal blood concentrations in mercury and lead significantly decreased between 1992 and 2012 (Table 3). Over the last 20 years, maternal blood levels in mercury declined from 59.7 to 23.6 nmol.L^{-1} (a 60-% decrease), and from 0.2 to 0.06 µmol.L^{-1} for lead (a70-% decrease).

Selenium: No data on maternal blood selenium levels are available for the year 1992. However, comparison of selenium levels between 2004 and 2012 was possible. According to our analyses based on Kruskal-Wallis non-parametric test, no significant change in selenium concentrations was observed over the last 8 years (Table 3). The geometric mean for selenium blood content is still very high (4.15 µmol.L^{-1}) and suggests a continuing significant marine food consumption by pregnant Inuit women (Dewailly et al 2008).

Considering the small sample sizes used to assess these temporal trends (particularly, for the year 1992 (n=11), the results presented in table 3 should be interpreted with caution. Indeed, it was assumed that the metal concentrations measured in 1992 and 2004 (n=11, and n=26 respectively), were representative of all Inuit pregnant women population levels. Because no additional data are available, it is difficult to evaluate the validity of data collected for pregnant women in 1992. Thus, an alternative way was to compare the mercury and lead levels measured in these 11 pregnant women to those obtained at the same time in the larger population of women of childbearing age (n=175; from 18-39 years). Blood mercury and lead concentrations in women of childbearing age were respectively 64.5 [59.2-70.2] nmol.L^{-1} and 0.33 [0.31-0.36] umol.L^{-1} (Dewailly et al. 2007). These values are quite similar to those measured in pregnant women in 2012.

POPs

Temporal trends for POPs were also investigated. Due to limited sample sizes, missing data and difficulties related to limit detection values, comparisons of POPS in maternal blood levels between 1992, 2004 and 2012 were not always possible. Nevertheless we were able to conduct the analyses for several legacy POPs. Results are shown in table 4.

PCBs and chlorinated pesticides

According to our model adjusted for age, *p.p'*-DDE *p.p'*-DDT, oxychlordane, trans-nonachlor, mirex, cis-nonachlor, hexachlorobenzene, PCB-118, PCB-138, PCB-153, PCB-170 and PCB-180 plasma concentrations significantly decreased between 1992 and 2012 (Table 4). On average, plasma levels dropped by 79-%. Only two time points were available for toxaphene congeners Parlar 26 and Parlar 50. However, comparisons of plasma levels suggest a decline of Inuit mother exposure to these two contaminants between 2004, and 2012.

PBDE

Kruskal-Wallis and Student's t-tests were used to compare pregnant women PBDE plasma levels between 2004 and 2012. Statistical analysis revealed that PBDE-47 and PBDE-99 concentrations significantly decreased over the last 8 years (44-% and 32-% decreases, respectively). However, Inuit pregnant women exposure to PBDE-153 seems to have significantly increased (50-% increase; see table 4).

PFOS

Comparison of maternal PFOS levels between 2004 and 2012 were also performed by using a Student's t-test after log-transformation. Statistical analysis suggests that the PFOS plasma concentration significantly declined in Inuit pregnant women (63-% decrease; see table 4).

The results reported above should again be interpreted with caution. First, small sample sizes, and non-parametric tests were used to perform some of these analyses. Secondly, the equations used to estimate plasma lipid content were not the same in 1992, 2004 and 2012. Contrary to 1992 and 2004, the phospholipids were considered in addition to triglycerides and cholesterol to estimate the total plasma lipid content in 2012. According to Bernert et al (2007), this should have a limited impact on lipids and POPs level estimates. However, additional efforts should permit to obtain a harmonized estimate of total lipids between 1992, 2004 and 2012. Finally, these temporal trends were assessed regardless of pregnancy stage, parity or the number of child breastfed. Previous studies revealed that these factors could significantly affect maternal POP plasma levels (Verner et al., 2008). Additional efforts in this direction should permit us to assess the impact of these factors on our conclusions, and eventually, refine our analyses.

Fatty acids

Statistical analyses for fatty acids were performed by using Student's t-tests and Kruskal-Wallis non-parametric tests. Results are shown in table 5. No significant changes in DPA and DHA levels were observed between 2004 and 2012. However, the EPA levels, EPA+DHA contents and n-3/n-6 PUFA ratio seem to have significantly dropped over the last 8 years. EPA+DHA and n3/n6 ratio are both frequently considered as biomarkers of dietary marine food intakes (Jeppesen et al 2012). As a result, their decreases suggest a decline of marine food consumption by Inuit pregnant women. However, the good news is that levels of total trans fatty acids have significantly decreased in maternal blood over the last 8 years (70-% decrease) revealing the effectiveness of interventions implemented to reduce trans fats in imported foods (Counil et al., 2012).

Perception and knowledge on contaminants

A communication campaign was launched in 2010 to provide results from the Nunavik Child Cohort Study (NCCS) and disseminate public health recommendations related to country food consumption during pregnancy (i.e. one year before the beginning of MTP project). The recommendations especially addressed to pregnant women were 1) to decrease beluga meat consumption (given that beluga meat was identified as the main source of mercury exposure for Inuit pregnant women), and 2) increase the n-3 PUFA intake during pregnancy (RRSSS, 2011). Various communication means were used to disseminate this information to Inuit population including press releases, radio shows, production of a YouTube video-capsule and distribution of a plain language fact sheets (Muckle, 2013). To assess the efficiency of this communication campaign, three questions were inserted in MTP questionnaires 1) to evaluate if pregnant women heard about this campaign; 2) if they have modified their eating habits according to the public health recommendations disseminated, and 3) if it was the case, which changes were made. Statistical analyses of participant answers revealed that 32.2-% (n=30) of recruited pregnant women had heard about the health recommendations formulated by the RRSSS. Among this subgroup, 25-% (n=8) declared having modified their eating habits according to the health recommendations. More specifically, three women declared that they had reduced their beluga meat consumption, two declared that they did not eat it anymore, and two declared that they had increased their beluga meat consumption (one woman answered she did not know). This suggests that additional communication efforts are needed.

Conclusion

All the temporal trends on contaminants reported above are consistent with the conclusions previously made by Donaldson et al (2010). In 2010, they reported a decrease of metals (mercury and lead) and several POPS (oxychlordane, trans-nonachlor, *p,p'*-DDE, PCB-138, PCB-153, and PCB-180) in maternal blood between 1992 and 2007. A marked decrease in maternal exposure to lead, mercury and several legacy POPs was noticed over the past 20 years. This decline could be due 1) to some national and international measures implemented to reduce environmental contaminations by metals and POPS, and/or 2) a significant decrease in traditional foods consumption by pregnant Inuit women. The decreases in n-3/n-6 PUFA ratio and EPA+DHA blood levels rather support our second assumption, i.e. lower traditional food consumption. Besides, note that levels of some emerging POPs for which none or few actions has been taken also dropped. However, this assumption is inconsistent with the stable selenium blood level noted during the same period. Further analyses are needed to clarify these points.

NCP Performance Indicators

- The number of northerners engaged in your project: this phase of the project involved northerners such as local interpreters/recruiters and health professionals.
- The number of meetings/workshops you held in the North: one NNHC meeting in Kuujjuaak and few conference calls with health professionals coordinators, head of laboratories, nurses of both coasts (Ungava and Hudson), and the Nunavik Regional Board of Health.
- The number of students (both northern and southern) involved in your NCP work: one student enrolled (Thérèse Adamou).
- The number of citable publications (e.g. in domestic/international journals and conference presentations book chapters etc): 0

Expected Project Completion Date

March 2014

Acknowledgments

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Table 1. Sociodemographic data of 95 pregnant Inuit women from Nunavik (2012)

Education level among pregnant women from Nunavik	n	%
No formal schooling	0	0
Elementary school completed	4	4.2
some years of secondary school	58	61.1
Secondary school completed	15	15.8
Partial schooling in a CEGEP. a private college or a technical institute	10	10.5
Diploma or certificate from a CEGEP. a private college or a technical institute	6	6.3
Some university (not completed)	1	1.1
University degree (completed)	1	1.1
total	**95**	**100**

Familial situation (living with)	n	%
Husband & children	7	7.4
Husband & children & family	1	1.1
With another person as a part of a couple & children	22	23.2
With another person as a part of a couple & children & family	32	33.7
Single & children & family	29	30.5
Single & children	4	4.2
Divorced & children	0	0
Divorced & children & family	0	0
total	**95**	**100**

Table 2. Personal and familial incomes of 95 pregnant Inuit women from Nunavik (2012)

	Personal (%)	Familial (%)
Less than $ 20.000	48.4	5.3
$ 20.000 to less than $ 40.000	20	9.5
$ 40.000 to less than $ 60.000	7.4	8.4
$ 60.000 or more	5.3	9.5
Doesn't know	19	66.3
Refusal	0	1.5
Response rate	100	100

Table 3. Time trends of metal concentrations (Geo. mean [95% CI]) in 95 pregnant Inuit women from Nunavik (2012)

	1992 (n=11)	2004 (n=26)	2012 (n=94)	p-value
Hg ($nmol.L^{-1}$)	59.7 [37.7-94.5]	41.4 [30.4-56.4]	23.6 [18.7-29.8]	0.0015*
Pb ($\mu mol.L^{-1}$)	0.2 [0.1-0.3]	0.09 [0.07-0.11]	0.06 [0.05-0.07]	<0.0001*
Se ($\mu mol.L^{-1}$)	NA	3.4 [2.8;4.1]	4.2 [3.6-4.7]	0.226

* statistically-significant difference using regressions adjusted for age.

Table 4. POP concentrations (ug.kg-1 lipids) measured in plasma of pregnant Inuit women from Nunavik (Geometric mean [IC 95%])

	1992	2004	2012	p-value*
Oxychlordane	79.1 [49.5-126.5]	37.4 [26.8-52.2]	20.1 [16.0-25.2]	<.0001*
trans-Nonachlor	116.6 [76.4-178.0]	71.0 [51.1-98.6]	36.5 [28.8-46.2]	<.0001*
p,p'-DDE	652.7 [457.6-931.0]	249.7 [184.5-338.0]	122.4 [102.9-145.6]	<.0001*
p,p'-DDT	26.43 [15.7-44.6]	9.47 [7.3-12.3]	4.4 [3.9-5]	<.0001*
Mirex	12.9 [8.7-19.3]	4.1 [2.9-5.7]	3.0 [2.5-3.6]	<.0001*
cis-Nonachlor	28.5 [18.4-44.3]	10.9 [8-15]	5.3 [4.3-6.7]	<.0001*
Hexacholorobenzene	97.9 [68-141.1]	36.4 [26.8-49.5]	18.0 [15.0-21.4]	<.0001*
PCB 118	29.5 [20.4-42.6]	13.3 [9.8-18]	6.1 [5.1-7.2]	<.0001*
PCB 138	116.7 [87.3-156]	40.1 [29.3-54.9]	17.2 [14.3-20.8]	<.0001*
PCB 153	176.9 [134.4-232.9]	78.5 [56.6-108.9]	38.7 [31.8-46.9]	<.0001*
PCB 170	31.8 [23.6-42.8]	9.8 [6.9-13.8]	5.5 [4.5-6.6]	<.0001*
PCB 180	92.2 [69.5-122.2]	33.4 [23.7-46.9]	16.3 [13.3-20.1]	<.0001*
PCB 183	14.5 [10.5-20.2]	4.8 [3.6-6.5]	2.4 [2.04-2.85]	<.0001*
Toxaphene Parlar 26	NA	10.1 [7.3-14]	4.4 [3.4-5.7]	0.004#
Toxaphene Parlar 50	NA	17.5 [12.5-24.5]	6.9 [5.3-8.9]	0.001#
PBDE 47	NA	7.3 [5-10.6]	4.1 [3.5-4.7]	0.003#
PBDE 99	NA	2 [1.5-2.7]	1.4 [1.3-1.5]	0.007#
PBDE 153	NA	2 [1.4-2.8]	3 [2.6-3.5]	0.019##
PFOS		10.1 [8.3-12.3]	3.7 [3.2-4.3]	<.0001##

* significant difference ($p<0.05$) using regressions adjusted for age (age was treated as a continuous variable).

significant difference using Kruskal-Wallis non parametric test

Significant difference using Student's t-test following log-transformation.

Table 5. Time trends of fatty acid content in erythrocyte membranes (%) of pregnant Inuit women from Nunavik

(%)	2004 (n=26)	2012 (n=94)	p-value
DPA	1.9 [1.7-2.2]	1.91 [1.9-2]	0.198
EPA	0.8 [0.6-1]	0.64 [0.56-0.73]	0.013*
DHA	5.2 [4.5-6]	4.4 [4.1-4.7]	0.322
EPA+DHA	6.07 [5.2-7]	5.1 [4.7-5.4]	0.005#
n-3/n-6 PUFA ratio	0.33 [0.28-0.38]	0.28 [0.26-0.30]	0.027#
Total trans fatty acids	0.99 [0.64-1.34]	0.31 [0.28-0.34]	<0.0001*

* statistically significant difference using Student's t-test after log-transformation.
\# significant difference using Kruskal-Wallis non parametric test

POPs and cardio-vascular diseases in Inuit

Les POP et les maladies cardiovasculaires chez les Inuits

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Abstract

Very recently, scientific papers have reported associations between cardio vascular risk factors (high blood pressure, heart rate variability, diabetes), diseases (atherosclerosis) and persistent organic pollutants (POPs). These health conditions are rising in the Arctic and our hypothesis is that this rise is not only due to a changing life style but also to contaminant exposure. This project aims at investigating associations between exposure to POPs and the emergence of heart diseases and related risk factors using large epidemiologic studies conducted among adults in Arctic Canada.

Résumé

Tout récemment, divers articles scientifiques ont fait état de liens observés entre les facteurs de risques cardiovasculaires (hypertension artérielle, variabilité de rythme cardiaque, diabète), les maladies (athérosclérose) et les polluants organiques persistants (POP). Ces problèmes de santé sont en hausse dans l'Arctique et nous avançons que cette hausse n'est pas attribuable uniquement à un changement du mode de vie, mais également à une exposition aux contaminants. Le présent projet a pour but d'examiner les rapports entre l'exposition aux POP et l'apparition de maladies cardiaques et de facteurs de risque connexes à l'aide de grandes études épidémiologiques réalisées auprès d'adultes de l'Arctique canadien.

Key Messages

- The results of these studies conducted in Arctic populations highly exposed to POPs suggest that some polychlorinated biphenyl (PCB) congeners and organochlorine (OC) pesticides could increase the risk of hypertension.
- Furthermore, some OC pesticides could be associated with heart rate variability (HRV) impairment. However, as divergent results were observed across these populations, further epidemiological studies using cohort designs are necessary to validate these results.
- Our results for the International Polar Year (IPY) cohort showed a positive and significant association between plasma concentrations of POPs mixture and carotid intima media thickness (CIMT). We did not find any associations in the Nunavik cohort after adjustment. This could be a consequence of a lack of power, as the sample was small (adults n=268 versus n=738)
- The significant associations observed between PCBs, OC pesticides and fasting glucose, fasting insulin and/or insulin resistance suggest that exposure to these contaminants could have a detrimental impact in early stage of diabetes.

Messages clés

- Les résultats de ces études menées auprès des populations arctiques fortement exposées aux POP donnent à penser que certains congénères du biphényle polychloré (BPC) et des pesticides organochlorés (OC) pourraient accroître le risque d'hypertension.
- De plus, certains pesticides OC pourraient être associés à des troubles de la variabilité du rythme cardiaque (VRC). Cependant, comme on a observé des résultats divergents chez ces populations, il a fallu réaliser d'autres études épidémiologiques à l'aide de plans de cohorte pour valider ces résultats.
- Il ressort de nos résultats portant sur la cohorte étudiée dans le cadre de l'Année polaire internationale (API) une importante association positive entre les concentrations de mélanges de POP dans le plasma et l'épaisseur intima-média carotidienne (EIMC). Après certains ajustements, nous n'avons trouvé aucune association dans l'étude de la cohorte au Nunavik. Il peut s'agir d'une des conséquences du manque de puissance, puisque l'échantillon était restreint (adultes n = 268 contre n = 738).
- Les liens étroits observés entre les PCB, les pesticides OC et la glycémie à jeun, l'insuline à jeun et/ou la résistance à l'insuline suggèrent que l'exposition à ces contaminants pourrait avoir des effets indésirables au stade précoce du diabète.

Objectives

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

- POPs exposure is associated with elevated *blood pressure* in adults.
- POPs decreases *heart rate variability*.
- POPs are a risk factor for *atherosclerosis*.
- To study the association between POPs and *diabetes*.

Introduction

Studies among Nunavik Inuit suggest that the consumption of marine products, a major source of omega-3 polyunsaturated fatty acids (n-3 PUFA), is beneficial to cardiovascular health (Dewailly et al. 2001). Dewailly et al. concluded that the traditional Inuit diet was probably responsible, in part, for the low mortality rate from ischemic heart disease in this population. However, recent scientific papers have reported associations between cardiovascular risk factors (high blood pressure, heart rate variability, diabetes), diseases (atherosclerosis) and POPs which accumulate in the Arctic marine food chain. POPs include OC pesticides as well as PCBs, which contain mixtures of chlorinated compounds that were manufactured for use as lubricants and coolants in various electrical components. The use of PCBs is now banned but they are still widespread in the environment, sometimes reaching remote regions with no known industrial contamination. Both groups of chemicals enter the food web, either terrestrial or aquatic, and accumulate in animal tissues becoming more concentrated as they move up the food chain. Thus, Arctic populations, whose traditional diet is mainly based on fish and marine mammals, are the most exposed in the world (Deutch, Pedersen et al. 2004; Van Oostdam, Donaldson et al. 2005). After the Stockholm convention, levels of PCBs have decreased among Inuit from Nunavik (Dallaire, Dewailly et al. 2003) but data collected in 2004 revealed that 11% of the adult population still presented total PCBs concentrations above the level of concern determined by Health Canada (20 µg/L in whole blood) (Dewailly, Dallaire et al. 2007).

Activities in 2012-2013

Follow up of medical files (Nunavik)
Approval for the project was renewed at the ethics committee of CHU-CHUL on June 15th 2012. 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 (only five missing medical files). The capture of the database for the Nunavik cohort was completed, and statistical analysis were conducted.

Statistical analyses on three cohorts: POPs exposure and blood pressure, heart rate variability, atherosclerosis and diabetes: see below

Results

POPs and blood pressure (BP)
The associations between POPs and hypertension were analyzed using data collected among Inuit from Nunavik in 1992 (**"Santé Quebec" health survey**), 2004 (**"Qanuipitaa?" health survey**) and in Inuit from Nunavut, Nunatsiavut and the Inuvialuit Settlement Region (Adult Inuit health survey or **IPY survey**).

Statistical analyses were conducted on a sample of 315 adults aged 18 years and over who participated in the 1992 **"Quebec Santé" health survey**. The results of logistic regression show significant associations between total PCBs, the sum of non-dioxin-like PCBs and hypertension. Furthermore, the analysis of individual PCBs revealed higher risk of hypertension in relation to higher plasma concentrations of congeners 101, 105, 138 and 187. The associations became significant after including n-3 PUFAs (EPA+DHA) in the models and remained significant after considering other contaminants such as lead and mercury. Furthermore, significant associations were observed between some OC pesticides and hypertension after adjusting for confounders. *p,p´*-dichlorodiphenyldichloroethylene (*p,p´*-DDE) was associated with increased risk of hypertension while inverse associations were observed with *p,p´*-dichlorodiphenyltrichloroethane (*p,p´*-DDT), β-hexachlorocyclohexane (HCH) and oxychlordane.

Regarding the 2004 **"Qanuipitaa?" health survey**, the analyses were conducted in a sample of 594 adults aged 18 years and over with complete data on POPs and BP. Mean age of the participants was 36.3 ± 36 years and the sample was composed of 267 men (45%) and 327 women (55%). Means of the sum of dioxin-like PCBs and non-dioxin-like PCBs were 0.21 and 3.6 µg/L; respectively. The sum of dioxin-like PCBs were higher in women than men (0.30 vs. 0.24 µg/L, p= 0.003) while no significant difference was observed for the sum of non-dioxin-like PCBs (p= 0.14). No significant difference was observed between men and women except for mirex that was higher in men than women (0.07 vs. 0.06 µg/L, p= 0.03). Hypertension was present in 99 participants (16.7%) and 54 of them (9.1%) were taking anti-hypertensive medication. The results of logistic regression show significant associations between all PCB congeners and hypertension. However, after adjusting for confounders only the association with PCB 203 remained statistically significant while the association with PCB 156 and 180 approached the significance level (OR= 1.36, p= 0.09 and OR=1.41, p= 0.06; respectively). Regarding OC pesticides, only *p,p´*-DDE was significantly associated with higher risk of hypertension after adjusting for confounders .
Regarding the **IPY Survey**, the statistical analyses were conducted in a sample of 1877 adults (≥ 18 years) with complete data on POPs and BP. Mean age was 42 ± 15 years and the study sample was composed of 715 men and 1162 women. The sum of dioxin-like PCBs and non-dioxin-like PCBs was higher in men than women (0.21 vs. 0.15 µg/L, p< 0.0001 and 2.33 vs. 1.38 µg/L, p< 0.0001; respectively). Levels of OC pesticides were also higher in men (p< 0.0001 in all cases). Four hundred thirteen participants (22%) were classed as hypertensive (systolic BP ≥ 140 mm Hg, diastolic BP ≥ 90 mm Hg or anti-hypertensive treatment), and the proportion did not differ between men and women (p= 0.06).

The results of logistic regression showed higher risk of hypertension in the 3rd and 4th quartile of the sum of dioxin-like PCBs, non-dioxin-like PCBs and total PCBs compared to the 1st quartile. These associations were attenuated after considering traditional BP risk factors such as age, sex, waist circumference, total lipids, fasting glucose, alcohol consumption, smoking and physical activity. However, they became significant after including other contaminants such as mercury and lead as well as fish nutrients (n-3 PUFAs and selenium). Regarding OC pesticides, no significant association was observed except for hexachlorobenzene that was inversely associated with hypertension.

POPs and HRV

The associations between POPs and HRV were analyzed in adults (≥ 40 years) from Nunavik (n= 205) and the IPY study (n= 767). HRV represents the variations of the heart rate due to the sympathetic and parasympathetic modulation of the autonomic nervous system (ANS). Reduced HRV, caused by decreased parasympathetic activity or increased sympathetic activity, indicates low adaptability to stressful situations and may lead to fatal arrhythmias and sudden cardiac death (Makikallio et al. 2001).

The results of multiple linear regressions conducted among Inuit from **Nunavik** did not show significant associations between PCBs and HRV parameters after adjusting for risk factors (age, sex, smoking, fasting glucose, waist circumference, total lipids and physical activity). Further adjustment for mercury and total n-3

PUFAs did not change the results. Models using individual congeners revealed similar results. However, *p,p'*-DDE was associated with increasing SDNN. In addition, some borderline associations were observed between LF and *p,p'*-DDT (β= -0.35, p= 0.05), β-HCH (β= -0.22, p= 0.06) and hexachlorobenzene (β= -0.22, p= 0.06) after adjusting for risk factors as well as mercury and n-3 PUFAs.

The results of multiple linear regressions conducted among Inuit from the **IPY study** show that increasing plasma levels of the sum of dioxin-like PCBs and non-dioxin-like PCBs were associated with lower LF and HF after adjusting for risk factors (age, sex, smoking, fasting glucose, waist circumference, total lipids and physical activity). However, only the association between the sum of dioxin-like PCBs and HF approached the significant level (β= -0.11, p= 0.06) after including mercury, which is correlated with POPs in this population and has been associated with lower HRV in this (Valera et al, unpublished results) and other populations (Valera et al. 2008; Lim et al. 2009; Yaginuma-Sakurai et al. 2009). Further adjustment for n-3 PUFAs did not change the results. Models using individual congeners revealed similar results. Analyses concerning OC pesticides, showed significant associations between increasing levels of *cis*-nonachlor, hexachlorobenzene, mirex, oxychlordane, β-HCH, *trans*-nonachlor and lower LF and HF. These associations remained significant after considering mercury levels as well as n-3 PUFAs.

POPs and CIMT in Inuit population: IPY and Nunavik cohorts

The potential association between POPs and CIMT, considered as a surrogate marker of atherosclerosis progression phenomenon (Lorenz *et al*. 2007), were studied in two different cross-sectional studies ; The 'Qanuipitaa?' health survey (2004), and among Inuit from the IPY cohort (2007 and 2008). Our samples were limited to adults ≥ 40 years old because of known increasing risk of cardiovascular diseases from this age.

For Nunavik, we measured 276 CIMT. Because people were weighted to be representative of the population only 268 participants were considered in our analyses. For IPY, we measured 741 CIMT but because of some missing data about age and gender we considered 738 participants in our analyses. We limited our analyses to POPs quantified in both cohorts and detected in ≥ 70% of the 2 samples. Plasma concentrations of POPs were expressed in µg per kg of total lipids.

In both cohorts, CIMT significantly differed by gender, and means of age were similar. Blood n-3 PUFAs proportion was almost twice as much for Nunavik (12.1%) as for IPY (7.7%). Environmental contaminants (in whole blood for mercury and in plasma for POPs) were at least 2 times or 2.5 times more concentrated in the blood of Inuit from Nunavik than in the blood of Inuit from IPY, except for ß-hexachlorocyclohexane (ß-HCH) and for hexachlorobenzene where the concentrations were very close in both cohorts. With a geometric mean of 1139.4 µg per kg of total lipids (/kg tot lipids) for the Nunavik and of 475.6 µg/kg tot lipids for IPY, Dichlorodiphenyldichloroethylene (*p,p'*-DDE) appeared to be the most concentrated POPs in both cohorts, followed by the PCB-153 with a geomean of 556.3 µg/kg tot lipids for Nunavik and 233.1 3 µg/kg tot lipids for IPY. In Nunavik cohort *trans*-nonachlor (370.8 µg/kg tot lipids), PCB-180 (305.2 µg/kg tot lipids) and PCB-138 (215.5 µg/kg tot lipids) concentrations were also quite high.

When choosing only 3 POPs in each cohort (PCB-153, *p,p'*-DDE and toxaphene congener Parlar 26) we observed a really high correlation (frequently more than 0.80 and until 0.99) between them and the other POPs which indicated that it would be difficult to dissociate their potential effect on CIMT with a linear regression model. We decided to use only this 3 POPs as exposition variable, considered representative of the presence of the others together (POPs mixture).

For the Nunavik cohort, we found that all POPs tested were significantly associated with increasing CIMT in the crude model but did not remain significant after adjusting for age and for other confounders including blood mercury.

In the IPY cohort, we found that all POPs tested were significantly associated with increasing CIMT in the crude model and remained significant after adjusting for age, systolic blood pressure, waist circumference, smoking, and n3-fatty acids. However, when supplementary adjustments were done for the region (ie Kivaliq, Baffin, Kitikmeot, Inuvialuit and Nunatsiavut), only the PCB-153 remained significant, and for blood mercury, any association remained significant.

POPs and insulin resistance

The associations between POPs and fasting plasma glucose (FPG), fasting plasma insulin (FPI) and insulin resistance were studied in a sample of 703 non-diabetic adults ≥ 18 years who participated in the "Qanuippitaa" health survey in Nunavik. Insulin resistance was estimated through the Homeostasis model assessment (HOMA-IR: FPG x FPI / 22.5) (Matthews et al. 1985). Geometric means of FPG, FPI and HOMA-IR were compared across quintiles of POPs distribution using the analysis of variance (ANOVA) and covariance (ANCOVA). Models were adjusted for age, gender, waist circumference, total lipids, smoking and physical activity. The linear and quadratic trends were examined using the contrast test.

Adjusted means of FPI and HOMA-IR increased with quintiles of the sum of dioxin-like PCBs and non-dioxin-like PCBs showing a quadratic trend. In addition, FPG increased across quintiles of dioxin-like PCBs and non-dioxin-like PCBs but the tests for linear and quadratic trends were not statistically significant. Regarding OC pesticides, a quadratic trend was observed between mirex, *trans*-nonachlor, oxychlordane, *p,p'*-DDE and FPI and HOMA-IR. None of the OC pesticides was significantly associated with FPG.

Discussion and Conclusion

POPs and blood pressure

The results obtained in these health surveys showed significant associations between PCBs and higher risk of hypertension. In the Inuit from Nunavik, PCBs 101, 105, 138 and 187 were associated with higher risk of hypertension using data collected in 1992 during the "Santé Quebec" health survey. However, the results obtained using data collected in 2004 showed a significant association only with PCB 203 although positive borderline associations were observed with congeners 156 and 180. Furthermore, data collected among Inuit from Nunavut, Nunatsiavut and the Inuvialuit Settlement Region showed significant associations between the sum of dioxin-like PCBs, non-dioxin-like PCBs, total PCBs and higher risk of hypertension.

These results agree with some previous studies reporting significant associations between PCBs and increased risk of hypertension although the strength of the associations with individual congeners varies across the studies. Increases in systolic BP and diastolic BP were observed across tertiles of most PCBs (congeners 138+158, 146, 153, 156, 157, 189, 170, 172, 177, 178, 180, 183, 187, 194, 195, 196+203, 199, 206 and 209) in a study conducted among residents of Anniston, Alabama, who lived near a plant that manufactured PCBs from 1929 until 1971 (Goncharov et al. 2011). Everett et al. also reported significant associations between 7 PCBs (congeners 74, 99, 118, 126, 138/158, 170, and 187) and hypertension among participants in the NHANES 1999-2002 (Everett et al. 2008). Similarly, we observed positive ORs between congeners 138, 187 and hypertension using data from the "Santé Québec" health survey. In addition, PCB 203 was associated with higher risk of hypertension using data from the "Qanuippitaa?" health survey while borderline associations were observed with PCB 156 and 180. A significant association between the sum of dioxin-like PCBs and hypertension was also observed in a study conducted among 1374 Japanese not occupationally exposed to POPs, which aimed to study the association between PCBs and the metabolic syndrome (MS) and its individual components (Uemura et al. 2009). We observed a similar association only in the IPY survey. An important difference with respect to the previous study is the definition of hypertension (≥ 130/85 mm Hg or diagnosed hypertension), which involved lower BP values probably leading to the detection of a higher number of hypertensives. In addition, a larger number of dioxin-like PCB congeners (n=12) were included in the analyses, which increases the probability of detecting significant associations. In contrast, non-significant associations were observed between congeners 138, 153, 170, 180 and 187 and hypertension in a cross-sectional study conducted among 721 non-diabetic adults participating in the NHANES 1999-2002 (Lee et al. 2007). Only PCB 126 was significantly associated with hypertension showing a positive and significant trend.

Regarding OC pesticides, *p,p'*-DDE was associated with increased risk of hypertension using data from the "Québec Santé" health survey while inverse associations were observed for *p,p'*-DDT, β-HCH and oxychlordane. A significant association between *p,p'*-DDE and higher risk of hypertension was also observed using data collected in 2004. In contrast, hexachlorobenzene was inversely associated with hypertension. These results disagree with previous studies not reporting significant associations between OC pesticides and BP. For example, in a study conducted among adults ≥ 40 years who participated in the NHANES 1999-2000, no significant association was observed between oxychlordane, *trans*-nonachlor and hypertension (Ha et al. 2009). Moreover, there was no significant association between 4 OC pesticides (oxychlordane, *trans*-nonachlor, *p,p'*-DDE, β-HCH) and hypertension among non-diabetic adults participating in the same health survey (Lee et al. 2007). However, Goncharov et al. observed a significant association between β-HCH and diastolic BP in a study conducted among subjects without antihypertensive medication (Goncharov et al. 2011). The positive association observed with *p,p'*-DDE in Inuit from Nunavik using data collected in 1992 and 2004 could be explained by the highest levels presented in this population. However, the protective effect observed for *p,p'*-DDT, β-HCH, oxychlordane and hexachlorobenzene is difficult to explain since no evidence exists suggesting a protective effect of OC pesticides on BP. The results obtained in the present study suggest that OC pesticides could influence BP. However, epidemiological studies using cohort designs are needed to elucidate the divergent results obtained with *p,p'*-DDT, β-HCH, oxychlordane and hexachlorobenzene. In addition, experimental studies are required in order to determine the mechanisms involved in the toxicity of OC pesticides on BP.

POPs and heart rate variability (HRV)

The results of the analyses performed among Inuit from Nunavut, Nunatsiavut and the Inuvialuit Settlement Region showed significant associations between some OC pesticides (*cis*-nonachlor, hexachlorobenzene, mirex, oxychlordane, β-HCH, *trans*-nonachlor) and lower LF and HF. In addition, the association between the sum of dioxin-like PCBs and HF approached the significant level. Among Inuit from Nunavik, *p,p'*-DDE was associated with increasing SDNN while borderline associations were observed between *p,p'*-DDT, β-HCH, hexachlorobenzene and lower LF after adjusting for risk factors as well as mercury and n-3 PUFAs.

To our knowledge, these are the first studies to evaluate the associations between POPs and HRV. The results suggest that some OC could impair HRV via the parasympathetic system. However, the significant associations observed with LF and HF should be confirmed in future studies. As low HRV can lead to ventricular fibrillation and sudden cardiac death (SCD) (Makikallio et al. 2001), exposure to environmental contaminants could be associated with higher risk of cardiovascular disease in populations with high fish and marine mammals' consumption as is the case of Arctic populations.

POPs and CIMT in Inuit population: IPY and Nunavik cohorts

Our descriptive results showed important variations in the levels of blood environmental contaminants between the 2 cohorts. One hypothesis is that it could reflect some differences in way of life (traditional food versus food supply in stores) and/or some differences in environmental contamination in different regions of the Canadian Arctic and/or contaminants' measurements done in different period of time (2004 versus 2007-2008).

Our results for the IPY cohort showed a positive and significant association between plasma concentrations of POPs mixture and CIMT. However, we noticed that the region could reduce the strength of this association and its significance. More investigations should be done to clarify if some local characteristics (represented by the region) could be confounding factors in the relation between POPs and CIMT. Indeed blood mercury could also challenge this association, maybe because of its proper potential effect on CIMT (see 2012 NCP Report).

Our results for the Nunavik cohort were a little bit surprising because of no association remained significant after adjustment, although concentrations of POPS and contaminants in general were higher than in the IPY cohort. This could be a consequence of a lack of power, as the sample was small (adults n=268 versus n=738), and probably in relation with a really strong effect of age as a predictive and as a confounding factor in this sample. In fact, in both cohorts, age predicted nearly 30% of the CIMT and the concentrations of POPs seemed to be more correlated with age in Nunavik cohort than in IPY cohort (data not shown).

More statistical analysis should be realised to elucidate how taking into account the high correlation between POPs and how to deal with the important effect of age on CIMT. Our results are supported by other studies. Several authors agree to declare circulating POPs as possibly involved in increasing risk factors of cardiovascular diseases (CVD) such as hypertension, obesity, metabolic syndrome and diabetes (Everett *et al.* 2008; Ha *et al.* 2007, 2009; Lee *et al.* 2007, 2011b; Uemura *et al.* 2009). Indeed POPs have also been related to history of CVD such as myocardial infarction (Flesch-Janys *et al.* 1995; Sergeev and Carpenter 2005), stroke (Lee *et al.*2012). A review resumed the possible implication of POPs and plastic-associated chemicals as cause of CVD (Lind and Lind, 2012) and one study found that circulating PCBs were associated with atherosclerosis, using CIMT evaluation (Lind *et al.* 2012).

POPs and insulin resistance

In the present study, the sum of dioxin-like PCBs as well as non-dioxin-like PCBs was associated with higher FPG, FPI and insulin resistance in non-diabetic participants. In addition, higher FPI and insulin resistance were observed in relation with higher plasma levels of oxychlordane, *trans*-nonachlor, *p',p*-DDE and mirex.

A growing body of experimental studies suggests that POPs can affect the beta cell function and thus promote the development of diabetes as reviewed Remillard and Bunce (2002). In addition, many epidemiological studies have reported significant associations between PCB and/or OC pesticides and higher risk of diabetes (Rylander et al. 2005; Lee et al. 2006; Codru et al. 2007; Philibert et al. 2009; Rignell-Hydbom et al. 2009; Turyk et al. 2009; Uemura et al. 2009). However, few of them have analyzed the associations between POPs and insulin resistance. Lee et al. observed significant associations between POPs and increased fasting glucose and insulin resistance in two studies conducted among non-diabetic adults aged ≥ 20 years who participated in the National Health and Nutrition Examination Survey (NHANES 1999–2002) (Lee et al. 2007a; Lee et al. 2007b). In the first study, Lee et al. explored the associations between POPs and the metabolic syndrome (MetS) and its individual components (Lee et al. 2007b). In addition to MetS, significant associations were observed between the sum of dioxin-like PCBs, non-dioxin-like PCBs, *p,p'*-DDE, and high fasting plasma glucose while no significant association was observed with oxychlordane, trans-nonachlor and β-HCH. In the second study, Lee et al. aimed to examine the associations between the same POPs and insulin resistance (Lee et al. 2007a). Oxychlordane and *trans*-nonachlor were associated with higher insulin resistance (HOMA-IR) while no significant association was observed with *p,p´*-DDT and β-HCH. Furthermore, no significant association was observed with the sum of dioxin-like PCBs and non-dioxin-like PCBs while the analysis of individual congeners revealed significant associations with congeners nos. 170 and 187.

Similarly to the first study (Lee et al. 2007b), we observed significant associations between the sum of dioxin-like PCBs, non-dioxin-like PCBs and FPG. Furthermore, the analysis of individual congeners revealed significant associations between PCBs 170, 187 and HOMA-IR consistently with the associations observed by Lee et al. (2007a). Regarding OC pesticides, our results are in accordance with both studies regarding the non-significant impact of β-HCH on FPG, FPI or HOMA-IR. Similarly, the results concerning oxychlordane and *trans*-nonachlor are consistent across the studies and suggest that these pesticides could increase insulin resistance through a mechanism involving insulin levels instead of glucose levels. In contrast, divergent results were observed for *trans*-nonachlor and *p,p'*-DDE, which requires further investigation.

The significant associations observed between PCBs, OC pesticides and fasting glucose, fasting insulin and/or insulin resistance suggest that exposure to these contaminants could have a detrimental impact in early stage of diabetes. However, their impact on the development of diabetes in this population using longitudinal data should be carefully investigated.

NCP Performance Indicators

- The number of northerners engaged in your project: Local inuit were hired in each community in order to assist the research nurse in the process of the medical file review.
- The number of meetings/workshops you held in the North: One NNHC meeting in Kuujjuuak.
- The number of students (both northern and southern) involved in your NCP work: 3: Beatriz Valera post-doctoral student, and Claire Dupont PhD student.
- The number of citable publications (e.g., in domestic/international journals, and conference presentations, book chapters, etc): Peer review papers: 6 conferences: 9.

Expected Project Completion Date

March 2013

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In vivo Study of the Effects of a Northern Contaminant Mixture on the Development of Metabolic and Cardiovascular Diseases under Conditions Typifying the Diets and Lifestyles of Northerners

Substudy I: the effects of a NCM on the development of metabolic and cardiovascular diseases under a binge drinking condition

Étude *in vivo* des effets d'un mélange de contaminants nordiques sur le développement de maladies métaboliques et cardiovasculaires dans des conditions caractérisant les régimes et modes de vie des résidants du Nord

Sous-étude I : les effets d'un mélange de contaminants nordiques sur le développement de maladies métaboliques et cardiovasculaires en cas de consommation occasionnelle excessive d'alcool

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Abstract

An *in vivo* study was conducted to investigate the role of exposure to Northern contaminants as a risk factor for the development of metabolic and cardiovascular diseases using obese and lean JCR rats in the presence or absence of alcohol. Obese and lean JCR rats were treated with a northern contaminants mixture (NCM) in the presence or absence of alcohol. Blood and various organs were collected and analyzed for markers of metabolic and cardiovascular disease. Some of the results were presented in the 2011 Synopsis Report, which suggest that the obese animals, as compared to lean animals, were in a higher state of systemic inflammation and had a compromised immune function and liver steatosis, in addition to hyperlipidemia and hyperinsulinemia. NCM treatment worsened the state liver steatosis, which was associated with decreased levels of cholesterol and lipoproteins in the circulation, suggesting an inhibited transportation of lipids and lipoproteins from liver to circulation. The concentrations of the organic components of contaminant mixture in the sera of dosed rats were found to be in the range between the geometric mean and the maximum concentrations found in the Inuit plasma. More in depth analysis of tissue samples was conducted in 2012, and the results revealed that the mercury levels found in the dosed animal livers were in the range of mercury levels found in marine mammals. The obese animals had higher concentrations of mercury in liver, kidney, muscle and pancreas than the lean animals. NCM treatment at the higher dose used decreased PON1 activity in the circulating HDL regardless of alcohol treatment, which in the absence of alcohol, was associated with increased levels of Ox-LDL in the obese animals. The NCM-induced changes in circulation paralleled with upregulation of genes involved in cholesterol synthesis and down-regulation of genes involved in carbohydrate and fatty acid metabolism and lipid and lipoprotein secretion. Overall, our data suggest that NCM at levels relevant to human exposures in Canadian North may increase the risk of developing liver steatosis shown by increased cholesterol synthesis in the liver and decreased lipid and

Résumé

Une étude in vivo a été menée sur le rôle de l'exposition aux contaminants nordiques comme facteur de risque de maladies métaboliques et de maladies cardiovasculaires chez des rats JCR obèses ou maigres exposés ou non à l'alcool. Les rats JCR, obèses et maigres, ont reçu un mélange de contaminants nordiques (MCN) avec ou sans alcool. Du sang et des organes ont été prélevés pour le dosage des marqueurs de maladies métaboliques et de maladies cardiovasculaires. Certains des résultats ont été présentés dans le rapport sommaire de 2011, lesquels semblent indiquer que les animaux obèses, par comparaison avec les animaux maigres, présentaient une plus forte inflammation générale, un système immunitaire déprimé et une stéatose hépatique, en plus d'une hyperlipidémie et d'une hyperinsulinémie. L'exposition au MCN a aggravé la stéatose hépatique, laquelle a été associée à une diminution des concentrations de cholestérol et de lipoprotéines dans la circulation qui laisse croire à une inhibition du transport des lipides et des lipoprotéines depuis le foie vers la circulation. Les concentrations sériques des composés organiques du mélange de contaminants chez les rats exposés se trouvaient dans la plage des valeurs situées entre la concentration moyenne géométrique et la concentration maximale mesurée dans le plasma des Inuits. Une analyse plus approfondie des échantillons de tissus effectuée en 2012 a révélé que les concentrations de mercure dans le foie des animaux exposés se trouvaient dans la plage des concentrations de mercure mesurées chez les mammifères marins. Les concentrations de mercure dans le foie, le rein, le muscle et le pancréas étaient plus élevées chez les animaux obèses que chez les animaux maigres. À la dose la plus forte de MCN administrée, une diminution de l'activité de l'enzyme PON1, laquelle est fixée aux lipoprotéines HDL circulantes, a été constatée que les animaux aient été exposés ou non à l'alcool, et, chez les rats n'ayant pas reçu d'alcool, cette diminution était associée à une augmentation des concentrations de LDL oxydées (LDLox) chez les animaux obèses. Les changements induits par le MCN dans la

lipoprotein secretion from liver to circulation, and associated increase in circulating CRP and Ox-LDL/LDL and decrease in circulating PON1/HDL activity and NO levels, which is consistent with an increased risk of developing cardiovascular disease.

circulation s'accompagnaient d'une régulation positive de gènes intervenant dans la synthèse du cholestérol et d'une régulation négative de gènes jouant un rôle dans le métabolisme des glucides et des acides gras ainsi que dans la sécrétion des lipides et des lipoprotéines. Dans l'ensemble, nos données tendent à indiquer que le MCN, aux concentrations correspondant à l'exposition humaine dans le Nord canadien, pourrait accroître le risque de stéatose hépatique. En témoignent l'augmentation de la synthèse du cholestérol dans le foie et la diminution du passage du foie vers la circulation des lipides et lipoprotéines sécrétés, ainsi que la hausse de la protéine C réactive (CRP) et des lipoprotéines LDLox/LDL circulantes et la baisse de l'activité de PON1/HDL en circulation et des concentrations de NO qui leur sont associées, toutes ces observations concordant avec un risque accru de maladie cardiovasculaire.

Key Messages

- Obesity may be associated with increased systemic inflammation, compromised immune function, liver steatosis, hyperlipidemia and hyperinsulinemia.
- Exposure to NCM at levels similar to those detected in some of the Inuit people in the Canadian North may increase the risk of developing liver steatosis as a result of increased cholesterol synthesis and decreased energy metabolism in the liver, and decreased lipid and lipoprotein secretion from liver to circulation. In addition, NCM increased systemic inflammation oxidation of LDL, and decreased circulating levels of PON1, a lipid antioxidant associated with HDL, which is consistent with increased risk of metabolic and cardiovascular diseases.

Messages clés

- L'obésité pourrait être associée à une inflammation générale forte, à un système immunitaire déprimé, à une stéatose hépatique, à une hyperlipidémie et à une hyperinsulinémie.
- L'exposition à des concentrations de MCN similaires à celles mesurées chez certains Inuits du Nord du Canada pourrait accroître le risque de stéatose hépatique par suite d'une augmentation de la synthèse du cholestérol et d'un ralentissement du métabolisme énergétique dans le foie, ainsi que d'une diminution du passage du foie vers la circulation des lipides et lipoprotéines sécrétés. Le MCN a également augmenté l'oxydation des LDL causée par l'inflammation générale et réduit les concentrations circulantes de l'enzyme PON1, un antioxydant des lipides fixé aux lipoprotéines HDL, ce qui concorde avec un risque accru de maladies métaboliques et de maladies cardiovasculaires.

Objectives

Short-Term:

- To determine the effects of a Northern contaminant mixture at levels found in human blood of Northerners on markers of metabolic and cardiovascular disease such as oxidative stress, lipid profile, insulin action, and endothelial function, using an animal model; and
- To examine the modulating effects of dietary factor such as fats and sugars and lifestyle (alcohol consumption) on contaminant mixture-induced changes in these markers.

Long-Term:

- To demonstrate and understand mechanistically the potential role of Northern contaminants in the development and progression of metabolic and cardiovascular diseases and their interplay with specific diets and lifestyles of Northerners;
- To provide more biomarker tools for monitoring and assessing the health risk of Northern populations; and
- To provide scientific basis for the Canadian Government to institute and implement more effective strategies for contaminant control and heath promotion in the Canadian North.

Introduction

Increasing evidence points to environmental contaminants such as heavy metals, PCBs, and organochlorines as potential risk factors for obesity, diabetes, and cardiovascular diseases (Baker et al. 1980, Sorensen et al. 1999, Jokinen et al. 2003, Lind et al. 2004, Stern 2005, Fillion et al. 2006, Lee et al. 2006, 2007, Ha et al. 2007, Goncharov et al. 2007, Muniyappa and Quon 2007, Segreev and Carpenter 2005, Valera et al. 2008, NCP 2009). Northern populations have been exposed to elevated levels of contaminant mixtures mainly through consumption of contaminated fish and marine mammals for a few decades. Along with this, there has also been an increase in the prevalence of obesity, hypertension, diabetes, and/or cardiovascular disease in the Northern populations (Erber et al. 2010, Riediger et al. 2010). Although increased sedentariness and lower levels of physical activity, as well as shift from traditional foods to more energy-dense processed high sugars and fats foods have been associated with the prevalence of chronic diseases, it remains to be investigated if and how exposure to elevated levels of contaminant mixtures may contribute to the development of these chronic disease in the Northern populations, and if and how changes in diet and lifestyle may alter the health effects of Northern contaminants.

We conducted an in vivo study to investigate the effects of a Northern Contaminant Mixture (NCM) on the development of metabolic and cardiovascular diseases using the obese JCR rats, a rodent model of human cardiovascular disease, and the lean JCR rats as control. The chemical components, animal treatment scheme, and parts of the data have been reported to NCP in the 2011 Synopsis report. In this report, we present the data from more in depth analysis of serum markers, liver fatty acid profiling, and PCR array analysis of hepatic genes involved in glucose and lipoprotein metabolism.

Activities in 2011-2012

1. Serum Markers Related to Cardiovascular Disorders

C-Reactive Protein (CRP)
Serum CRP was measured using an ELISA kit from Alpha Diagnostic International (Cat # 1010) (TX, USA) according to manufacture's instruction. The assay is based on a two antibody sandwich ELISA. Samples were diluted 7800 times in sample diluent prior to analysis.

Oxidized LDL (Ox-LDL)
Serum Ox-LDL was measured using Mercodia Oxizided LDL Competitive ELISA kits from ALPCO Diagnostic (Cat#10-1158-01) (NH, USA) according manufacture's

instruction. Samples were diluted by 41 times in sample buffer prior to analysis.

Paraoxonase-1 (PON1)
Serum PON1 activity was measured using an EnzChek Paraoxonase Assay Kit from Invitrogen (Cat # E33702, Molecular Probes Inc., OR, USA) following the manufacture's instruction. The samples were diluted 170 times during the assay.

Endothelin-1 (ET-1)
Serum ET-1 was measured using a ET-1 Quantikine ELISA kit from R&D Systems (Cat#DET100) according to manufacture's instruction. Serum samples were filtered through a Microcon centrifugal filter devices with10K MW cutoff (Cat#42407) before analysis.

Nitric Oxide (NO)
Serum NO was measured using a colormetric non-enzymetic assay kit from Oxford Biomedical Research (Cat# NB88) according to manufacture's instruction. Samples were diluted 3 times before assay.

6-keto-Prostaglandin $F_{1\alpha}$
Serum 6-keto prostaglandin $F_{1\alpha}$ was measured using a EIA kit from Cayman Chemical Company (Cat# 515211) according to manufactures instruction. Serum samples were diluted 40 times before assay.

2. Organ Mercury Content Analysis

Liver, Kidney, Muscle and Pancreas tissue samples were analyzed for total mercury (THg) in ppm using the Nippon MA3000 direct combustion mercury analyzer (Nippon North America, College Station, TX). Ten-fifteen mg wet weight of frozen sample was added to sample boats. Analytical accuracy and precision were monitored through the use of Standard Reference Materials (SRMs), and intermittent analysis of duplicate samples. SRMs included National Research Council of Canada (NRCC) DOLT-4 (dogfish liver) and DORM-3 (dogfish muscle).

3. PCR array Analysis of Hepatic Genes Involved in Glucose and Lipoprotein Metabolism

Effects of NCM and alcohol on glucose and lipoprotein metabolism were determined in liver samples from the OWV, OWH, OEV, and OEH treatment groups using PCR pathway arrays. Total RNA from each sample was extracted using QIAzol reagent (Invitrogen Life Technologies, Burlington, ON, Canada) and purified and DNase I treated on RNeasy mini columns (Qiagen, Mississauga, ON, Canada). The concentration of the total RNA was determined using a NanoDrop ND-1000 UV/Vis Spectrophotometer (NanoDrop Technologies, Inc. Wilmington, DE, USA). The quality of the purified RNA was assessed by a Bioanalyzer (Agilent 2100 Bioanalyzer, Agilent Technology, Waldbronn, Germany). One µg of high quality RNA (RNA integrity number above 9.0) was reverse-transcribed to synthesize cDNA with RT2 First Strand Kit (Qiagen). Rat Lipoprotein signaling & Cholesterol Metabolism PCR Array (Cat. No. PARN-080C, Qiagen) and Rat Glucose Metabolism PCR Array (Cat. No. PARN-006A, Qiagen) were performed on an ABI 7500 PCR System (Applied Biosystems, Foster city, CA, USA) using RT2 SYBR Green / ROX qPCR Master Mix (Qiagen). Normalized values (gene-of-interest / house-keeping genes) were calibrated to the control group (set as 1.0) based on Web-Based PCR Array Data Analysis (Qiagen). mRNA expression data were analyzed further using Ingenuity Pathway Analysis (IPA) to NCM-induced changes in gene functions and metabolic pathways.

4. Analysis of Hepatic Fatty Acid Profile

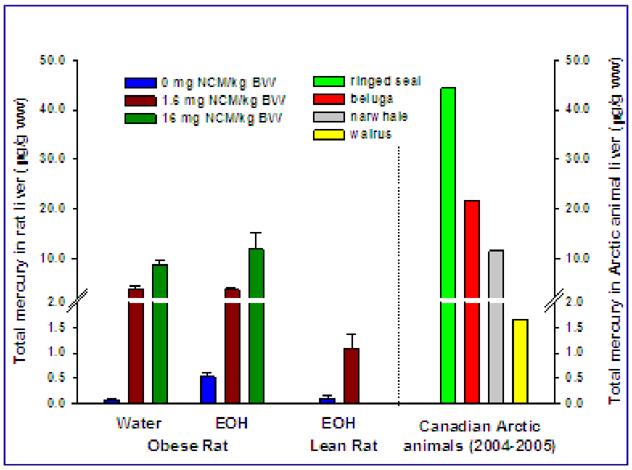
Free fatty acid profile in the rat liver samples were determined using a modified method of Blighand Dyer (1959). Rat livers were firstly pulverized using a CP02 CryoPrep Dry Pulverization System from Covaris. Pulverized samples were homogenized 10 ml of Chloroform:Methanol (2:1) mixture using a Polytron PT 1300 D instrument (5000rpm for 1min). The homogenate was filtered through Wattman paper No1. Free fatty acids (FFA) in the filtrates were extracted in 6 ml NaCl 0.58%, which was then centrifuged to separate the organic phase containing FFA from the aqueous phase. After rinsing, the organic FFA-containing phase was dried by incubation with sodium sulfate (Na_2SO_4) granulate salt. Chloroform was removed using a Meyer N-Evap analytical evaporator under a stream of nitrogen gas at 40^{o}C for 1-3h. FFA was resuspended in 1 ml of Hexane, and derivitized to methyl ester using Boron trifluoride methanol solution. Fatty acid methyl esters (FAME) were cleaned with several hexane and deionized water and dried with granular sodium sulfate salt and resuspended in hexane. FAME were analysed by GC with a flame ionization decay detector and auto-sampler (Agilent Technologies 6890N) using a biscyanopropyl column (24056 Supelco, SP-2560, L × I.D. 100 m × 0.25 mm, df 0.20 µm). The fatty acids were identified by comparing their retention times with those of a standard mixture of fatty acid methyl esters (Supelco 37 FAME catalogue number 47 885-U; Supelco Inc.). The fatty acids were expressed as % of total fatty acids.

Results

Mercury concentration in rat organs

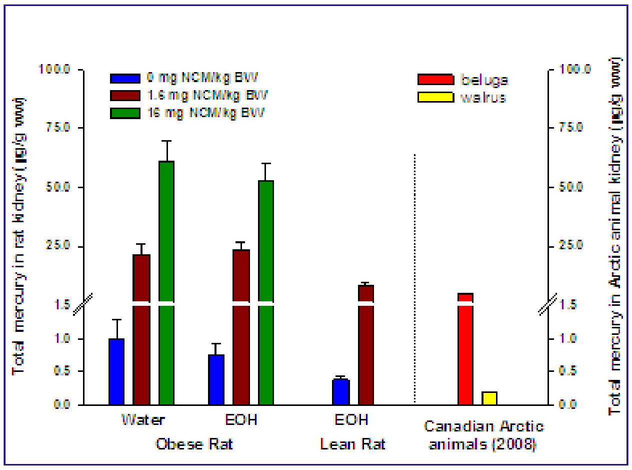
The concentrations of total mercury in the liver of dosed rats were comparable to the levels found in the liver of marine mammals in the Canadian Arctic (Fig. 1), and they were higher in the rats received higher mercury dose, but not proportionally. Alcohol treatment did not affect mercury content in rat livers. However, the lean rats had lower mercury content than the obese rats treated with the same dose of mercury.

Fig. 1. Total mercury concentrations in obese and lean JCR rat liver after four weeks of oral exposure to NCM with or without alcohol (EOH), as compared with reported total mercury concentrations in the liver of marine mammals. The vertical bars are the mean values of 5-6 animals. The error bars are the standard errors of the means.



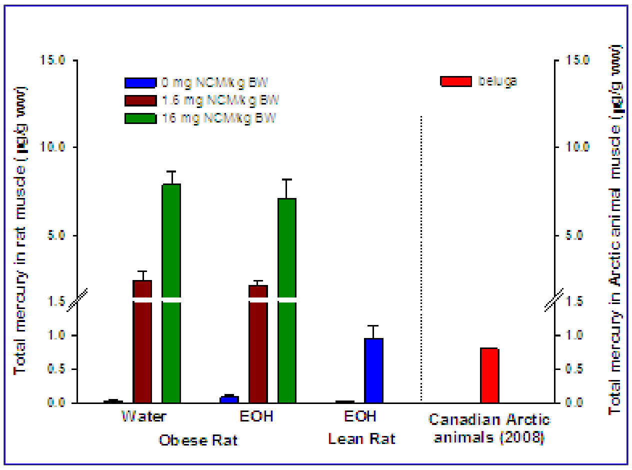
The total mercury contents in rat kidney for the low dose group were comparable with those found in marine mammals, but for the high dose group were higher than those found in marine mammals in the Canadian Arctic (Fig. 2). Kidney mercury content increased with NCM dose, but not proportionally. Alcohol did not affect mercury content in the rat kidney, but the obese animals had higher mercury content in the kidney than the lean animals.

Fig. 2. Total mercury contents in the obese and lean JCR rat kidney after four weeks of oral exposure to NCM with or without alcohol (EOH), as compared with reported total mercury concentrations in the liver of marine mammals. The vertical bars are the mean values of 5-6 animals. The error bars are the standard errors of the means.



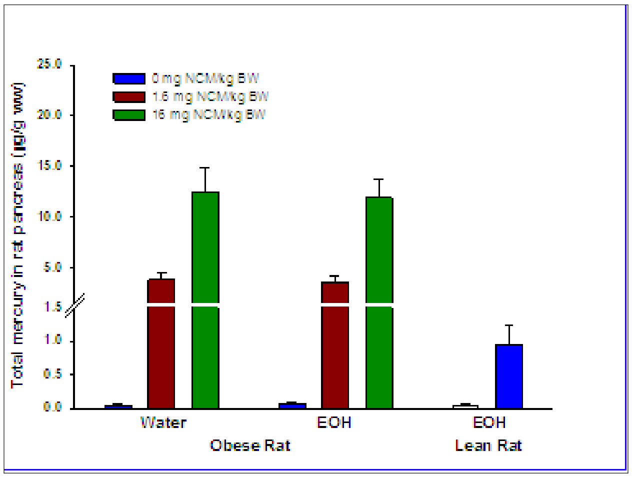
The total mercury contents in rat muscle of the low dose group were comparable to those of marine mammals, but for the high dose group were higher than those of marine mammals (Fig. 3). The obese animals had higher concentrations of mercury in muscle than the lean animals. Alcohol did not affect mercury contents in muscle.

Fig. 3. Total mercury content in the obese and lean JCR rat muscles after four weeks of oral exposure to NCM with or without alcohol (EOH), as compared with the reported total mercury concentration in the muscle of marine mammals. The vertical bars are the mean values of 5-6 animals. The error bars are the standard errors of the means.



No information on the total mercury concentrations in the pancreas of marine mammals could be found in the literature. In rats, pancreatic mercury content increased with dose, but not proportionally (Fig. 4). The obese animals retained higher mercury content in the pancreas than the lean animals when being treated with the same dose of NCM.

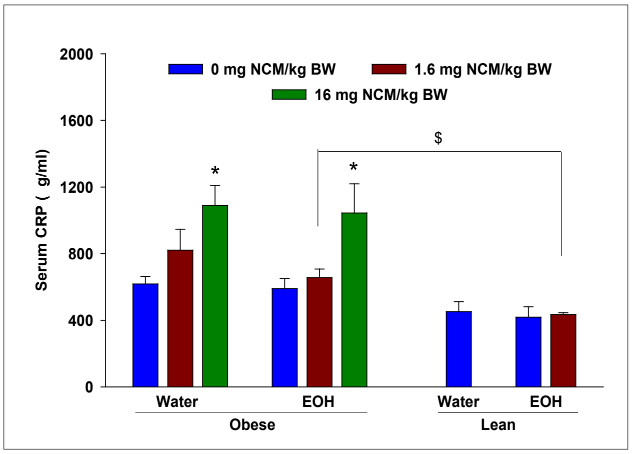
Fig. 4. Total mercury content in the obese and lean JCR rat pancreas after four weeks of oral exposure to NCM with or without alcohol (EOH). The vertical bars are the mean values of 5-6 animals. The error bars are the standard errors of the means.



Serum Markers Related to Cardiovascular Disorders

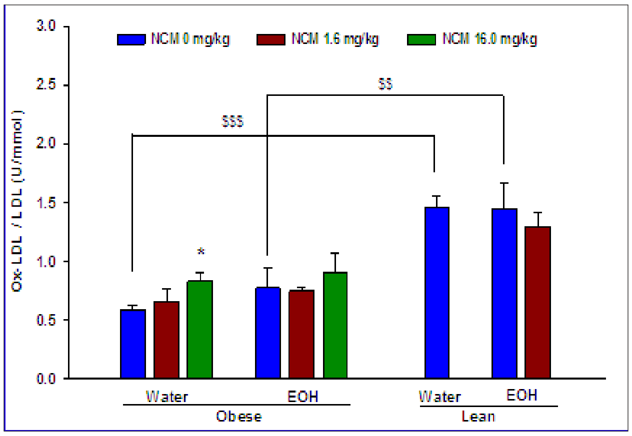
The levels of circulating CRP were generally higher in the obese than the lean animals (Fig. 5). Alcohol had no effects on serum CRP levels, while NCM at the high dose used significantly increased serum CRP levels in the obese animals.

Fig. 5. Serum CRP levels in the obese and lean JCR rats after four weeks of oral exposure to NCM in the presence or absence of alcohol (EOH). The vertical bars are the mean values of 5-6 animals. The error bars are the standard errors of the means. "*" indicates a significant difference from the 0 mg NCM/kg group at p<0.05. "\$" indicates a significant difference between the two treatment groups located under the lines at p<0.05.



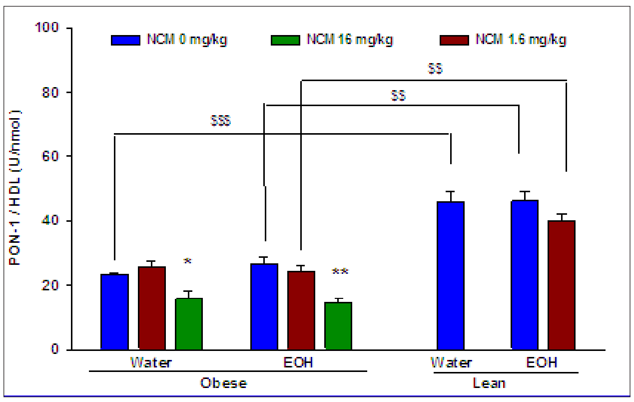
The levels of Ox-LDL per unit of LDL were significantly higher in the lean animals as compared to obese animals, regardles of the alcohol (Fig. 6). NCM at the higher dose used significantly increase the ratio of Ox-LDL to LDL, but only in the obese rats given water.

Fig. 6. Serum Ox-LDL/LDL levels in the obese and lean JCR rats after four weeks of oral exposure to NCM with or without alcohol (EOH). The vertical bars are the mean values of 5-6 animals. The error bars are the standard errors of the means. "*" indicates a significant difference from the 0 mg NCM/kg group at p<0.05. "\$\$"and "\$\$\$" indicate significant differences between the two treatment groups located under the lines at p<0.01 and 0.001, respectively.



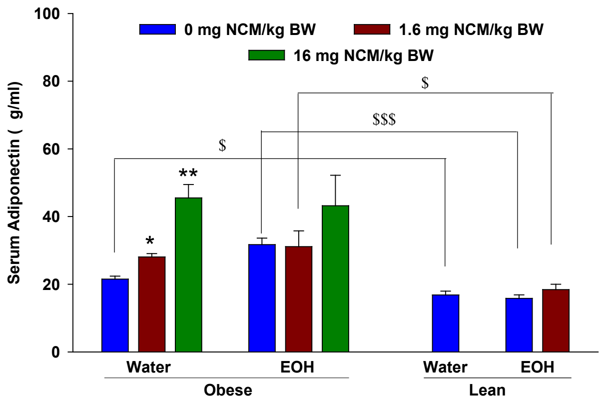
The lean rats had significantly higher circulating PON1 activity per unit of HDL than the obese rats regardless of the alcohol and NCM (Fig. 7). The high dose of NCM significantly decreased PON1/HDL, regardless of the

Fig. 7. Serum PON1 activity per unit of HDL in the obese and lean JCR rats after four weeks of oral exposure to NCM with or without alcohol (EOH). The vertical bars are the mean values of 5-6 animals. The error bars are the standard errors of the means. "*" and "" indicate a significant difference from the 0 mg NCM/kg group at p<0.05 and p<0.01, respectively. "\$", "\$\$" and "\$\$\$" indicate significant differences between the two treatment groups located under the lines at p<0.05, 0.01 and 0.001, respectively.**



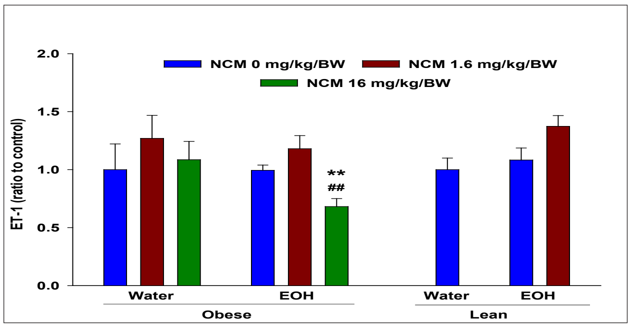
The obese animals had significantly higher levels of circulating adiponectin than the lean animals regardless of EOH and NCM (Fig. 8). Both low and high doses of NCM significantly increased serum adiponectin levels in the obese animals given water.

Fig. 8. Serum adiponectin levels in the obese and lean JCR rats after four weeks of oral exposure to NCM with or without alcohol (EOH). The vertical bars are the mean values of 5-6 animals. The error bars are the standard errors of the means. "*" and "" indicate a significant difference from the 0 mg NCM/kg group at p<0.05 and p<0.01, respectively. "$", "$$" and "$$$" indicate significant differences between the two treatment groups located under the lines at p<0.05, 0.01 and 0.001, respectively.**



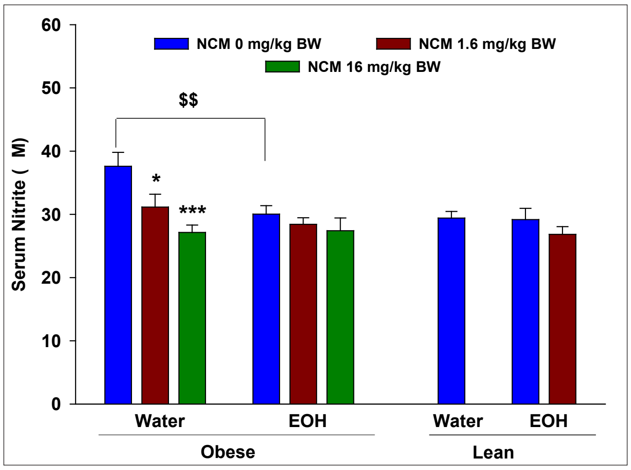
No significant differences in serum levels of ET-1 were found between the obese and the lean animals (absolute value not shown). The high dose of NCM significanly decreased serum ET-1 as compared to the vehicle control and the low NCM dose group in the obese rats given alcohol (Fig. 9).

Fig. 9. Serum ET-1 levels in the obese and lean JCR rats after four weeks of oral exposure to NCM with or without alcohol (EOH). The vertical bars are the mean values of 5-6 animals. The error bars are the standard errors of the means. "" and "##" indicate a significant difference from the 0 mg NCM/kg/BW and 1 mg NCM/kg/BW groups, respectively, at p<0.01.**



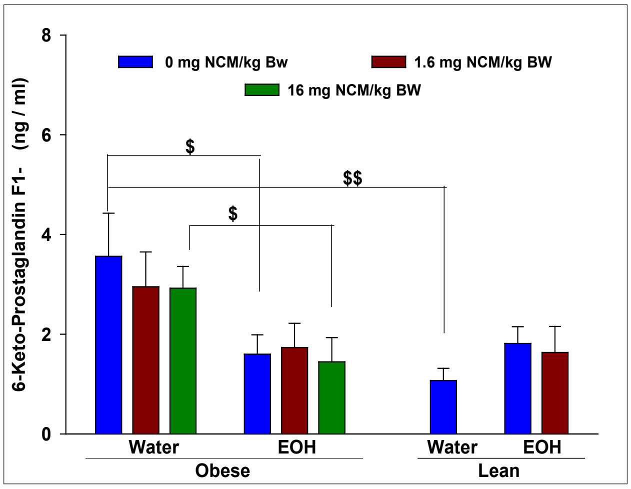
Alcohol significantly decreased serum NO levels in the obese vehicol control rats (Fig. 10). Both the low and the high dose NCM significantly decreased serum NO levels in the obese animals given water.

Fig. 10. Serum NO levels in the obese and lean JCR rats after four weeks of oral exposure to NCM with or without alcohol (EOH). The vertical bars are the mean values of 5-6 animals. The error bars are the standard errors of the means. "*" and "*"indicate a significant difference from the 0 mg NCM/kg/BW at p<0.05 and 0.001, respectively.**



The lean animals given water had significantly lower serum levels of 6-keto-prostaglandin $F_{1\alpha}$ than the obese animals given water. Alcohol signficantly decreased serum 6-keto-prostaglandin $F_{1\alpha}$ in the obese animals regardless of NCM, which NCM had no effects on this marker in the serum.

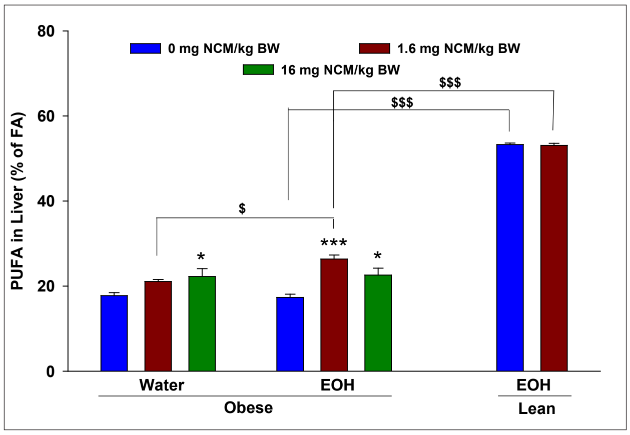
Fig. 11. Serum 6-ketoprostaglandin F1α levels in the obese and lean JCR rats after four weeks of oral exposure to NCM with or without alcohol (EOH). The vertical bars are the mean values of 5-6 animals. The error bars are the standard errors of the means. "$"and"$$" indicate significant differences between the two treatment groups located under the lines at p<0.05 and 0.01, respectively.



Liver Fatty Acid Profile

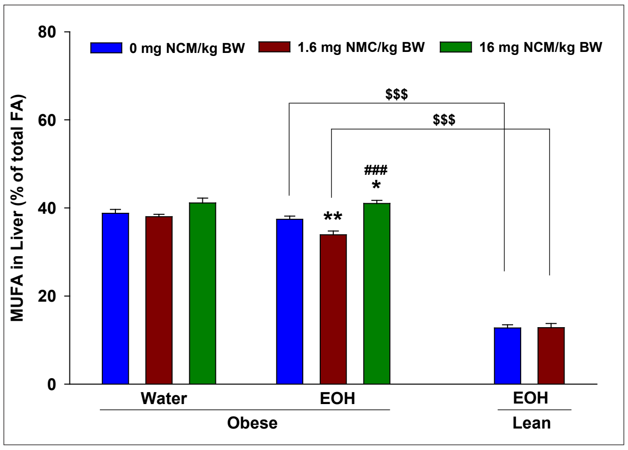
The lean rats given alcohol had significantly higher levels of polyunsaturated fatty acids (PUFA) thans the obese animals given alcohol, regardless of NCM (Fig. 12). Alcohol did not affect hepatic PUFA levels in the liver of obese animals. Both high and low doses of NCM significanly increased levels of liver PUFA in the obese animals given alcohol. The high dose NCM also increased levels of liver PUFA in the obese rats given water.

Fig. 12. Liver PUFA levels in the obese and lean JCR rats after four weeks of oral exposure to NCM with or without alcohol (EOH). The vertical bars are the mean values of 5-6 animals. The error bars are the standard errors of the means. "*", "", "***"indicate a significant difference from the 0 mg NCM/kg/BW at p<0.05, 0.01, and 0.001, respectively. "$", "$$" and "$$$" indicate significant differences between the two treatment groups located under the lines at p<0.05, 0.01 and 0.001, respectively.**



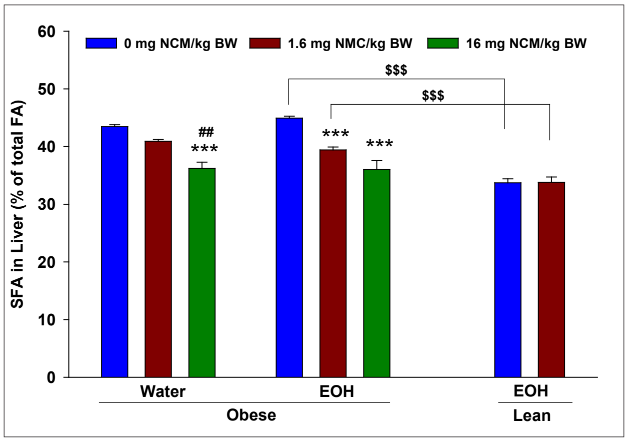
The obese animals given alcohol had significantly higher levels of monounsaturated fatty acids (MUFA) in the liver than the lean animals given alcohol (Fig. 13), regardles of NCM. The low dose NCM significantly decreased, while the high dose NCM significantly increased, the levels of MUFA in the liver of obese animals given alcohol.

Fig. 13. Liver MUFA levels in the obese and lean JCR rats after four weeks of oral exposure to NCM with or without alcohol (EOH). The vertical bars are the mean values of 5-6 animals. The error bars are the standard errors of the means. "*"and "" indicate a significant difference from the 0 mg NCM/kg/BW group at p<0.05 and 0.01, respectively. "###" indicates a significant difference from the 1 mg NCM/kg/BW group at p<0.001. "$$"indicates a significant difference between the two treatment groups located under the lines at p<0.05.**



The obese animals given alcohol had significantly higher levels of saturated fatty acids (SFA) in the liver than the lean animals given alchol, regardless of the NCM (Fig. 14). Both the low and high doses of NCM significantly decreased the levels of SFA in the obese animals given alcohol. The high dose NCM also significantly decreased liver SFA in the obese animals given water.

Fig. 14. Liver SFA levels in the obese and lean JCR rats after four weeks of oral exposure to NCM with or without alcohol (EOH). The vertical bars are the mean values of 5-6 animals. The error bars are the standard errors of the means. "*" indicates a significant difference from the 0 mg NCM/kg/BW group at p<0.001. "##" indicates a significant difference from the 1 mg NCM/kg/BW group at p<0.01. "$$" indicates a significant difference between the two treatment groups located under the lines at p<0.01.**



Expression of Genes Involved in Glucose and Lipoprotein Metabolism in the Liver

To further understand the effects of NCM on metabolism and the association between NCM-induced changes in the circulation and those in liver, effects of NCM (high dose) on glucose and lipoprotein metabolism in the liver were examined at gene transcription level.

High dose NCM significantly down regulated genes involved gluconeogenesis and metabolism (Table 1) in the obese rats given water. This effect of NCM was intensified by alcohol (Table 3). The gene functions significantly affected by NCM are shown in Table 2 and Table 4.

Table 1. Effects of the high dose NCM on the expression of genes involved in glucose metabolism in the obese rats given water. Blue color (fold of change < 0) represents downregulation. Red color represents upregulation (fold of change > 0).

Symbol	Entrez Gene Name	p-value	Fold Change
PCK1	phosphoenolpyruvate carboxykinase 1 (soluble)	2.73E-03	-3.127
G6PC	glucose-6-phosphatase, catalytic subunit	6.96E-04	-2.986
PC	pyruvate carboxylase	9.20E-05	-2.618
GCK	glucokinase (hexokinase 4)	1.94E-02	-2.239
HK3	hexokinase 3 (white cell)	3.76E-02	-1.847
HK2	hexokinase 2	3.38E-02	-1.763
PYGM	phosphorylase, glycogen, muscle	1.24E-02	-1.510
PHKA1	phosphorylase kinase, alpha 1 (muscle)	3.62E-02	-1.498
PCK2	phosphoenolpyruvate carboxykinase 2 (mitochondrial)	1.51E-02	-1.373
LDHA	lactate dehydrogenase A	1.08E-03	-1.359
ENO2	enolase 2 (gamma, neuronal)	1.52E-03	-1.354
ALDOB	aldolase B, fructose-bisphosphate	2.25E-02	-1.280
GSK3B	glycogen synthase kinase 3 beta	2.64E-02	-1.144
PGLS	6-phosphogluconolactonase	3.92E-02	-1.113
SDHC	succinate dehydrogenase complex, subunit C, integral membrane protein, 15kDa	1.75E-02	1.118
PGM1	phosphoglucomutase 1	1.77E-03	1.168
PRPS1	phosphoribosyl pyrophosphate synthetase 1	1.09E-02	1.185
SDHA	succinate dehydrogenase complex, subunit A, flavoprotein (Fp)	1.13E-03	1.228
SDHB	succinate dehydrogenase complex, subunit B, iron sulfur (Ip)	6.59E-04	1.236

Table 2. Effects of the high dose NCM on the functions of genes involved in glucose metabolism in the obese rats given water. Blue color (z-score < 0) represents inhibition. Red color represents activation (z-score > 0).

Functions Annotation	p-Value	Activation z-score	Molecules
Metabolism of pyruvic acid	5.64E-08	-1.974	FBP2, LDHA, PC, PCK1
Cell death of brain	3.53E-03	-1.729	GSK3B, HK2, SDHA, SDHB
Neuronal cell death	1.53E-02	-1.301	GSK3B, HK2, HPRT1, SDHA, SDHB
Concentration of triacylglycerol	3.82E-03	1.445	G6PC, GCK, IDH1, PCK1

Table 3. Effects of high dose NCM on expression of genes involved in glucose metabolism in the obese rats given alcohol. Blue color (fold of change <0) represents downregulation. Red color represents upregulation (fold of change >0).

Symbol	Entrez Gene Name	p-value	Fold Change
GCK	glucokinase (hexokinase 4)	4.70E-05	-5.385
G6PC	glucose-6-phosphatase, catalytic subunit	5.94E-03	-3.466
PCK1	phosphoenolpyruvate carboxykinase 1 (soluble)	4.50E-04	-3.103
PC	pyruvate carboxylase	1.00E-06	-2.635
PKLR	pyruvate kinase, liver and RBC	6.97E-03	-2.172
PHKA1	phosphorylase kinase, alpha 1 (muscle)	5.24E-03	-1.610
LDHA	lactate dehydrogenase A	7.68E-03	-1.552
ALDOB	aldolase B, fructose-bisphosphate	1.78E-03	-1.539
FBP1	fructose-1,6-bisphosphatase 1	1.36E-03	-1.530
PYGL	phosphorylase, glycogen, liver	3.17E-02	-1.459
PCK2	phosphoenolpyruvate carboxykinase 2 (mitochondrial)	3.81E-02	-1.430
PDK1	pyruvate dehydrogenase kinase, isozyme 1	1.81E-03	-1.413
ENO3	enolase 3 (beta, muscle)	4.10E-03	-1.391
MDH1	malate dehydrogenase 1, NAD (soluble)	4.48E-03	-1.370
MDH1B	malate dehydrogenase 1B, NAD (soluble)	1.53E-02	-1.240
PHKG2	phosphorylase kinase, gamma 2 (testis)	3.14E-02	-1.231
SUCLA2	succinate-CoA ligase, ADP-forming, beta subunit	1.19E-02	-1.228
PGLS	6-phosphogluconolactonase	4.51E-02	-1.215
PDK4	pyruvate dehydrogenase kinase, isozyme 4	1.76E-02	2.107
FBP2	fructose-1,6-bisphosphatase 2	4.63E-03	2.905

Table 4. Effects of the high dose NCM on the functions of genes involved in glucose metabolism in the obese rats given alcohol. Blue color (z-score < 0) represents inhibition. Red color represents activation (z-score > 0).

Category	Functions Annotation	p-Value	Activation z-score	Molecules
Energy Production	metabolism of pyruvic acid	3.11E-11	-2.200	FBP2, LDHA, PC, PCK1, PKLR
	conversion of pyruvic acid	3.71E-11	-2.000	LDHA, PC, PCK1, PKLR

The high dose NCM significantly downregulated many genes involved in fatty acid and steroids metabolism, and lipid and lipoprotein secretion and efflux (Table 5), but upregulated genes involved in cholesterol synthesis, while alcohol enhenced the effects of NCM (Table 7). The functions of the genes affected by NCM are listed in Table 6 and Table 8.

Table 5. Effects of the high dose NCM on the expression of genes involved in lipoprotein metabolism in the obese rats given water. Blue color (fold of change <0) represents downregulation. Red color represents upregulation (fold of change >0).

Symbol	Entrez Gene Name	p-value	Fold Change
OLR1	oxidized low density lipoprotein (lectin-like) receptor 1	1.13E-03	-3.798
APOA4	apolipoprotein A-IV	3.82E-04	-2.565
APOA1	apolipoprotein A-I	1.30E-05	-2.212
SREBF1	sterol regulatory element binding transcription factor 1	4.74E-02	-1.859
LCAT	lecithin-cholesterol acyltransferase	4.92E-03	-1.491
APOD	apolipoprotein D	4.14E-02	-1.479
INSIG2	insulin induced gene 2	4.42E-02	-1.462
LDHA	lactate dehydrogenase A	2.01E-03	-1.374
OSBPL1A	oxysterol binding protein-like 1A	1.10E-03	-1.315
SCARF1	scavenger receptor class F, member 1	3.49E-02	-1.202
HMGCS2	3-hydroxy-3-methylglutaryl-CoA synthase 2 (mitochondrial)	4.24E-02	1.212
SOAT2	sterol O-acyltransferase 2	1.42E-02	1.282
PRKAA1	protein kinase, AMP-activated, alpha 1 catalytic subunit	2.78E-02	1.320
CYB5R3	cytochrome b5 reductase 3	1.86E-03	1.340
LDLR	low density lipoprotein receptor	3.45E-02	1.352
PMVK	phosphomevalonate kinase	6.72E-03	1.354
EBP	emopamil binding protein (sterol isomerase)	6.78E-03	1.367
ACAA2	acetyl-CoA acyltransferase 2	4.89E-03	1.546
HMGCR	3-hydroxy-3-methylglutaryl-CoA reductase	1.61E-02	1.556
CYP39A1	cytochrome P450, family 39, subfamily A, polypeptide 1	2.51E-04	1.761
DHCR7	7-dehydrocholesterol reductase	7.83E-03	1.814
CYP51A1	cytochrome P450, family 51, subfamily A, polypeptide 1	2.64E-03	1.833
TM7SF2	transmembrane 7 superfamily member 2	1.27E-03	1.917
HMGCS1	3-hydroxy-3-methylglutaryl-CoA synthase 1 (soluble)	1.08E-02	2.058
NR0B2	nuclear receptor subfamily 0, group B, member 2	8.32E-03	2.156
IDI1	isopentenyl-diphosphate delta isomerase 1	1.29E-02	2.492
FDFT1	farnesyl-diphosphate farnesyltransferase 1	8.03E-04	2.585
PCSK9	proprotein convertase subtilisin/kexin type 9	5.39E-03	2.844

Table 6. Effects of the high dose NCM on the functions of genes involved in lipoprotein metabolism in the obese rats given water. Blue color (z-score <0) represents inhibition. Red color represents activation (z-score >0).

Functions Annotation	p-Value	Activation z-score	Molecules
metabolism of carbohydrate	4.46E-05	-1.981	APOA1, APOA4, APOD, LCAT, LIPE, LRP6, PRKAA1, SREBF1
secretion of lipid	3.09E-05	-1.960	APOA1, APOA4, LDLR, PRKAA1, SREBF1
concentration of D-glucose	3.73E-06	-1.919	APOA4, LCAT, LDLR, LIPE, NR0B2, PRKAA1, SREBF1
synthesis of carbohydrate	2.45E-04	-1.710	APOA1, LCAT, LIPE, LRP6, PRKAA1, SREBF1
quantity of hdl cholesterol in blood	1.70E-13	-1.654	APOA1, APOA4, LCAT, LDLR, NR0B2, OLR1, PCSK9, SOAT2
fatty acid metabolism	2.58E-06	-1.529	ACAA2, APOA1, APOA4, INSIG2, LCAT, LDLR, OLR1, OSBPL1A, SREBF1
glucose metabolism disorder	5.69E-03	-1.452	APOA1, HMGCR, HMGCS2, LDLR, LIPE, NR0B2, SREBF1
steroid metabolism	1.89E-24	-1.309	APOA1, APOA4, CYP39A1, CYP51A1, DHCR7, EBP, FDFT1, HMGCR, IDI1, INSIG2, LCAT, LDLR, NR0B2, PCSK9, PMVK, PRKAA1, SOAT2, SREBF1
concentration of triacylglycerol	3.12E-10	-1.247	APOA1, APOA4, APOD, LCAT, LDLR, LIPE, NR0B2, PRKAA1, SOAT2, SREBF1
leukocyte migration	1.29E-02	1.264	ACTB, APOA1, LCAT, LDLR, OLR1, SREBF1

Table 7. Effects of the high dose NCM on the expression of genes involved in lipoprotein metabolism in the obese rats given alcohol. Blue color (fold of change < 0) represents downregulation. Red color represents upregulation (fold of change > 0).

Symbol	Entrez Gene Name	p-value	Fold Change
APOA4	apolipoprotein A-IV	5.85E-04	-2.451
APOA1	apolipoprotein A-I	5.17E-03	-2.350
SREBF1	sterol regulatory element binding transcription factor 1	3.81E-02	-1.746
LCAT	lecithin-cholesterol acyltransferase	2.55E-03	-1.739
LDHA	lactate dehydrogenase A	1.38E-02	-1.586
SNX17	sorting nexin 17	4.83E-04	-1.496
PRKAA2	protein kinase, AMP-activated, alpha 2 catalytic subunit	1.82E-02	-1.478
APOF	apolipoprotein F	1.72E-02	-1.475
OSBPL1A	oxysterol binding protein-like 1A	4.86E-04	-1.425
APOE	apolipoprotein E	1.62E-02	-1.394
APOC3	apolipoprotein C-III	4.10E-02	-1.378
LRP6	low density lipoprotein receptor-related protein 6	5.54E-03	-1.350
LRP12	low density lipoprotein receptor-related protein 12	4.84E-03	-1.341
ANGPTL3	angiopoietin-like 3	4.23E-02	-1.339
COLEC12	collectin sub-family member 12	4.24E-02	-1.332
HDLBP	high density lipoprotein binding protein	1.92E-03	-1.301
Ankra2/LOC100360129	ankyrin repeat, family A (RFXANK-like), 2	3.50E-03	-1.265
ABCA1	ATP-binding cassette, sub-family A (ABC1), member 1	3.27E-02	-1.253
CEL	carboxyl ester lipase (bile salt-stimulated lipase)	4.36E-02	-1.248
NR1H3	nuclear receptor subfamily 1, group H, member 3	3.60E-02	-1.200
NR1H2	nuclear receptor subfamily 1, group H, member 2	2.54E-02	-1.180
PRKAA1	protein kinase, AMP-activated, alpha 1 catalytic subunit	1.89E-02	1.280
PMVK	phosphomevalonate kinase	1.50E-02	1.313
ACAA2	acetyl-CoA acyltransferase 2	1.62E-02	1.314
MVD	mevalonate (diphospho) decarboxylase	4.90E-02	1.372
HPRT1	hypoxanthine phosphoribosyltransferase 1	6.97E-03	1.452
CYP51A1	cytochrome P450, family 51, subfamily A, polypeptide 1	2.47E-03	1.748
FDPS	farnesyl diphosphate synthase	7.20E-03	1.772
HMGCS1	3-hydroxy-3-methylglutaryl-CoA synthase 1 (soluble)	7.99E-03	1.871
PCSK9	proprotein convertase subtilisin/kexin type 9	1.84E-02	2.019
FDFT1	farnesyl-diphosphate farnesyltransferase 1	3.32E-03	2.088
IDI1	isopentenyl-diphosphate delta isomerase 1	9.54E-04	2.546
CDH13	cadherin 13, H-cadherin (heart)	3.36E-02	2.766

Table 8. Effects of the high dose NCM on the functions of genes involved in lipoprotein metabolism in the obese rats given alcohol. Blue color (z-score <0) represents inhibition. Red color represents activation (z-score >0).

Functions Annotation	p-Value	Activation z-score	Molecules
size of atherosclerotic lesion	5.43E-07	1.214	APOA1, APOA4, APOE, CEL, LCAT
quantity of macrophages	2.03E-06	1.239	ABCA1, APOA4, APOE, NR1H2, NR1H3, SREBF1
accumulation of lipid	1.02E-11	1.325	ABCA1, APOA1, APOC3, APOE, CEL, FDFT1, LCAT, NR1H2, NR1H3, PRKAA2, SREBF1
atherosclerosis	1.88E-09	1.334	ABCA1, ANGPTL3, APOA1, APOA4, APOC3, APOE, CDH13, CEL, LCAT, LRP6, NR1H3
mass of liver	1.52E-07	1.342	ANGPTL3, APOA1, APOE, CEL, FDFT1, NR1H3
vascular disease	3.64E-08	1.355	ABCA1, ANGPTL3, APOA1, APOA4, APOC3, APOE, CDH13, CEL, HPRT1, LCAT, LRP6, NR1H3
organismal death	2.73E-04	1.363	ABCA1, ACTB, ANGPTL3, APOE, CYP51A1, FDFT1, HPRT1, LRP6, NR1H2, NR1H3, PRKAA2, SREBF1
quantity of leukocytes	6.21E-03	1.415	ABCA1, APOA1, APOA4, APOE, NR1H2, NR1H3, SREBF1
accumulation of sterol	1.93E-11	1.520	ABCA1, APOE, CEL, NR1H2, NR1H3, PRKAA2, SREBF1
quantity of blood cells	7.51E-04	1.553	ABCA1, APOA1, APOA4, APOE, LCAT, NR1H2, NR1H3, PRKAA1, SREBF1
accumulation of cholesterol	6.14E-10	1.779	ABCA1, APOE, NR1H2, NR1H3, PRKAA2, SREBF1
quantity of foam cells	1.05E-08	1.964	APOA4, APOE, NR1H2, NR1H3
endocytosis	1.20E-06	2.000	ABCA1, APOC3, APOE, CDH13, NR1H2, NR1H3, SNX17
concentration of hormone	2.23E-07	-2.777	ABCA1, APOE, CDH13, CEL, LCAT, NR1H2, NR1H3, PRKAA1, PRKAA2
efflux of cholesterol	1.68E-13	-2.742	ABCA1, APOA1, APOA4, APOC3, APOE, APOF, NR1H2, NR1H3, SREBF1
fatty acid metabolism	6.98E-12	-2.458	ABCA1, ACAA2, ANGPTL3, APOA1, APOA4, APOC3, APOE, APOF, CEL, LCAT, NR1H2, NR1H3, OSBPL1A, SREBF1
esterification of lipid	6.96E-10	-2.353	ABCA1, APOA1, APOA4, APOE, CEL, LCAT
synthesis of carbohydrate	3.21E-05	-2.335	APOA1, APOE, LCAT, LRP6, PRKAA1, PRKAA2, SREBF1
synthesis of fatty acid	1.81E-07	-2.180	ABCA1, APOA4, APOC3, APOE, CEL, NR1H2, NR1H3, SREBF1
efflux of phospholipid	1.11E-09	-2.160	ABCA1, APOA1, APOA4, APOC3, APOE
esterification of cholesterol	8.34E-09	-2.132	ABCA1, APOA1, APOA4, APOE, LCAT
concentration of triacylglycerol	1.90E-14	-2.023	ABCA1, ANGPTL3, APOA1, APOA4, APOC3, APOE, APOF, LCAT, NR1H2, NR1H3, PRKAA1, PRKAA2, SREBF1
secretion of lipid	9.28E-11	-2.001	ABCA1, APOA1, APOA4, APOC3, APOE, NR1H2, NR1H3, PRKAA1, SREBF1
quantity of insulin in blood	6.85E-04	-1.982	APOE, CEL, LCAT, PRKAA2
transmission of lipid	4.07E-10	-1.951	ABCA1, APOA1, APOA4, APOC3, APOE
biosynthesis of cyclic nucleotides	1.81E-03	-1.951	ABCA1, APOA1, APOE, FDPS
quantity of protein in blood	9.70E-10	-1.858	ABCA1, APOA1, APOA4, APOC3, APOE, APOF, CEL, LCAT, NR1H2, NR1H3, PCSK9, PRKAA2
metabolism of carbohydrate	6.85E-06	-1.806	ANGPTL3, APOA1, APOA4, APOE, LCAT, LRP6, PRKAA1, PRKAA2, SREBF1
transport of sterol	2.00E-10	-1.722	ABCA1, APOA1, APOC3, APOE, LCAT, OSBPL1A
concentration of cholesterol ester	9.67E-09	-1.673	ABCA1, APOA1, APOC3, APOE, LCAT
hydrolysis of lipid	2.91E-06	-1.671	APOA1, APOC3, APOE, CEL, PRKAA1, PRKAA2
synthesis of lipid	3.14E-14	-1.667	ABCA1, APOA1, APOA4, APOC3, APOE, CEL, CYP51A1, FDFT1, FDPS, IDI1, LCAT, MVD, NR1H2, NR1H3, PMVK, PRKAA1, SREBF1
quantity of hdl cholesterol in blood	2.25E-13	-1.481	ABCA1, APOA1, APOA4, APOC3, APOE, APOF, LCAT, PCSK9
transport of cholesterol	1.28E-08	-1.474	ABCA1, APOA1, APOC3, APOE, LCAT

Discussion/Conclusions/ Future Work

a. Discussion

This report presented additional data from an animal study, which was completed by the end of 2012. Data on body weight, food consumption, water consumption, serum biochemistry, hematology, and serum levels of organic chemicals, alcohol, cholesterols, and lipoproteins have been included in the 2011 synopsis report to NCP.

Total mercury content was a few times higher in kidney than liver, muscle, and pancreas, while similar total mercury content were found in rat liver, muscle and pancreas, suggesting that the effects of mercury in the last two tissues need not to be overlooked. In fact, our previous data demonstrated that the same dose of NCM significantly decreased pancreas weights and serum insulin and creatine kinase levels in the obese rats, which could be attributed to mercury intoxication. Higher concentrations of total mercury were found in tissues of obese than lean animals. This could be due to that the obese animals have less, than the lean animal, protein mass to which mercury is known to be associated with in biological systems, or that the obese animals had lower rate of secretion by which mercury is excluded from the body. This would suggest that obese human individuals may be more prone to mercury-induced health effects.

The obese and the lean rats had similar levels of circulating PON1 per unit volume of serum (data not shown). However, the lean rats had nearly twice as much PON1 activity per unit of HDL as compared with the obese rats, suggesting that the lean rats had more functional HDL than the obese rats. This is consistent with the finding that the lean and obese rats had similar levels of Ox-LDL per unit volume of serum, but only in the obese rats, NCM increased OX-LDL per unit of LDL. This seems to suggest that obese individuals may be more prone to chemical-induced oxidation of LDL as a result of compromised circulating HDL quality, and therefore have higher risk of developing cardiovascular disorders when exposed to chemical contaminants.

The higher levels of serum CRP and Ox-LDL/LDL and lower levels of serum PON1/HDL and NO in the obese rats exposed to the high dose NCM strongly suggest that NCM may increase the risk of developing atherosclerosis and hypertension when exposure levels are in the higher end of the exposure range found in the Inuit population (Dewailly et al. 2006) or similar to the exposure level of Arctic marine mammals (NCP 2006, 2009).

The obese rats had much more saturated and monounsaturated fatty acids, but much less polyunsaturated fatty acids than the lean rats in the liver. The high dose NCM altered the composition of fatty acids in the liver of obese animals, especially when alcohol is used at the same time, suggesting an interaction between NCM and alcohol on fatty acid metabolism.

The high dose NCM down regulated many genes involved in gluconeogenesis, glycolysis, carbohydrate metabolism, and lipoprotein secretion, but upregulated genes involved in cholesterol synthesis. This is consistent with increased liver weight and liver steatosis, and decreased circulating cholesterol, triglyceride, LDL and HDL in the dosed obese animals.

It is noted that the expression of GCK and PCK1 genes were downregulated for a few folds by the high dose of NCM, especially in the presence of alcohol. Dysregulation of GCK and PCK1 have been linked to insulin resistance and diabetes in animals and humans (Massa et al. 2011, Beale et al. 2007). It remains to be confirmed if the NCM-induced down-regulation of GCK1 and PCK1 contributes insulin resistance and diabetes in the obese JCR rats.

b. Conclusions

Data from this animal study suggest that

1. obese individuals may be more prone to NCM-induced toxicities than lean individuals;
2. NCM at the exposure levels found in a small proportion of Inuit people (higher end of exposure range) may increase the risk of developing liver steatosis, atherosclerosis, hypertension, metabolic disorders and diabetes;
3. moderate consumption of alcohol may alter NCM-induced effects in the liver; and
4. more proteomic analyses are required to confirm the NCM-induced changes in glucose and lipoprotein metabolism in rat liver, and association with metabolic disorders and diabetes.

c. Future Work

- Complete sample and data analysis
- Present and publish data
- Communicate with Northern communities about the findings of our animal studies
- Communicate with scientists involved in human health monitoring in the North and provide new biomarkers for human epidemiological studies.

Consultation

This is a laboratory experimental study. No Northern consultation is needed. However, information generated from this study is highly relevant and completely accessible to NCP and Northern communities.

Deliverables

The deliverables of this project include:

- mechanisms for the potential role of Northern Contaminant Mixtures as potential risk factors of metabolic and cardiovascular diseases;
- characterization of the interactive effects of lifestyle factors such as alcohol consumption and contaminants on metabolic and cardiovascular health;
- potential new biomarkers for health monitoring and risk assessment and future epidemiological studies of the Northern populations;
- established capacities, expertise, and valuable information for guiding future animal studies to characterize the dose-response relationship of contaminants and cardiovascular and metabolic disease;
- valuable information provided to Northern communities and Canadian Government to implement enhanced policies and strategies for contaminant control and health promotion in the Canadian North;
- presentations at NCP Results Workshop and other scientific meetings in 2013-2014; and
- publication in peer reviewed scientific journals in 2013-2014.

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

Aliments traditionnels et santé cardiovasculaire au Nunavik : étude de l'équilibre complexe entre le sélénium et les contaminants environnementaux

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Abstract

Selenium (Se) is an essential element highly present in the traditional marine diet of Inuit and their exposure to this element is among the highest in the world. In fish and marine mammal eating populations, there is increasing evidence suggesting that high Se intake may play a role in offsetting some deleterious effects of methylmercury (MeHg) exposure. However, in other populations, elevated plasma Se

Résumé

Le sélénium (Se) est un élément essentiel très abondant dans l'alimentation traditionnelle, de source marine, des Inuits. Les Inuits figurent parmi les populations les plus exposées à cet élément au monde. Dans les populations qui se nourrissent de poissons et de mammifères marins, de plus en plus de données tendent à indiquer qu'un grand apport en sélénium pourrait atténuer certains effets néfastes de

concentrations have been recently associated to type 2 diabetes, hypercholesterolemia and/or hypertension. In addition to plasma Se levels, the most common biomarker of Se status, several other biomarkers (e.g. selenoproteins and small Se molecules such as selenoneine) have been identified and these may help to better characterise Se status. We will investigate relations between these new biomarkers of Se status and emerging health issues such as diabetes and cardiovascular diseases in Inuit adults, taking into account possible interactions with mercury and other environmental contaminants. We will also identify the forms of selenium and mercury present in various traditional foods and their bioaccessibility. These much needed data will improve our capacity to assess the risks and benefits of Se intake and the traditional marine diet in this population.

l'exposition au méthylmercure (MeHg). Cependant, dans d'autres populations, des concentrations plasmatiques élevées de sélénium ont été récemment associées au diabète de type 2, à l'hypercholestérolémie et à l'hypertension. Outre la concentration plasmatique de sélénium, qui constitue le biomarqueur le plus usuel du statut à l'égard du sélénium, plusieurs autres biomarqueurs (p. ex. les sélénoprotéines et de petites molécules contenant du sélénium, notamment la sélénonéine) qui pourraient aider à mieux caractériser le statut à l'égard du sélénium ont été identifiés. Nous étudierons les relations entre ces nouveaux biomarqueurs et les problèmes de santé qui commencent à apparaître chez les Inuits adultes (p. ex. le diabète et les maladies cardiovasculaires) en tenant compte des interactions possibles avec le mercure et d'autres contaminants environnementaux. Nous recenserons également les formes de sélénium et de mercure présentes dans divers aliments traditionnels et déterminerons dans quelle mesure ils sont bioaccessibles. Ces données très attendues nous permettront de mieux évaluer les risques et les bienfaits associés à l'apport en sélénium et à l'alimentation marine traditionnelle des Inuits.

Key messages

- Beluga meat, seal liver and lake trout contain very high total Hg concentrations;
- Seal liver, beluga mattaaq and sculpin eggs are exceptionally high in Se;
- Hg bioaccessibility varies greatly among country foods;
- Selenium and mercury speciation in plasma samples of Inuit adults and country food samples are on-going.

Messages clés

- Les concentrations totales de mercure sont très élevées dans la viande de béluga, le foie de phoque et le touladi.
- Le foie de phoque, le mattaaq de béluga et les œufs de chabots sont exceptionnellement riches en sélénium.
- La bioaccessibilité du mercure varie considérablement d'un aliment traditionnel à l'autre.
- La spéciation du sélénium et du mercure dans les échantillons de plasma d'Inuits adultes et d'aliments traditionnels est en cours.

Objectives

The first section focuses on nutrient/contaminant interactions and their effects on cardio-metabolic health outcomes. The objectives are:

- To measure various biomarkers of Se status [selenoproteins such as selenoprotein P (SelP), glutathione peroxidases (GPx) and thioredoxin reductase (TRxR), plasma total Se (P-Se), inorganic Se (Se+4 and Se+6), selenoneine, methylselenoneine, selenocysteine (SeCys), selenomethionine (SeMet) and selenoalbumin (SeAlb)] and speciate Hg fractions [methylmercury (MeHg) and inorganic mercury (IHg)] in archived blood samples from the Inuit Health in Transition Study (on-going);
- To examine the associations between these biomarkers, taking into consideration possible interactions with Hg, other contaminants, and omega-3 fatty acids (n-3 PUFAs).

The second section focuses on Se and Hg concentrations, speciation and bioavailability in Nunavik country foods. The objectives are:

- To collect selected country foods from several Nunavik villages in collaboration with community members and the Nunavik Research Center of Makivik Corporation;
- To determine the age of the animals sampled and measure total Se and Hg concentrations in the corresponding country food samples;
- To measure Se and Hg species and to study the bioaccessibility of Se and Hg and Se-Hg interactions in these same country food samples using a gastrointestinal model coupled with in vitro cell line (Caco-2) model;
- To evaluate the associations between Se and Hg bioaccessibility found in country foods, and Se and Hg biomarkers in human.

Introduction

The Inuit population of Nunavik displays among the highest selenium (Se) intake and blood Se status in the world since their traditional marine mammal diet is exceptionally rich in Se (Valera et al., 2009). Se is an essential element involved in several body functions through selenoproteins expression, including regulation of oxidative stress, and immune and thyroid functions (Reeves and Hoffmann, 2009). In fish and marine mammal eating populations, high dietary Se intake may play a role in offsetting some deleterious effects of high methylmercury (MeHg) exposure (Ayotte et al., 2011; Boucher et al., 2010; Lemire et al., 2010; Lemire et al., 2011; Valera et al., 2009). Conversely, in Europe and the United States, high plasma Se has been related to type-2 diabetes, hypercholesterolemia and hypertension (Stranges et al., 2010). Contrary to most European and North American populations, Inuit present an exceptional intake of n-3 PUFAs, a preventive factor for CVD (Dewailly et al., 2001). They can also be highly exposed to MeHg, PCB, PFOS and trans-fat, all risk factors for CVD (Chateau-Degat et al., 2010; Counil et al., 2009; Valera et al., 2009).

While plasma or blood Se are the biomarkers most often used to evaluate the associations between Se status and health effects, several other biomarkers (e.g. selenoproteins and small Se molecules such as selenoneine) have been identified and these may help to better characterise Se status (Xia et al., 2010). Several selenoproteins share common metabolic pathways with glucose and insulin, and it remains unclear whether increased plasma Se and selenoproteins' activity is the cause or the consequence of the disease (Steinbrenner et al., 2011). Selenoproteins have also been postulated as the key targets of Hg toxicity; Hg exhibits a very high affinity for selenol groups in the active site of selenoproteins and high Se intake may restore their enzymatic functions (Khan and Wang, 2009). In addition, TRx has recently been identified as a toxicological target of both MeHg and HgII in in vivo studies (Branco et al., 2011), pointing out to the potential use of this selenoprotein as a biomarker of Hg toxicity (32) (Branco et al., 2012). SelP may also promote MeHg demethylation and/or bind to HgII or MeHg and reduce its availability for target proteins and organs (Khan and Wang, 2009). Others have showed that PCBs, arsenic and cadmium may also interfere with selenoprotein activity (Twaroski et al., 2001; Zwolak and Zaporowska, 2012).

Several factors may also influence Se and Hg concentrations and bioavailability in country foods. In the case of Hg, the levels vary in relation to the type of ecosystem (marine, freshwater and terrestrial) and the position in the aquatic food chain (AMAP, 2011). Hg concentrations also vary between the different parts of an animal; Hg presents a very high affinity for proteins and accumulates mostly in organs and meat and much less in fat (Clarkson, 2002). Traditional Inuit food preparations can also influence contaminants and nutrients concentrations. Several country foods are eaten raw or frozen, while others are dried, fermented or cooked (Blanchet and Rochette, 2008).

The chemical forms of Se and Hg ingested may also influence Se and Hg absorption, Se bioavailability for selenoprotein synthesis, and Se and Hg related-health effects (Clarkson, 2002; Rayman et al., 2008). Although some studies on Se chemical forms have been conducted in fish species and inorganic Hg-Se has been identified in seabirds and marine mammals organs (Ikemoto et al., 2004; Lemes and Wang, 2009; Yamashita and Yamashita, 2010), little information is available on Se and Hg speciation in country foods.

The nutrients can also affect the bioavailability of Hg in the gastrointestinal (GI) tract. We reported the relative contributions of MeHg and HgII to the bioaccessibility of Hg in foods using an in vitro model that simulates the physiological conditions of the human GI tract (Laird et al., 2009). Two recent publications adapted these in vitro procedures to include a human intestinal epithelial cell model (Caco-2) to mimic the intestinal uptake of Hg (Hwang and Shim, 2008) and Se (Gammelgaard et al., 2012). The coupling of in vitro GI models to Caco-2 cells vastly enhances the realism of bioaccessibility estimates since they provide an integrative measure of dissolution and absorption. Furthermore, including Caco-2 cells facilitates the comparison of oxidative stress responses providing the opportunity to quantify the ability of nutritional components to offset adverse effects from dietary Hg exposure.

Activities in 2012-2013

Section 1 of the project:

The technique for the analysis of the new biomarkers of Se has been developed at the Centre de Toxicologie du Québec (CTQ) of the Institut National de Santé Publique du Québec (INSPQ) by Pierre Ayotte and Pierre Dumas. The development of the analytical methods was co-funded by internal funds from INSPQ (48K), 2011-2012. The method is in its final validation stage. The results for half of the samples will be available in early May 2013 and the rest of the results are expected in December 2013. Analyses of blood MeHg levels are on-going; 255 samples have been analysed to date. Adel Achouba was integrated in the research team as a new MSc student at INSPQ for the development of the methods for small Se molecules. Chemists at the Organic Synthesis Service (CRCHU de Québec) have designed several approaches for the synthesis of selenoneine, for which an analytical standard is not available on the market, and are currently evaluating them. This analytical standard will be of central use for future selenoneine speciation in the present project.

Section 2 of the project:

The list of country food to be included in the study was selected by the research team according to the discussions on country foods in the villages, the most important sources of Hg or Se and/or those highly consumed in Nunavik (Lemire et al, in preparation). Michael Kwan provided several recently archived samples (2008-2012) from NRC to be included in the study and Mélanie Lemire completed the sampling in the villages (Kangiqsualujjuaq, Ivujivik, Inukjuak) between October 2011 and August 2012 (mussels, seaweeds, etc.). The sampling is almost completed with the exception of walrus meat, geese, ptarmigan, wildfowl eggs, other seaweeds and Arctic char, Atlantic salmon and brook trout eggs. Transformed country foods (nikku, pitsik and igunak) will be addressed separately (sampling before and after) over the coming months.

Michael Kwan almost completed all total Hg and Se analysis and age determination in the currently available samples at NRC and sent the analysed samples to UOttawa (n = 291) for further Se and Hg speciation analysis, and Hg and Se bioavailability testing.

Brian Laird started the bioaccessibility analyses at the University of Ottawa: to date, 13 traditional foods have been extracted using the in vitro gastrointestinal model. Paulin Junior Vanié, a new MSc student at University of Ottawa, will start Hg and Se speciation analyses soon. All labs (Ayotte, Chan and Kwan) are sharing methods, reference materials and standards.

Other Capacity Building, Communications, and Traditional Knowledge Integration activities:

This project has been first discussed with different Inuit authorities and elaborated in collaboration with the Nunavik Health Nutrition Committee (NNHC) of the NRBHSS and NRC in order to better address health issues related to country foods in Nunavik. The project was publicly presented on October 5, 2011 by M. Lemire in Kuujjuaq (Annual general meeting of the NRBHSS), and in Inuktitut at the radio. A visit of four other villages also took place in October 2011 (Kangiqsualujjuaq, Kangiqsujjuaq, Inukjuak and Kuujjuaraapik) to discuss the project with mayors and health authorities. The sampling campaign was further conducted in March 2012 in collaboration with the Hunter Support Program and the Nunavik Hunting, Fishing and Trapping Association (NHFTA) in the villages. A similar field trip took place in Ivujivik in June 2012. The country foods targeted for analysis were selected based on discussions with the different community stakeholders, in order to choose those most frequently prepared and consumed in these villages. We also took into consideration results from the 2004 Inuit Health in Transition Study on food consumption and estimated intakes of Hg and Se.

During these trips, M. Lemire conducted environmental education activities on the links between living ecosystems (natural and built) in schools. This last activity was conducted in collaboration with Mylène Riva, adjunct professor at ULaval and researcher at CRCHU de Québec, and Maria Ruiz, a postdoctoral fellow, both working on housing conditions and health in Nunavik. The design of the activity was elaborated in collaboration with Let's Talk Science program and school teachers of the villages. The methodology used was a combination of Photo Voice activities all around the village and interactive mapping of the village ecosystem and the retroaction links between ecosystem health and Inuit health. The material for these activities was funded by Let's Talk Science program (cameras, printer, etc. 5K). Students were enthusiastic and future collaborations with school teachers for science fairs might occur. A publication describing the design of this activity was submitted to Journal of Aboriginal Health (currently in revision).

The Regional and Local Development of Kativik Regional Government invited M. Lemire to present the research project at the Nunavik Food Production Conference December 3-6, 2012 in Puvirnituq. Several local and Quebec governmental authorities were present and showed great interest to the project. Future collaborations are planned for 2013. M. Lemire also presented two posters describing the research project at 2012 ArcticNet conference in Vancouver.

Preliminary Results and Discussion:

A total of 255 blood samples have been analysed to date for MeHg (see Table 1). Preliminary comparisons of MeHg with total blood mercury concentrations revealed that MeHg represents on average 72% of total mercury in those samples.

Preliminary results for Hg and Se analyses of country foods are shown in Table 2. Data still need to be age-adjusted. Overall, they show that:

- Beluga meat (raw and nikku) , seal liver and lake trout present very high total Hg concentrations (> 0.5 mg/g), while beluga mattaaq and ringed seal meat are low-intermediate in Hg (0.2 – 0.5 mg/g);
- All other country foods currently included in the study are low in Hg (< 0.2 mg/g);
- Seal liver, beluga mattaaq and nikku and sculpin eggs are exceptionally high in total Se (> 1 mg/g);
- Beluga and seal meat, blue mussels and marine fish species are also good dietary sources of Se (> 0.2 mg/g);

Table 1. Concentrations of MeHg in blood samples of 255 adults from Nunavik (2004 Inuit Health in Transition study)

Analyte	Mean	Median	75th percentile	95th percentile	Maximum
MeHg nmol/L	76	52	100	232	480

Table 2. Total Hg and Se results for 291 country foods collected in Nunavik between 2008 and 2012

Food Item	n	Total Hg ($\mu g\ g^{-1}$ w.w.)		Total Se ($\mu g\ g^{-1}$ w.w.)	
		Range	Geometric Mean	Range	Geometric Mean
Beluga meat (raw)	20	0.39 – 2.7	1.1	0.60 – 1.1	0.73
Beluga meat (air-dried or nikku)	10	1.9 – 6.9*	4.0*	1.1 – 1.4*	1.3*
Beluga mattaaq (skin)	16	0.25 – 1.6	0.44	2.4 – 7.5	4.4
Ringed seal meat	20	0.13 – 1.1	0.30	0.28 – 0.68	0.44
Ringed seal liver	20	2.5 – 90.0	12.0	3.1 – 38.0	8.7
Caribou meat	30	0.014 – 0.054	0.027	0.10 – 0.29	0.20
Blue mussels	32	0.0078 – 0.040	0.018	0.31 – 0.74	0.42
Arctic char (sea-run)	18	0.020 – 0.11	0.044	0.27 – 0.48	0.32
Lake whitefish	20	0.10 – 0.30	0.17	0.17 – 0.40	0.23
Brook trout	24	0.065 – 0.68	0.12	0.18 – 0.29	0.23
Atlantic salmon	17	0.028 – 0.062	0.041	0.20 – 0.35	0.27
Lake trout	20	0.66 – 1.70	1.10	0.021 – 0.41	0.17
Shorthorn sculpin meat	25	0.071 – 0.38	0.19	0.24 – 0.70	0.35
Shorthorn sculpin eggs	19	< LOD	< LOD	1.1 – 1.7	1.4

*Concentrations per gram air-dried weight

Results of Hg in vitro bioaccessibility experiments are shown in Figure 1 for 12 of the 13 country foods analysed to date. Hg concentration was below the detection limit in sculpin eggs. In summary, the maximum Hg bioaccessibility was observed in ringed seal meat (95%). Hg in ringed seal liver showed relatively low bioaccessibility (25%). The low Hg bioaccessibility observed in ringed seal liver may in part offset the risks posed by the high total concentration. Large variation in Hg bioaccessibility was observed between fish species (e.g. Arctic char 9.4%; Lake trout 55.9%). Future work shall elucidate whether these differences in Hg bioaccessibility are driven by Se speciation.

It is important to mention that these results are preliminary and do not include the transport across the Caco-2 cells monolayer data (which simulate the intestinal absorption); therefore the present results should be interpreted with caution

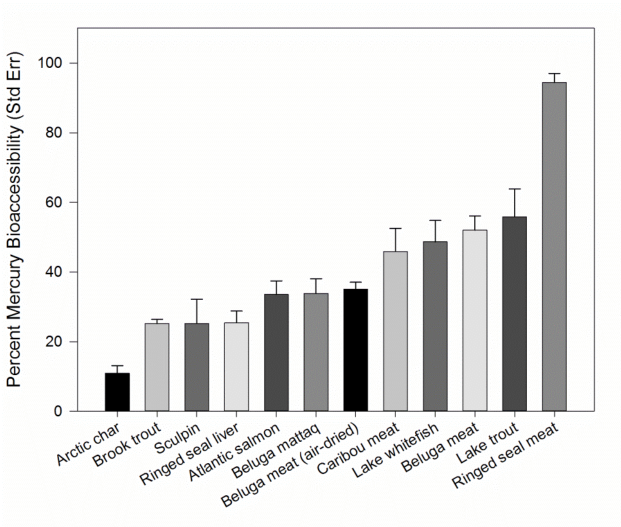

Figure 1. Hg in vitro bioaccessibility of 12 Nunavik country foods. Error bars represent standard error of the mean of at least 6 replicates.

Conclusions

Our results to date indicate that although several country foods are high in Hg, not all of them are equivalent with regard to the proportion of the toxic metal that is available for absorption. In 2013-2014, we will complete the bioaccessibility experiments and conduct Hg and Se speciation analyses in country foods and blood of participants to the Inuit Health in Transition Study. Linking both datasets will allow a better understanding of country foods that contributes the most mercury exposure and Se status. The relation between MeHg, Se biomarkers and cardiovascular risk factors will also be investigated.

Expected Project Completion Date

March 2014

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Quantifying the effect of transient and permanent dietary transitions in the North on human exposure to persistent organic pollutants

Quantification de l'effet des transitions alimentaires provisoires et permanentes dans le Nord sur l'exposition humaine aux polluants organiques persistants

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Abstract

Human exposure to persistent organic pollutants (POPs) in both industrialized and remote regions is strongly influenced by diet. What we eat and where these food items originate are key determinants of body burden and risks associated with chronic exposure to such compounds. It is well known that all foods are not equal with respect to contamination by POPs. This implies that contaminant exposure can be affected by changes in diet. Therefore we have investigated the impact of dietary transitions on human POP exposure, with examples of transient adjustment, e.g. if a woman who is pregnant temporarily avoids food items known to be more contaminated, and more gradual and permanent changes,

Résumé

Dans les régions industrialisées ou éloignées, l'alimentation influe fortement sur l'exposition humaine aux polluants organiques persistants (POP). Les aliments que nous mangeons et leur provenance sont d'importants déterminants de la charge corporelle et des risques associés à une exposition chronique à de tels composés. Il est généralement admis que les aliments ne sont pas tous également contaminés par les POP. Par conséquent, il est possible de varier l'exposition aux contaminants en modifiant l'alimentation. Nous avons donc étudié l'effet de transitions alimentaires sur l'exposition humaine aux POP à l'aide de scénarios d'ajustements provisoires (p. ex. si une femme enceinte écarte temporairement

e.g. if communities gradually shift from a traditional diet of locally hunted animals to a diet that includes more imported food. We have developed a series of computer-based simulation models that quantify how much such dietary changes can affect exposure to contaminants. They have been applied in the context of population-wide transitions away from traditional food among aboriginal Arctic groups, as well as for temperate populations temporarily complying with POP food consumption advisories. Our main findings are that the movement away from traditional food intake in Canada's North greatly affected observed human POP exposure trends. However, initial investigations for a Southern population suggest that short-term dietary transitions may be having a negligible effect on POP levels, especially for compounds exhibiting long human elimination half-lives.

de son alimentation les aliments réputés plus contaminés) et de changements plus graduels et permanents (p. ex. si des communautés remplacent graduellement leur alimentation traditionnelle à base de viande d'animaux chassés localement par une alimentation qui comprend davantage d'aliments importés). Nous avons mis au point une série de modèles de simulation informatique qui permettent de déterminer, quantitativement, dans quelle mesure de tels changements peuvent influer sur l'exposition aux contaminants. Ces modèles ont été appliqués à des communautés autochtones de l'Arctique, dans le contexte de l'abandon des aliments traditionnels à l'échelle de la population, et à des populations vivant sous un climat tempéré et respectant temporairement les avis relatifs à la consommation d'aliments contaminés par des POP. D'après nos principaux résultats, l'abandon des aliments traditionnels dans le Nord canadien a considérablement influé sur les tendances observées en matière d'exposition humaine aux POP. Cependant, les premières études menées dans une population vivant plus au sud semblent indiquer que les transitions alimentaires de courte durée pourraient avoir un effet négligeable sur les concentrations de POP, surtout s'il s'agit de composés possédant une longue demivie d'élimination.

Key Messages

- Large-scale dietary transitions among aboriginal Northern communities are an important factor underlying observed POP body burden temporal declines, as well as contributing to the variability within and between subpopulations.
- When assuming realistic periods of compliance (i.e. only during the 1.5 year period of pregnancy and breastfeeding), maternal food advisories are largely ineffective in reducing pre- and postnatal exposure to POPs with exceptionally long human elimination half-lives.
- Biomonitoring sampling year relative to year of peak Arctic environmental POP concentrations is a critical parameter in

Messages clés

Les transitions alimentaires à grande échelle dans les communautés autochtones du Nord jouent un rôle important dans la diminution temporelle de la charge corporelle des POP observée et contribuent à la variabilité intra- et interpopulationnelle.

Lorsque nous supposons des périodes d'observance réalistes (c.àd. seulement pendant la grossesse et l'allaitement, soit pendant une période d'un an et demi), les recommandations en matière d'alimentation chez les mères sont en grande partie inefficaces pour réduire l'exposition prénatale et postnatale aux POP dont la demivie d'élimination est exceptionnellement longue.

determining age-body burden trends of Northern human and wildlife populations; gender effects further contribute to variability in these relationships, while lifespan differences play a more limited role in determining age-body burden trends.

- Several new POP food chain bioaccumulation models (ex. bowhead whale, beluga whale, caribou) are being incorporated into our current Northern human exposure-modeling framework, to more holistically represent common traditional aboriginal diets.

L'échantillonnage de biosurveillance permettant de comparer d'une année à l'autre les concentrations environnementales maximales de POP en Arctique est un paramètre très important lorsqu'il s'agit de dégager les tendances de la charge corporelle en fonction de l'âge dans les populations humaines et fauniques du Nord; les effets liés au sexe contribuent eux aussi à la variabilité de ces relations, tandis que les différences sur le plan de la durée de vie ont un rôle plus limité au moment de déterminer les tendances de la charge corporelle en fonction de l'âge.

Dans notre cadre actuel de modélisation de l'exposition humaine dans le Nord, nous incorporons plusieurs nouveaux modèles de bioaccumulation des POP dans la chaîne trophique (p. ex. baleine boréale, béluga, caribou) afin de représenter de façon plus globale les régimes alimentaires traditionnels courants des Autochtones.

Objectives

Long-term

1. To establish the extent to which recent declines in human tissue concentrations of POPs observed in two Northern communities are due to declines in environmental contamination or due to dietary changes.

2. To assess the link between dietary consumption guidelines and exposures of Northerners to POPs with varying physical-chemical properties (e.g. hydrophobicity, susceptibility to biotransformation).

3. To maximize the value of existing monitoring data by evaluating the model predictions over space and time.

4. To build capacity for assessing human exposures in Northern communities to new and emerging chemicals of concern.

Short-term

1. To modify the human food chain bioaccumulation model ACC-Human to include the organisms (esp. marine mammals, caribou) most important for the dietary contaminant exposure of Canada's Northern populations.

2. To model the time trend of POP exposure of two maternal populations in Inuvik and Baffin considering both shifts in global emissions and long term dietary changes.

3. To model the efficacy of transient dietary changes in lowering infant exposure to POPs in Northern Canadian populations.

4. To include an accounting of the nutritional value (vitamins, iron, calcium, folate, omega-3 fatty acids, fibre) of various food items in the human food chain bioaccumulation model.

Introduction

The main route of human exposure to POPs in the Arctic is via high trophic level marine mammal consumption, with examples including polar bear, seal, and toothed whales (Donaldson et al. 2010). This factor may in part contribute to the ongoing trend of dietary transition among these communities away from country foods and toward imported items (Deutch et al. 2007; Kuhnlein et al. 2004). Though these observed dietary transitions have correlated with increased rates of obesity and reduced nutrient intake (Deutch et al. 2007; Kuhnlein et al. 2004), they may have contributed to declining historic POP levels among Northerners (Donaldson et al. 2010), and likely will continue to affect future exposures. Interestingly, though marine mammal contamination often exceed levels observed in imported foods (Hoekstra et al. 2005; O'Hara et al. 2005), some store-bought items (milk, fish, salmon, sardines) may possess higher organochlorine concentrations than local fish species (Arctic char, whitefish, pink salmon). Thus, transitioning from a traditional diet to more imported food would not necessarily lower organochlorine exposure in all cases.

In addition to these long-term population-wide dietary transitions among Northerners, POP exposures may also be impacted by short-term dietary transitions, such as food advisory compliance by women during pregnancy and nursing. As individuals are particularly susceptible to the neurocognitive effects of POPs during pre- and postnatal development (Stewart et al. 2008; Walkowiak et al. 2001), regulatory bodies often publish guidelines to promote safe maternal intake of certain foods, mainly fish (Turyk et al. 2012). The majority of current POP dietary consumption advisories are provided for temperate populations, such as those in the Great Lakes region (Bhavsar et al. 2011), while none have been published for specifically for aboriginal Arctic residents consuming a traditional diet. One reason for this being that sources of local food, the amounts consumed, and levels of contaminants are extremely variable throughout the Arctic and between aboriginal populations (Donaldson et al. 2010; Vaktskjold et al. 2009). Additionally, traditional food serves as a cultural and spiritual cornerstone of community health in many aboriginal groups. In fact, authors agree that among these populations country foods, including fish, should continue to be recommended for consumption based on local environmental conditions and only monitored for sensitive populations (children and pregnant women).

Ultimately, dietary transitions from a traditional to a market based diet currently occurring in Canada's North, or those practiced short-term by vulnerable populations, can be problematic from a nutritional and cultural point of view. As contaminant-related dietary consumption advisories may influence dietary choices, it is important that those advisories are based on the best available science and strike a balance between the desires to reduce contaminant exposure and to maximize the nutritional and cultural value of food. Our current work allows for quantitative assessments of the efficacy of such guidelines in reducing contaminant exposure. In fact, our model of human dietary contaminant uptake, comprehensively evaluated with existing biomonitoring datasets, may eventually be used to design dietary guidelines that are effective in reducing contaminant exposure without compromising the consumption of nutritionally beneficial traditional food items.

Activities in 2012-2013

One of the main activities in the past project year was the development of a methodology 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. Assessing the potential implications of intergenerational dietary transitions on human exposure to organic contaminants required an integrated approach combining chemical fate and bioaccumulation modeling. We combined the fate/transport model GloboPOP (Wania and Mackay 1995; Wania and Su 2004) with two food web bioaccumulation models, ACC-Human (Czub and McLachlan 2004) and ACC-Human Arctic (Czub et al. 2008), which have been evaluated against empirical data for PCBs in the past (Armitage et al. 2011; Breivik et al. 2010; Czub et al. 2008). The following elements needed to be developed and synthesized: i) estimated emission rates over time in areas of interest (e.g. regional to global-scale), ii) ambient environmental levels over time corresponding to the emission scenario, iii) human food web bioaccumulation models representative of the major dietary items of interest (e.g. air-grass-cow; water-phytoplankton-zooplankton-Arctic cod-seal), iv) scenarios defining the composition of different diet types (e.g. 100% traditional/locally-harvested vs. 100% imported food items), and v) scenarios defining the timing and nature of intergenerational dietary transitions. Once the overall scenarios were defined (i.e. accounting for the considerations outlined above), simulations were conducted to calculate human body burden as a function of time (i.e. longitudinal body burden age trends).

The second major activity was the adoption of a modeling approach for quantifying the effect of transient dietary transitions among women of childbearing age on the resultant prenatal, postnatal, and childhood exposures of their children to POPs. We initially estimated the effectiveness of fish consumption advisories in reducing exposure of infants and children in fish-eating Southern populations using the time-variant mechanistic model CoZMoMAN (Binnington et al. 2012; Binnington et al. submitted). Though this framework was initially applied to a temperate population, the same approach will be used for a simulated Northern group following the completion of the current Arctic ACC-Human modeling scheme.

The third and final activity of the past project year was the development of bioaccumulation models for several Arctic mammals that eventually will be included in the existing version of the ACC-Human Arctic model. Specifically, a model for bowhead whale was completed and evaluated (Binnington and Wania 2012, Binnington and Wania, unpublished data), and another for the lichen-caribou food chain is in progress at this time. We have also identified several other species necessary for model development using human biomonitoring and questionnaire data from each of two studies conducted in the Baffin and Inuvik regions (baseline and follow-up). (These data were provided to the modeling team by Health Canada personnel, who have been custodians of the data and also possess copies of the four territorial reports written at the completion of these studies.) These species include narwhal, beluga whale, and snow goose, and the models for these additional organisms will be developed during the next project year.

Communications

The results from these three major activities have been disseminated through a variety of means during this past year. We note that all of these scientific dissemination activities describe the outcome of hypothetical modeling scenarios and, as such, Northern human data were neither used nor presented. Findings from our Northern dietary transition work were published in Environment International (Quinn et al. 2012), and presented at meetings of the International Society of Exposure Science (Quinn et al. 2012b) and Society of Environmental Toxicology and Chemistry (Wania et al. 2012a), as well as during international invited lectures (Wania et al. 2012b). Results from our temperate dietary food advisory project are in the midst of review at Environmental Health Perspectives (Binnington et al. submitted), and also were described at a recent meeting of the Society of Environmental Toxicology and Chemistry (Binnington et al. 2012). At this same conference findings were also presented on our exploration of bioaccumulation trends in long-lived Arctic species (Binnington and Wania 2012).

Northern activities

Specific capacity building opportunities were not included in 2012-2013 project undertakings because of the nature of the proof-of-concept modeling work that was performed. However, the scope this project is being developed in consultation with the Government of the Northwest Territories, the Government of Nunavut, Inuit Tapiriit Kanatami, and the Nunavut regional office for AANDC. Outreach and capacity building activities appropriate to a modeling project, which will ultimately inform food advisories prepared by local authorities, will be developed using input from these partners.

Similarly, northern partners will be consulted to identify traditional knowledge holders who can assist in designing realistic dietary replacement scenarios in the second year of the project during the modeling of actual northern populations.

Results and Discussion

To investigate our first major research area, the modeling of intergenerational Arctic dietary transitions, long-term (1930-2050) dynamic simulations of Arctic human POP exposure were conducted for PCB-153 as an example compound, using realistic emission estimates. Female body burdens were calculated over time assuming five diets with varying proportions of traditional and imported food items and then used to illustrate the potential variability at a community/population level. At any given time point, individuals that consumed a 100% traditional diet (i.e. high intake of ringed seal blubber) possessed modeled body burdens approximately 10-150 times higher than individuals consuming a 100% imported food diet (Figure 1). Consumption of locally harvested fish and blubber-free seal meat were also associated with comparatively low body burdens (Figure 1). Declining emissions were predicted to decrease the PCB-153 body burden of 30-year old females by 6 to 13-fold from 1980 to 2020 (Figure 1) with dietary transitions accounting for an additional multiplier of 2–50 (i.e. 12–650 times lower in total) depending on the type of dietary transition and the origin of the imported food items. The model results indicate that dietary transitions are an important factor underlying the variability within and between subpopulations in addition to partially explaining the observed temporal trends.

Thus far our focus for this specific project has been the development of a modeling framework, essentially a proof-of-concept. Importantly, rather than using specific information on the nature and timing of dietary transitions for a particular population, we simulated several generic dietary transitions, that varied in the year of onset and the rate of dietary change. The study also allowed us to identify areas of potential improvement to the generic framework for population-specific modeling assessments. These include i) compiling/obtaining more detailed information on diets and dietary transitions in the communities of interest, ii) expanding the Arctic food webs to include additional terrestrial and aquatic species (e.g. caribou, goose, walrus, beluga, fresh water fish), and iii) applying more spatially-resolved fate/transport models to better distinguish between imported food items (e.g. North American vs. continental European origin). The calculations could also explicitly account for potential losses of contaminants during cooking/preparation (e.g. raw vs. fried fish).

For our second project, we assessed the effectiveness of current food consumption advisories in reducing human POP exposure by estimation and comparison of prenatal, postnatal and childhood PCB-153 levels under different scenarios of maternal guideline adherence; wherein these analyses were performed for both hypothetical constant and realistic time-variant chemical emissions. Scenarios differed in terms of length of compliance (1 vs. 5 years), extent of fish substitution (all vs. half), and replacement diet (uncontaminated produce vs. beef/dairy). We also calculated exposure reduction potential for a range of theoretical chemicals to explore how guideline effectiveness varies with a chemical's partitioning and degradation properties. When assuming realistic time periods of advisory compliance (Teisl et al. 2011),

Figure 1. The PCB-153 body burden predictions for a population of 30-year old Inuit women from 1980-2020 where each cohort in the population consumes an identical diet of traditional, imported temperate, imported boreal, or traditional (blubber-free) food.

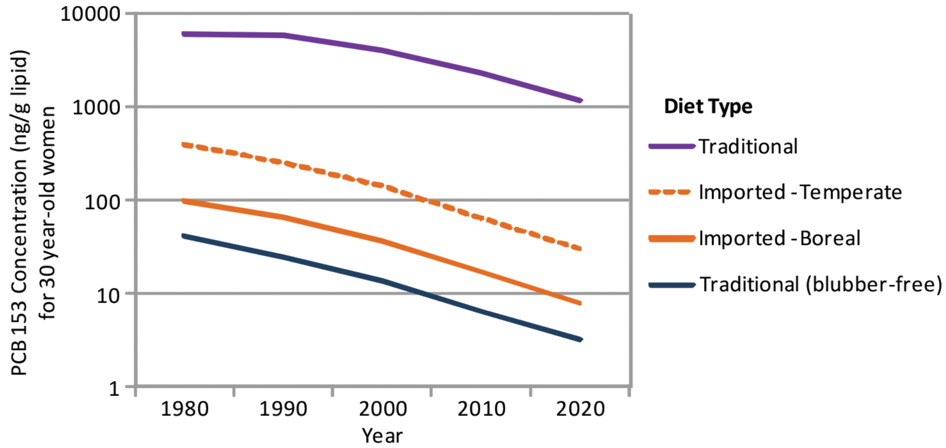
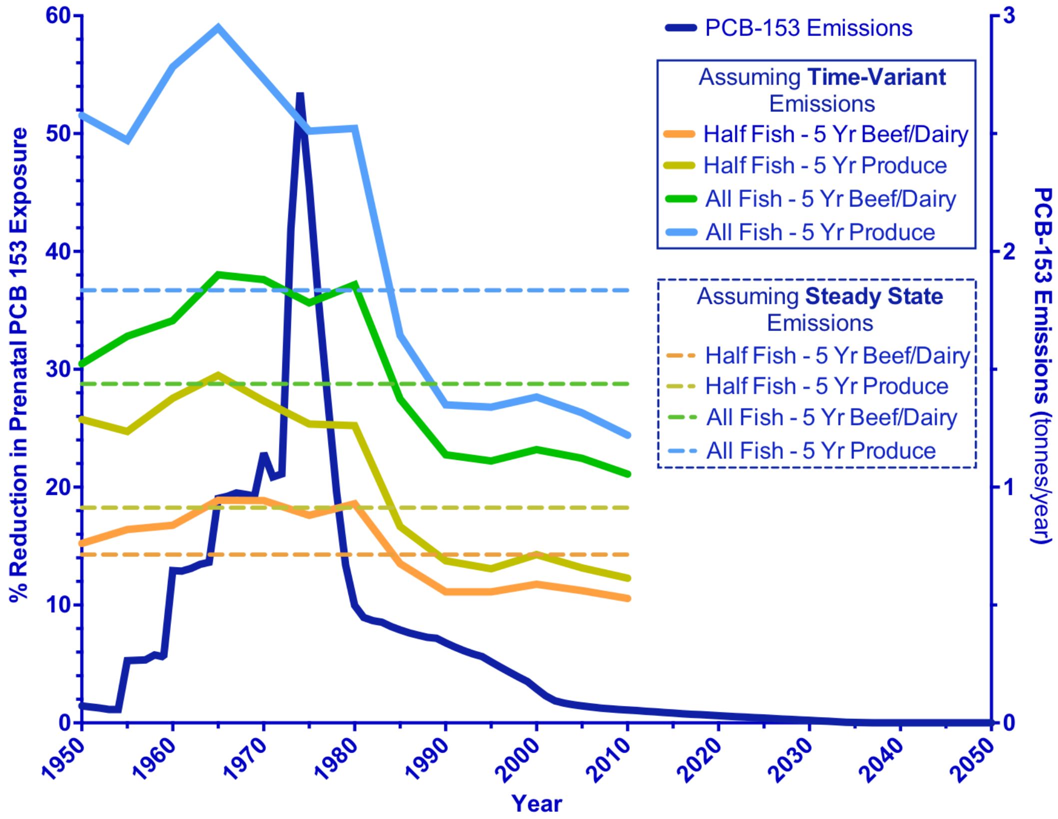


Figure 2. Percent reductions in prenatal exposure of modeled females to PCB-153 due to variation in maternal fish advisory compliance, and assuming time-variant emissions. The dotted lines represent the percent reduction in prenatal exposure for the same fish consumption scenarios described under steady state conditions. Plots are overlaid atop the time-variant emissions scenario used (Breivik et al. 2010).



temporarily eliminating or reducing maternal fish consumption was found largely ineffective in reducing pre- and postnatal exposure to substances with long elimination half-lives in humans (such as PCB-153), especially during periods of decreasing emissions (Figure 2). However, advisories can be highly effective in reducing exposure to substances with elimination half-lives in humans shorter than the length of guideline compliance, such as methylmercury. Also notable was our finding that replacement food items (beef and dairy) consumed to compensate for fish reductions actually resulted in higher exposure to certain groups of environmental contaminants. Overall, we conclude that at reported levels of advisory compliance, fish consumption advisories are not effective in lowering exposure to compounds with long human elimination half-lives.

Although this study has not yet been directly relevant to Northern communities, since to date it has focused on fish-eating populations in the South, it did allow us to successfully test the feasibility of our approach; using a mechanistic human food chain bioaccumulation model linked to an environmental fate model to test the efficacy of dietary consumption guidelines. In particular, the study showed that it is possible to test dietary guideline efficacy for real organic contaminants under realistic emission scenarios as well as for hypothetical chemicals varying in partitioning and degradation properties. It also highlighted the need to explicitly consider the contamination of potential dietary substitution items. A similar approach will be used to test the efficacy of dietary consumption advisories in the North. However, this will necessitate the creation of meaningful traditional diet substitution scenarios (i.e., to what extent should one dietary item be replaced for another, and for how long?), using traditional knowledge as a guiding principle. We envisage that these scenarios may explore substitutions both with dietary items imported from the South, as well as with other country foods (e.g. marine mammal fat vs. terrestrial mammals). While the study for a southern population suggested that dietary advisories are largely ineffective in lowering exposure to long-lived pollutants, this does not necessarily mean that this will also apply in the context of Northern communities. If the substitution is much less contaminated and compliance extends for several years prior to pregnancy, notable reductions in infant exposure even to long-lived pollutants may be feasible.

Conclusions

Long-term population-wide dietary transitions can significantly influence human POP exposure trends, while short-term dietary transition behaviours may be largely ineffective in having the same effect, especially for recalcitrant compounds in humans. However, we note that the latter finding has yet to be reproduced in Northern communities. Also, we determined the impact of several factors on typical Arctic POP biomonitoring age trends for both humans and wildlife: gender, lifespan, and sampling time relative to environmental concentration pattern.

Continuing work will consist of further expansion of the ACC-human Arctic model to include additional species important for POP exposure through traditional diets (narwhal, beluga whale, caribou, snow goose), and use of the improved model to assess short-term food advisory compliance on exposure in Northern populations. We also will utilize the expanded model, in concert with human POP biomonitoring data for two Northern regions (Inuvik and Baffin) across two sampling periods, to specifically describe the role of emissions regulation and dietary transitions in historical POP exposures. Finally, we plan to modify our current approach to assess human exposure trends for methylmercury, as it is likely the most pressing contaminant-related concern in Northern Canada.

Expected Project Completion Date

Most of the project tasks should be completed by the end of project year 2 (April 2014), although it may take longer to publish all of the project results.

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Community Based Monitoring

Surveillance communautaire

Mercury levels in food fish species in lakes used by DehCho community members with a focus on choice and risk perception of eating traditional country food

Concentrations de mercure dans des poissons comestibles présents dans des lacs utilisés par des membres de la collectivité des Dehcho, avec insistance sur le choix et la perception du risque lié à la consommation d'aliments traditionnels

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Abstract

The Dehcho AAROM program has been involved, for the past several years, in the collection of fish samples for mercury analysis from inland lakes fished by our member communities. In 2012-13, we collected fish samples from Trout, Gargan, Tathlina and Little Doctor lakes to update mercury level data. We also sampled a promising site, Mustard Lake in the Horn Plateau, to continue our search for alternate lakes where the fish are low in mercury. We have partnered with Environment Canada who analyse the samples and with GNWT, Health

Résumé

Le Programme autochtone de gestion des ressources aquatiques et océaniques (PAGRAO) de la région du Dehcho a servi, au cours des dernières années, à prélever des échantillons de poissons aux fins de l'analyse des concentrations de mercure dans les lacs intérieurs faisant l'objet de pêche par les collectivités membres. En 2012-2013, nous avons prélevé des échantillons dans les lacs Trout, Gargan, Tathlina et Little Doctor pour mettre à jour les données sur les concentrations de mercure. Nous avons également échantillonné

and Social Services who issue consumption guidelines as necessary. In 2012-13, a total of 141 fish from 5 lakes were sent to DOE.

We have learned from community leaders and harvesters during our communication processes that an unfortunate side effect of our mercury studies is that some of our members are no longer eating locally caught fish regardless of species, size or lake status. As a result we have changed our focus to communicating positive messages and finding safe sources of fish for each of our communities. "The Return to Country Food" workshop brought together leaders, resource managers and harvesters to learn more about contaminants and also about the health benefits of including fish and other country food in the diet. We are working with Health Canada on a country food diet survey and with GNWT, Health and Social Services to promote healthy eating. We have developed a mercury learning module for our youth programs and have begun to deliver healthy eating messages as a part of our youth camp curriculum.

un site prometteur, le lac Mustard, sur le plateau Horn, afin de poursuivre nos recherches de lacs de rechange où les poissons présentent de faibles concentrations de mercure. Nous nous sommes joints à Environnement Canada, qui analyse les échantillons, et au ministère de la Santé et des Services sociaux du gouvernement des Territoires du Nord-Ouest, qui publie des lignes directrices relatives à la consommation, au besoin. En 2012-2013, un total de 141 poissons issus de 5 lacs ont été envoyés au ministère de l'Environnement.

Pendant notre processus de communication, nous avons malheureusement appris de la part de dirigeants et de pêcheurs des différentes collectivités, qu'en raison de nos études sur le mercure, certains de nos membres ne mangent plus de poisson pêché localement, peu importe l'espèce, la taille du poisson ou l'état du lac. Nous avons donc modifié notre approche pour communiquer des messages positifs et pour trouver des sources sécuritaires de poissons pour chacune de nos collectivités. L'atelier portant sur le retour aux aliments traditionnels (« Return to Country Food ») a rassemblé des dirigeants, des gestionnaires des ressources et des pêcheurs désireux d'en apprendre davantage sur les contaminants et sur les bienfaits de la consommation de poisson et d'autres aliments traditionnels pour la santé. Nous travaillons avec Santé Canada pour réaliser un sondage sur la consommation d'aliments traditionnels, et avec le ministère de la Santé et des Services sociaux du gouvernement des Territoires du Nord-Ouest pour promouvoir l'alimentation saine. Nous avons élaboré un module d'apprentissage destiné aux jeunes sur le mercure, et nous avons commencé à véhiculer des messages sur l'alimentation saine dans le cadre du programme de notre camp de vacances pour les jeunes.

Key Messages

- There is a need for better communication on water quality and contaminants such as mercury in the Dehcho region.
- The health benefits of eating fish far outweigh the risks from mercury contamination in the Dehcho. Eat smaller (younger) fish and non-predators such as whitefish and suckers. Follow GNWT consumption guidelines if you eat predatory fish on a regular basis.
- All species of fish from Great Slave Lake, Willow Lake and Big Island Lake are low in mercury; Non-predatory fish such as Lake Whitefish, suckers and grayling are generally low in mercury in all lakes or rivers in the Dehcho.

Messages clés

- Une meilleure communication est nécessaire au sujet de la qualité de l'eau et des contaminants tels que le mercure dans la région du Dehcho.
- Les bienfaits pour la santé de la consommation de poisson sont de loin plus importants que les risques de contamination par le mercure dans la région du Dehcho. Consommez des poissons de petite taille (jeunes) et des poissons non prédateurs, comme les corégones et les suceurs. Suivez les lignes directrices relatives à la consommation publiées par le gouvernement des Territoires du Nord-Ouest si vous consommez régulièrement des espèces prédatrices.
- Les concentrations de mercure sont faibles chez toutes les espèces des poissons du Grand lac des Esclaves, du lac Willow et du lac Big Island. Les espèces non prédatrices, comme le grand corégone, les suceurs et l'ombre arctique présentent généralement de faibles concentrations de mercure dans tous les lacs et cours d'eau de la région du Dehcho.

Objectives

- To plan a study which facilitates a dialogue involving community leaders, harvesters, elders and youth, on changes from traditional country food to a more market based diet. Discussions would include health and wellness benefits of country food in community diets.
- To devise ways of increasing availability of country food, especially fish for inclusion in community diets.
- To educate youth on the importance of traditional culture and the benefits of a country food supplemented diet.
- To encourage youth to enrol in post secondary education especially in resource mgmt. and/or environmental and biological sciences.
- To complete the mercury testing on fish, in other waterbodies, which are used by the communities as a food source.

Introduction

Mercury levels in predatory fish in some inland lakes along the Mackenzie Valley have been reported to be high following a 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 has 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 higher than in the 1990's. Mercury levels in fish seem to be increasing in recent years (Evans 2010). Evans comments; *"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 (Evans et al. 2005; Lockhart et al. 2005). 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 GNWT, Health and Social Services (HSS) have issued a consumption advisory limit. The Sambaa K'e Dene Band resides on the shores of Trout Lake and fishes for trout and walleye. Have levels in walleye continued to increase? 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 heightened 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 species such as suckers and whitefish, which are usually fine.

Now that we are completing the testing and retesting of fishing lakes, Dehcho AAROM is changing its focus to education, capacity building and communications. We have organized workshops and initiated discussions between community leaders, harvesters, elders and youth in the communities with researchers who have conducted contaminant work in the area. 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 the fish are safe to eat.

Activities in 2012-2013

1. Fishing Projects;

All fishing projects were conducted by our member First Nations through contracts with participating Bands. Data was recorded on Catch per Unit effort and fish were sampled for length, weight, aging structures and sex and maturity. Flesh samples were taken for mercury analysis at the DOE lab. Since most collection was conducted late in the fiscal year, Dehcho AAROM has arranged to fund DOE to analyse the samples in early fiscal year 2013-14.

- Little Doctor Lake (61 53 00 N x 123 15 00W) was gillnetted for 10 days with the resulting catch of 1 Lake trout, 7 walleye, 8 burbot, 7 suckers and 20 whitefish (over a hundred whitefish were caught). The experienced Dene trapper who did the fishing suggested we conduct the study in the fall to catch more predatory species including pike. (Contract with Liidlii Kue FN)
- Mustard Lake (62 00 00N x 120 05 00W) was gillnetted with the resulting catch of 8 lake trout, 17 burbot, 16 northern pike and 18 lake whitefish. (Contract with Liidlii Kue FN)
- Trout Lake (60 35 00N x 121 10 00W) was gillnetted by a subsistence fisherman and 20 random trout samples were provided for sampling. (Contract with Sambaa K'e Dene Band)
- Tathlina Lake (60 33 00N x 117 39 00W) was gillnetted as part of a DFO, stock assessment

and 20 walleye were provided for sampling (Contract with Ka'a'gee Tu Dene Band)

- Gargan Lake (61 15 00N x 120 23 00W) was gillnetted by GNWT HSS with assistance of Dehcho AAROM resulting in a catch of 13 northern pike and 8 lake whitefish.

2. Mercury Educational Modules;

Educational modules were developed by BEAT Environmental Inc. and delivered at the Dehcho First Nations Ecology Camp hosted by Katlodeeche First Nation at Sandy Creek as well as at the "Return to Country Food" mini ecology camp held at Ekali Lake. The modules included "Quick Silver Sam" developed through NCP funding as well as five other science modules

3. "Return to Country Food" workshop;

Jean Marie River First Nation hosted a workshop to discuss contaminant issues during the week of Aug. 20, 2012.

Participants;

- Jean Marie River First Nation, Jean Marie River
  - Chief Stanley Sanguez,
  - Richard Sanguez, community member
  - Yvonne Norwegian, community member
  - Margaret Ireland, PAS Chair
  - Billy Norwegian, community member
- Sambaa K'e Dene Band, Trout Lake
  - Jessica Jumbo, community member, on behalf of Chief Dolphus Jumbo,
- Ka'a'gee Tu First Nation, Kakisa
  - Chief Lloyd Chicot,
  - Shawn Laidlaw, Environmental Coordinator
  - Melaine Simba, Environmental assistant
- Liidlii Kue First Nation, Fort Simpson
  - Cheryl Cli for Chief Keyna Norwegian,
  - Jermaine Gargan, Communication Officer,
  - Edward Cholo, AAROM monitor,
  - Nicholas DePelham, AAROM monitor,
  - Allan Bouvier, Resource Manager,
- Pehdzeh Ki First Nation, Wrigley
  - Daniel Steiner, Lands Coordinator
- Deh Gah Gotie Band, Fort Providence
  - Chief Wayne Sabourin,
  - Priscilla Canadien, Resource Management Board
  - Greg Sabourin, AAROM Monitor
  - Joe Lacorne, AAROM Monitor
- Métis Nations
  - Richard Lafferty, Fort Providence Métis Rep. and AAROM Advisory Committee member
  - Marie Lafferty, President, Fort Simpson Métis Nation
- Presentations and Resources
  - Herb Norwegian, Grand Chief, Dehcho First Nations
  - Mike Low, Dehcho First Nation, AAROM Technical Advisor
  - George Low, Dehcho First Nation, Dehcho AAROM Coordinator
  - Dr. Erin Kelly, GNWT-ENR, Manager of Watershed Programs and Partnerships, Land and Water Division.
  - Jennifer Fresque-Baxter, GNWT-ENR, Water Stewardship Advisor, Land and Water Division.
  - Dr. Kami Kandola, Deputy Chief Public Health Officer, GNWT-Department of Health and Social Services
  - Dr. Marlene Evans, Contaminant Researcher, Environment Canada
  - Bruce Townsend, BEAT Environmental Inc. Facilitator and Presenter
  - Caroline Lafontaine, Environmental Consultant, Recorder

The Return to Country Food workshop was very successful as it brought together the Dehcho Chiefs or designates as well as First Nations environmental managers with experts from various government departments and NGO's to learn about contaminants, especially mercury. Recommendations at the workshop will lead to a second workshop in Kakisa (pending funding) which will follow-up on progress over the year both on the gathering of new information (Diet Survey) and the development of communication strategies.

4. Other workshops and meetings;

A Resource management planning workshop was held in Sambaa K'e on May 30 and June 1, 2012. The Sambaa K'e Dene Band is developing an environmental management plan that will include contaminant monitoring including the possible effects of climate change on mercury levels in fish. Fish and other country food are very important to this isolated community. A follow-up meeting was held on November 8 with Dr. Heidi Swanson getting community input for a study design to address the issue of increasing mercury levels in fish in Trout Lake as well as lakes in the vicinity of Jean Marie River, Kakisa and Fort Simpson.

Participants:

- Acting Chief Dennis Deneron, Sambaa K'e Dene Band (SKDB)
- Ruby Jumbo, Band Manager, Sambaa K'e Dene Band
- Arthur Jumbo, councilor, SKDB
- Norma Jumbo, councilor, SKDB
- Tony Jumbo, councilor, SKDB
- Elder Joe Punch
- Elder Victor Jumbo
- Elder David Jumbo
- George Low, Dehcho First Nation, AAROM Coordinator
- Mike Low, Dehcho First Nation, AAROM Technical Advisor
- Christine Wenman, Wilfrid Laurier University & Ecology North
- Dr. Erin Kelly, GNWT – ENR, Manager, Land and Water Division
- Caroline Lafontaine, SKDB Consultant

The youth trip to Saskatoon was cancelled due to budget and logistical concerns. The activity was replaced by a "Youth Science and Culture Camp" held on August 23, 2012 at Ekali (Kelly) Lake which is one of our study lakes near Jean Marie River. Mike Low, Bruce Townsend and George Low provided science messages including the "Quicksilver Sam" mercury module developed by BEAT Environmental Inc. (Camp PowerPoint attached)

The mercury modules developed by BEAT Environmental were presented along with other science ecology messages at the Dehcho First Nations Youth Ecology camp hosted by the Katlodeeche First Nation at Sandy Creek near the shores of Great Slave Lake. This camp was not funded by our NCP project but was an opportunity to present our mercury messages and encourage eating fish as part of a healthy diet.

Results

- 141 fish were gillnetted, sampled for fork length, round weight, sex and maturity and aging structures. These fish were sent to Marlene Evans of DOE for aging and mercury analysis. Since most of these fish were caught late in the fiscal year they will be processed in 2013-14 at Dehcho AAROM expense by Marlene's lab. She is responsible to report the results to NCP and GNWT, HSS as required.
- The educational module "Quicksilver Sam" was developed by BEAT Environmental and presented at the "Return to Country Food" workshop as well as at two "Youth Science and Culture" camps.

- The “Return to Country Food” workshop increased the understanding of contaminant issues by the leaders and environmental managers and harvesters of six Dene Bands and two Metis Organizations in the Dehcho region.

- Due to the Sambaa K’e workshop and other project meetings updated research and monitoring programs were designed to address the concerns of our four of our member Bands.

- As a result of two “Youth Science and Culture” camps 24 youth gained a better understanding of aquatic ecology including “Quicksilver Sam” AKA mercury.

Discussion and Conclusions

- Our work over the past three years in partnership with Dr. Marlene Evans of Environment Canada and GNWT, Health and Social Services has resulted in updated data on the mercury levels in the various species of fish found most of our inland fishing lakes used by Dene and Metis in the Dehcho region.

- In some cases it was found that mercury levels in some species of fish in some lakes were increasing for reasons which are not fully understood. Our leadership is concerned and wants us to investigate what is going on. Are these changes due to climate change? Is climate change causing increased methylation of mercury from thawing wetlands? Are bioaccumulation and biomagnification rates being altered? Or are these changes due to increased size and age of fish in populations which according to local knowledge are not being fished as hard as they were previously.

- In order to begin answering some of these questions, Dehcho AAROM will continue to work with researchers Marlene Evans of DOE and Gary Stern and Jessie Carrie of the University of Manitoba. We have also attracted a new research partner from the University of Waterloo, Dr. Heidi Swanson who will be studying bioaccumulation and biomagnification and other effects in 5 lakes near Jean Marie River, lakes on the Horn Plateau as well as Trout and Tathlina lakes. She will be working closely with the communities and collaborating with several other researchers working in the NWT. (Funding pending from several sources)

- Our workshops and meetings especially the “Return to Country Food” workshop held last summer were a capacity building effort which has helped Dehcho leaders and managers better understand mercury and other contaminant issues. Dehcho AAROM, with funding from Health Canada has completed surveys in 4 of our 6 affected communities to explore the perception of contaminants and the effect on country food, especially fish in the diet.

- We are making progress on finding safe sources of fish in the Dehcho region. All species of fish from Great Slave Lake, Willow Lake, and Big Island Lake are below HEALTH CANADA guidelines for mercury. Whitefish and Suckers may be eaten in any quantities in our other inland lakes and rivers.

- Dehcho AAROM plans a second “Country Food” workshop at Kakisa in August 2013 (funding pending). We need to continue to get a positive message out on the health benefits of fish and other country foods in the diet.

- Our “Youth Science and Culture” camps are effective for a select number of youth in promoting healthy living, an appreciation of Dene and Metis culture and the workings of aquatic ecology. BEAT Environmental Inc is working with the GNWT, Department of Education to accredit our aquatic modules as a part of the curriculum.

- Dehcho AAROM plans to continue evolving our communication strategy with our various partners so that all our members are well informed on water quality and contaminant issues especially in regards to mercury.

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

Évaluation des facteurs hydroclimatiques favorisant le transfert de contaminants dans les chaînes alimentaires aquatiques du bassin hydrographique des lacs Husky (région désignée des Inuvialuit, Territoires du Nord-Ouest)

Project Leader:

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Donald Ross, Aurora Research Institute (Inuvik, NT) – Shannon McFadyen, University of Victoria (Victoria, BC) – Benjamin Kissinger, University of Manitoba (Winnipeg, MB) – Jennie Knopp, Trent University (Peterborough, ON) – Dr. Gary Anderson, University of Manitoba (Winnipeg, MB) Dr. Chris Furgal, Tent University (Peterborough, ON) – Dr. Holger Hintelmann, Department of Chemistry, Trent University (Peterborough, ON) – Dr. K. Olaf Niemann, Department of Geography, University of Victoria (Victoria, BC) – Dr. Jim D. Reist, Freshwater Institute, Fisheries and Oceans Canada (Winnipeg, MB)

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, a good understanding of sources of

Résumé

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

Hg 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 (NWT). In May 2012 we joined fishermen during spring fishing at Husky Lakes and Noell Lake via snowmobile, while Yaya and Big lakes were accessed by helicopter. In August 2012, sampling was conducted by boat at Husky Lakes, Noell and Yaya Lake. Local guides or ARI technicians were hired for all field work. Locations of sampling efforts were informed by the preliminary results of Traditional Knowledge interviews conducted in the spring of 2012. Sampling in May and August included 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. Preliminary results presented here include TK shared, as well as fish catch data total mercury (THg) and stable isotopes of mercury (dxHg, 'fingerprint') data, and otolith microchemistry scans. Initial mercury analysis indicates low total mercury concentrations in fishes at Husky Lakes; Mercury stable isotope fingerprints appear to vary with species and potentially by lake. Results for otolith microchemistry indicate that Lake Trout exhibit multiple life histories and potentially spawn in brackish water. Species distribution varied with salinity at each lake; juvenile Arctic Grayling were collected in brackish near shore habitat. Analysis is still ongoing, completion will be the next step, prior to reporting back to communities.

encore mal l'incidence des facteurs abiotiques et des paramètres biologiques sur l'accumulation du mercure (Hg) chez les prédateurs de niveau trophique supérieur. De plus, on en sait encore peu sur les sources de Hg et sur les processus qui ont lieu dans la colonne d'eau et au sein des 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 (Territoires du Nord-Ouest). En mai 2012, nous nous sommes joints à des pêcheurs durant la pêche de printemps dans les lacs Husky et dans le lac Noell (accès en motoneige), et dans les lacs Yaya et Big (accès en hélicoptère). En août 2012, l'échantillonnage a été réalisé par bateau dans les lacs Husky, Noell et Yaya. Des guides locaux et des techniciens de l'Institut de recherche Aurora ont été embauchés pour effectuer tout le travail de terrain. Les emplacements des activités d'échantillonnage ont été déterminés à l'aide des résultats préliminaires d'entrevues axées sur les connaissances traditionnelles réalisées au printemps 2012. Des échantillons d'eau de surface, d'invertébrés benthiques et pélagiques, de tissus de poissons pêchés et de poissons non ciblés y ont été prélevés en mai et en août. Les paramètres biologiques des poissons (âge, longueur, poids, régime alimentaire) ont été notés, et les invertébrés ont été répartis par espèce. Les résultats préliminaires présentés ici s'appuient sur les connaissances traditionnelles qui ont été partagées, sur des données issues de captures de poissons relatives au mercure total (THg) et aux isotopes stables du mercure (dxHg, « empreinte isotopique »), et sur des images numérisées permettant d'analyser la microchimie des otolithes. Les premières analyses portant sur le mercure indiquent de faibles concentrations de THg chez les poissons des lacs Husky. L'« empreinte » des isotopes stables du mercure semble varier d'une espèce à l'autre et, potentiellement, d'un lac à l'autre. Les résultats des analyses de la microchimie des otolithes révèlent que le touladi présente de multiples cycles vitaux, et qu'il se reproduit peut-être en eaux saumâtres. La répartition des espèces varie selon la salinité de chaque lac. Des ombres arctiques juvéniles ont été prélevés dans un milieu riverain en eaux saumâtres. Les analyses se poursuivent, et la prochaine étape sera de conclure l'étude, puis de présenter les résultats aux collectivités.

Key messages

- We aim to provide the communities of Tuktoyaktuk and Inuvik with baseline information on contaminants (e.g., mercury) in fish 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 (TK) interviews, and expert consultations. The results of the interviews were used to direct sampling.
- Mercury concentrations in Lake Trout from Husky Lakes are generally low, and seem lower than in nearby Noell Lake.
- Mercury concentrations in freshwater apex-species (e.g., lake trout) were greater than in smaller, marine species such as Pacific Herring.
- Mercury stable isotope 'fingerprint' in fishes indicate that signatures may be species specific, do vary among tissues and from lake to lake.
- The mercury 'fingerprint' in sediments did not reveal significant variations among lakes or along chemical gradients.
- Species composition of fish and invertebrates changed from freshwater species to saltwater species with increasing salinity; notable is the collection of juvenile salmonids in the brackish near shore environment.
- The lake trout population within the Husky Lakes exhibit multiple life histories in relations to their use of saline environments.
- Microchemistry profiles indicate that the lake trout population within Husky Lakes utilize multiple spawning habitats and otolith strontium concentrations suggest that lake trout population may spawn in brackish water.
- Invertebrate size may be related to salinity levels (analysis is ongoing).

Messages clés

- Nos travaux visent à fournir aux collectivités de Tuktoyaktuk et d'Inuvik des données de référence sur les contaminants (p. ex. le mercure) chez les poissons pêchés dans quatre lacs de la région, en particulier dans les lacs Husky.
- Dans le cadre de notre projet, nous interagissons continuellement avec les deux collectivités dans le cadre 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.
- Les concentrations de mercure chez le touladi des lacs Husky sont généralement faibles, et semblent inférieures à celles mesurées dans le lac Noell, situé à proximité.
- Les concentrations de mercure chez les espèces d'eau douce de niveaux trophiques supérieurs (p. ex. le touladi) étaient plus élevées que chez les espèces marines plus petites, comme le hareng du Pacifique.
- L'« empreinte » des isotopes stables du mercure chez les poissons indique que la signature isotopique pourrait être propre à l'espèce, et varie selon les tissus examinés, et d'un lac à l'autre.
- L'« empreinte » du mercure dans les sédiments n'a pas révélé de variations significatives entre les lacs ou le long de gradients chimiques.
- L'augmentation de la salinité a entraîné le remplacement graduel des poissons et des invertébrés d'eau douce par des espèces d'eau salée; à preuve, on a prélevé des salmonidés juvéniles dans les eaux saumâtres près de la rive.
- Les individus de la population de touladis des lacs Husky montrent de multiples cycles vitaux, selon leur utilisation des milieux salins.
- Les profils microchimiques indiquent que la population de touladis des lacs Husky exploite divers milieux pour se reproduire,

et les concentrations en strontium des otolithes laissent croire qu'elle pourrait se reproduire en eaux saumâtres.

- La taille des invertébrés pourrait être liée au degré de salinité (des analyses sont en cours).

Objectives

- 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 [Hg].
- To interpret the effects of saline habitat use on lake trout growth.
- Review of existing and new documentation of 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.

Since the fall of 2011, 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 (see Gantner and Gareis 2012). 2012 was our research and field work intense year, with data collection in March, April-May, and August-September. Sample collections in 2012 were conducted following TK interviews and in conjunction with spring fishing by residents of Tuk/Inuvik. Local people were hired for this work and trained in relevant methods for future work on lakes, possibly as Community Based Monitoring effort. We compare sites in the Husky Lakes Watershed (along a local salinity gradient) with Big Lake and Yaya Lake. The results 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. Once a baseline is established, 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 food web structure, and subsequently contaminants transfer along those salinity gradients. We 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 used the chemical makeup of the Lake Trout earbone (otolith) to determine general movement patterns of Lake Trout within the Husky Lakes. We 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 aims to 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 2012-2013

In April 2012, almost all team members attended the IPY 2012 Conference in Montreal, N. Gantner and S. McFadyen presented posters on the overall project and initial findings. N. Gantner participated in an APECS Early Career workshop as mentor and presented the study to young scientists.

Field work

Prior to each field trip to the communities outlined below, we informed the community of our arrival and plans while in the community via phone, email, posters, job advertisements, and radio announcements or interviews. These documents were jointly prepared during regular Skype meetings between N Gantner, B Kissinger, and S McFadyen with input from J Gareis and D Ross at ARI. Local guides were hired and aided by the Hunters and Trappers Committees, when possible. Required licenses and permits were obtained, journey management plans were filled with the Aurora Research Institute for increased field safety. GPS Spot devices were carried in the field for field safety purposes and to record of travel- and sampling locations. Snowmobiles or boats were rented from ARI or community members. Teams stayed in tents and/or used cabins when permitted while at the lakes. Measurements and samples of fishes were taken when fishermen were willing to share the fish with the scientist. Edible parts were returned to the fishermen and carcasses left on the ice for birds and wildlife to eat. All fish collected in 2012 are listed in Table 1.

May 2012

Husky Lakes – Trip 1

The team set out on an initial trip to Husky Lakes from May 9-11 2012. The team of D Ross, N Gantner, and B Kissinger left the by snowmobile with gear and supplies were prepared at the Western Arctic Research Centre. The team traveled across the uplands north-east of Inuvik to Noell Lake, then continued on towards Husky Lakes (~125 km). During this 3-day trip, the team approached subsistence fishers from Tuktoyaktuk and asked about their catch. The fishers reported that fishing in the area was very poor, so the team decided to try fishing in different parts of the lake. Fishing through the ice, their total fish catch was low during this early trip.

Husky Lakes – Trip 2

The team set out on a main trip to Husky Lakes from May 17-22 2012. The team of N Gantner, S McFadyen, B Kissinger, and guides Douglas Panaktuluk and Jimmy Carpenter left Tuk by snowmobile with gear and supplies prepared at a B&B in Tuk. We travelled on rented snowmobiles from fishing camp to fishing camp and collected measurements and samples of fish that fishermen had caught. All lake trout collected in May were caught and donated to the project by community members. Upon our return to town, we asked for donation of fishes from people that had them in their freezers and added several trout to the project's collection. A list with length, weight, and ages (once determined) of each fish was provided to the HTC in Tuk for anyone interested to phone in and find out the age of the fish they donated.

August/September 2012

During the open water season, Husky Lake was accessed via helicopter from Inuvik on August 13 2012, by Douglas Joe Esagok, B Kissinger, and S McFadyen; Sampling at the South end of the lake (basin 1 and 2) included water sampling near shore sampling of invertebrates, seine and gill netting. To be more efficient, we split into two groups to check the nets, while two remained on shore and continued sampling. Three near shore sites per basin were selected and samples collected using standard methods such as kick sweeping and seine netting. Three to four gill nets were set within ~1 km of each near shore site and checked regularly. Fish and invertebrates were processed immediately on shore. Samples were stored on ice during the sampling period. Nikolaus joined Ben and Shannon on Aug 18 2012 near Zeamen from Tuk by helicopter along with Douglas Panaktuluk to sample the North end of the lakes. D J Esagok returned to Inuvik by helicopter and delivered samples to ARI for storage. Supplies were dropped off and samples sent to ARI by helicopter once during the second half of this trip. We continued sampling as outlined above in basin 3 and 4. On August 26 2012, we had to abandon our trip near Thumb Island (basin 4), as our out board motor malfunctioned. The team returned to Inuvik to repair the motor two days ahead of schedule. A team of two later flew out to return the rented boat to basin 1, taking water samples in the process. D Panaktuluk then returned to Tuk by helicopter.

Yaya Lake

D Ross, N Gantner, S McFadyen, and B Kissinger departed Inuvik on September 4-6 2012. They traveled about 100 km downstream through the Mackenzie Delta by boat before arriving at Yaya Lakes. The trip took about 2.5 hours due to the various channels and rivers they had to travel through to get to the field site. Once they arrived at Yaya Lakes, the team set three nets in different locations in the Northern basin of the lake, and checked them every three hours to log the catch. On the next day, two nets were set on the South basin of the lake.

Noell Lake

N Gantner, S McFadyen, and B Kissinger accessed Noell Lake by helicopter for a one day sampling trip to set three nets and collect invertebrates.

Big Lake

Sampling at Big Lake was limited to water sampling by air in May and near shore seine netting on August 15 2012 by N Gantner, due to a restrictive catch limit set by DFO and logistical reasons.

Analysis and Results presentation

Following intense field work, students returned to their respective Universities to continue degree and departmental requirements, as well as initiate analysis of samples and data. B Kissinger has recently upgraded to a PhD program at the University of Manitoba. J Knopp is finalizing her PhD (Trent University) and started working for the Joint Secretariat in Inuvik in Jan 2013; S McFadyen is continuing a MSc program at the University of Victoria. Initial mercury results were presented at a SETAC Conference Long Beach, CA (Nov 2012, Gantner et al 2012b), jointly by Donald and Nikolaus at ArcticNet Vancouver, BC (Dec 2012, Gantner et al 2012c), and by Nikolaus at the FJMC meetings in Winnipeg, Jan 2013. A presentation is planned for the CZS Meeting in Guelph, ON (Kissinger et al 2013). Available reports and results were submitted to HTCs in Tuktoyaktuk and Inuvik in late March 2013 and the continuation of the work proposed to CIMP and NCP programs.

Environment Canada withdrawal

Proposed Total Mercury analysis and trophic stable isotope analysis for this year have been delayed, in part due to Environment Canada's withdrawal from for this project in May (slated support $50K in-kind and $6K stable isotope analysis, DMA80 instrument for mercury analysis, and field equipment), subsequently limiting instrument access to weekends only (freeze drier) and not providing the instrument (DMA 80); Efforts were thus focused on completing sample collections in May and August 2012 via the existing partnerships and on establishing improved working conditions to complete the proposed work. However, ongoing administrative challenges at the University of Victoria eventually led to N Gantner's NSERC

Banting Fellowship ending, NCP funding being amended in November and project samples and equipment being removed from campus for safe keeping in February 2013, as these were intermittently appropriated by Dr Niemann in December 2013.

Project co-lead Dr. N Gantner intermittently supported the 2012 fieldwork through bridge funds (~$25K) and as recipient of the funds via Gantner Consulting Services (sole proprietorship), has since transitioned to an appointment at Trent University (Peterborough, ON) as Visiting Scholar in Dr Hintelmann's laboratory to continue the proposed mercury analysis.

Capacity Building

As proposed, we aimed for 50:50 participation of southern and northern crew members while in the field. This year, we hired 3 local persons for two field trips from Tuktoyaktuk or Inuvik and demonstrated field dissections to approximately 25 community members during fieldwork or in town. In addition, we employed ARI Technician Donald Ross on trips from Inuvik. We engaged with High Schools in Tuktoyaktuk during field work and conducted a logo contest. We involved 2 MSc graduate students, one of whom recently upgraded to PhD program. A third, grad student (PhD) is near completion. One Banting post doc completed his term in 2013.

Communications

This remains a key aspect of the study. The project houses its website at ARI Inuvik, available here http://www.nwtresearch.com/programs/environmental-monitoring/husky-lakes-fish-health. We continued to provide regular updates to our open and public facebook group, available here: https://www.facebook.com/groups/105659876193939/

In preparation for the IPY 2012 meeting in Montreal, N Gantner and S McFadyen prepare 'youtube-frostbytes' videos, which can be found at www.youtube.com.

Prior, during and following field work, we submitted announcements to the community radio station. These announcements indicated who, what, when, why and where we would be in town or in the field. CBC North's Northwind program requested a radio interview (aired May 24 2013). N Gantner attended Tuktoyaktuk HTCs AGM Meeting in August, and planned to attend the Inuvik HTC meeting, which was later cancelled. N Gantner, B Kissinger and S McFadyen met with IRC Shannon O'Hara in August to discuss needs for 2013/14. We planned to present posters at the 20th NCP Workshop in Inuvik in September 2012 however; this workshop was postponed to 2013. We did present a poster and gave a co-presented (N Gantner and D Ross) talk at the ArcticNet ASM in Vancouver (Dec 2012), which was also attended by J. Knopp, J Reist, C. Furgal, and H Hintelmann. Team members N Gantner, B Kissinger, J Knopp and J Reist attended the Fisheries Joint Management Committee Meeting in Winnipeg in January 2012. We regularly send updates via email to HTCs, Tuk Community Corporation and Inuvialuit Land Administration.

Traditional Knowledge Integration

Between February 2012 and April 2013, 18 semi-directed Traditional Knowledge (TK) interviews were conducted with local experts in Inuvik and Tuktoyaktuk. 14 local experts in Tuktoyaktuk and 4 local experts in Inuvik were interviewed to discuss fish and lake ecosystem knowledge about Husky, Big, Yaya and Noell Lakes. J. Knopp conducted the 14 TK interviews in Tuktoyaktuk with the assistance of Nikolaus. J. Knopp conducted 1 TK interview in Inuvik with the assistance of Shannon and Benjamin. J. Knopp and C. Furgal trained Shannon on semi-directed interview methods and Shannon conducted the final 3 TK interviews in Inuvik.

J. Knopp and C. Furgal with the assistance of V. Rajdev carried out the TK interview analyses including: interview transcriptions and verification of transcriptions for typing accuracy; interview analyses in NVivo using standardized qualitative analyses methods; creation of synthesis maps from the interviewee maps for key features of the study lake ecosystems; analyses and synthesis map verification with interviewees; and, TK summary report writing. The TK summary report is underway and will be completed in the coming months. Initial synthesis figures presenting the breadth of knowledge shared are provided below (Figure 6,7). The report will need to be verified by the interviewees before the final version can be completed and released. The work for the Traditional Knowledge component of this project was completed in-kind by J. Knopp and C. Furgal during the 2012-2013 year due to limited funding available the project for this fiscal year. The TK report and results within will then be compared with the science results and joint reports or publications will be derived integrating the two knowledge basis, where possible.

Results and Discussion

Mercury 'fingerprint' in fish

Mercury stable isotope analysis was conducted on a sub-set of fishes and sediments collected in November 2011 from Husky lakes and 2009 and 2010 from Noell Lake. This relatively new methodology (also referred to as fingerprint) has the potential to indicate differences in mercury processing in lakes or potential differences in the source of mercury. Mass-dependent (MDF) and mass-independent fractionation (MIF, $\Delta 199Hg$) were derived following Gantner et al (2009). Preliminary results for fishes are presented here compared among the two lakes, fish species, and fish organs (muscle and liver). Greater MIF was observed in Lake trout from Noell Lake (freshwater) compared to Husky Lakes (marine). This could be explained by a wider dietary base in marine influenced environments, and resulting different growth rates. In Noell Lake, MIF fractionation was tissue-specific, with greater MIF in muscle than liver while this was not evident in Husky Lakes. This may be due to different diet or trophy at time of sampling (summer & winter). Greater fractionation was found in liver tissues from freshwater versus estuarine samples. This could be due to the differences in food availability and thus turnover rates in liver tissues. Selected results of mercury stable isotope analysis are presented in Figure 1 (from Gantner et al 2012b). Results for Total Mercury in fishes are presented in last year's NCP report (Gantner and Gareis 2012). Additional fish and water samples for Mercury stable isotope analysis and total mercury were collected and analysis is pending.

Lake Trout Movement:

Linear regression of [Sr] and water salinity indicate a significant positive relationship ($p < 0.01$, Figure 2). Three life histories have been qualitatively identified within Husky Lakes form Sr otolith microchemistry profiles obtained from ten selected lake trout. These include life history 1: described by a flat profile with minimal year to year median [Sr] variation, life history 2: described by variable year to year median [Sr], and life history 3: described as low and flat [Sr] through early annuli with a marked increase after a number of years (Figure 3). Both life histories 1 and 2 have 2-6 times the median [Sr] in the first ten years of life compared to life history 3 (Figure 4).

The significant relationship between water [Sr] and salinity support observation of (Secor & Rooker, 2000; Zimmerman, 2005), indicating that otolith [Sr] can be used to detect large scale movements of lake trout along the Husky Lakes salinity gradient (Figure 2). The observation of multiple life histories indicates that lake trout use multiple habitats and have the ability to tolerate various salinity levels throughout their lives (Figures 3 and 4). The observation that a subset of Husky Lakes lake trout has 2-5 times the [Sr] in the first 10 years when compared with life history 3 indicates that more than one spawning and rearing location is used.

Expected Project Completion Date:

March 2014

Acknowledgments

We would like to thank the Northern Contaminants Program (AANDC) for continued funding and the Aurora Research Institute in-kind support. PCSP and Aklak-Canadian Helicopters provided invaluable and safe logistical support in the field. Gantner Consulting Services provided administrative support. Support for laboratory work was gratefully provided by Amy Sett (EC Burlington) and Brian Dimock (TrentU). We thank all interview participants in Tuk, 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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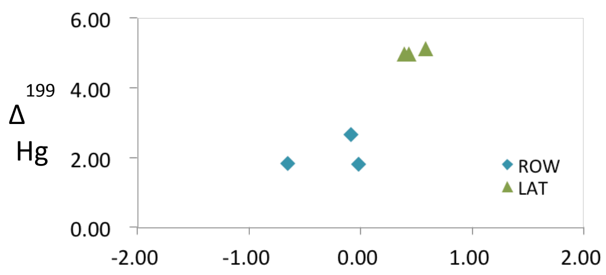
Table 1: Husky Lakes 2012 Gillnet and seine net fish catch data per lake (or basin).

Species/Location	TOTAL	HL1	HL2	HL3	HL4	500(HL1)	Yaya Lk	Noell Lk	Big Lk
ARCTIC CISCO	**22**	-	-	9	13	-	-	-	-
ARCTIC FLOUNDER	**4**	-	-	-	4	-	-	-	-
ARCTIC GRAYLING	**55**	31	19	3	-	5	-	-	-
BROAD WHITEFISH	**19**	-	8	2	5	-	4	-	-
FOURHORN SCULPIN	**22**	10	5	5	2	-	-	-	-
INCONNU	**12**	1	1	-	-	-	10	-	-
LAKE TROUT	**35**	11	12	-	-	-	12	-	-
LAKE WHITEFISH	**71**	22	18	6	1	4	11	9	-
LEAST CISCO	**15**	-	2	3	6	-	4	-	-
NORTHERN PIKE	**38**	17	10	1	-	-	9	1	-
PACIFIC HERRING	**13**	4	-	8	1	-	-	-	-
ROUND WHITEFISH	**7**	4	-	-	-	-	-	3	-
SAFFRON COD	**1**	-	-	-	1	-	-	-	-
STARRY FLOUNDER	**6**	-	1	5	-	-	-	-	-
ARCTIC FLOUNDER	**3**	-	-	-	3	-	-	-	-
NINESPINE STICKLEBACK	**88**	11	4	10	4	10	20	17	12
SLIMY SCULPIN	**11**	-	-	-	-	-	11	-	-
Juv WHITEFISH (no ID)	**13**	3	-	-	-	-	10	-	-
BURBOT	**1**	-	-	-	-	-	1	-	-
POND SMELT	**2**		2	-	-	-	-	-	-

Noell Lake



Husky Lakes (Basin 2 & 3)

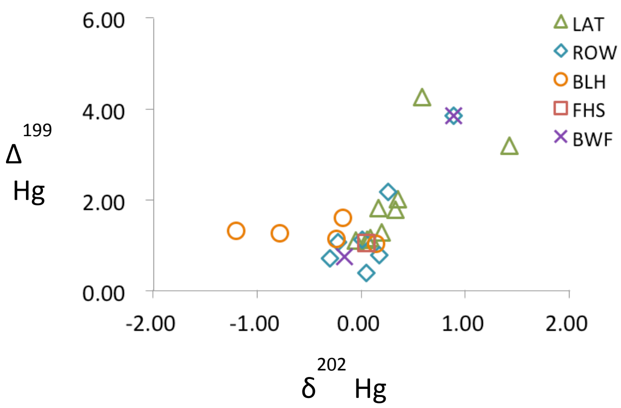


Figure 1: Top: Mercury stable isotope ratios (mercury 'fingerprint') in muscle (MIF; Δ^{199}Hg, and MDF; δ202Hg) from Lake Trout (LAT, n=3) and Lake Whitefish (LAW, n=3) collected from Noell Lake (freshwater lake (FW), 2009). **Bottom:** Hg SIRs in muscle from Broad Whitefish (BWF, n=2), Lake Whitefish (LAW, n=3), Blue Herring (BLH, n=5), Fourhorn Sculpin (FHS, n=2) and Lake Trout (LAT, n=6) from the Husky Lakes Basin 2/3 (marine influenced lake (M), 2011). Figures modified from: Gantner et al. 2012b.

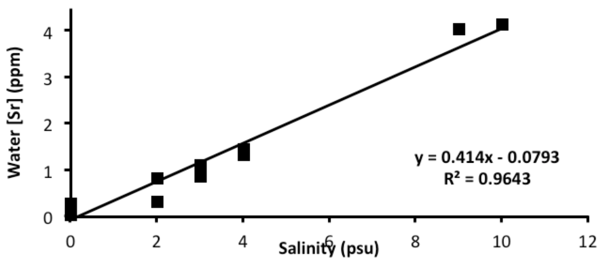
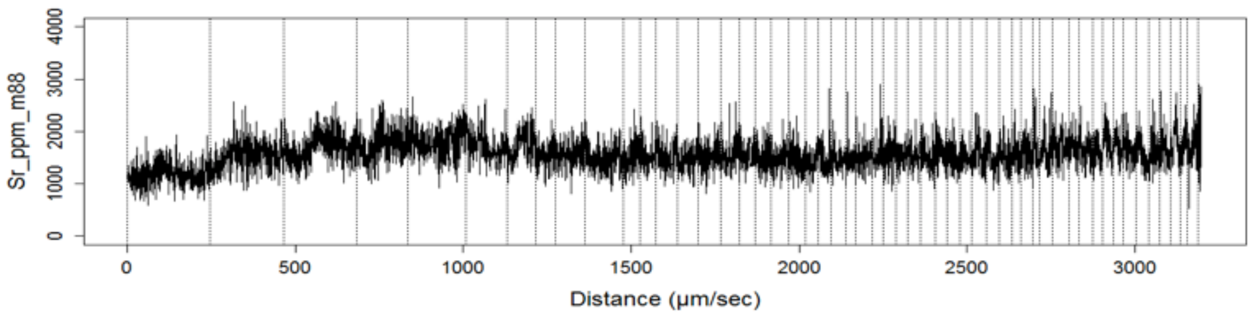


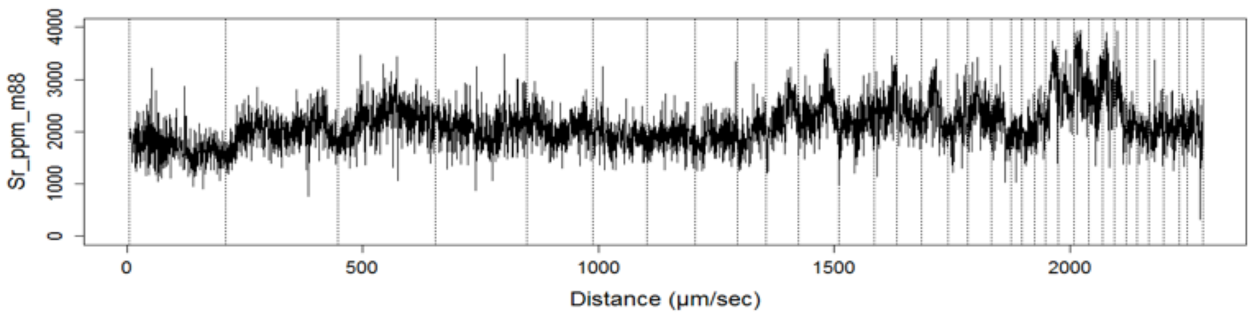
Figure 2. (Left) The relationship between [Sr] and salinity of water sample obtained from Husky Lakes (n=11, salinity range 0-10psu), Yaya Lakes (n=1, 0psu), Noell Lake (n=1, 0psu), Big Lake (n=1, 0psu), and 500 Lake (n=1, 0psu) May 2012.

Figure 3. (Below) Examples of three resident lake trout otolith [Sr] profiles from Husky Lakes lake trout sampled in May 2012. Otolith increment distances are represented by vertical dashed bars. The distance between vertical dashed lines represents one year of otolith growth. The first increment represents the time before hatch (age 0). The last increment is the [Sr] of the ablated epoxy. Note: X-Axis scales vary according to fish age.

Lake trout life history 1



Lake trout life history 2



Lake trout life history 3

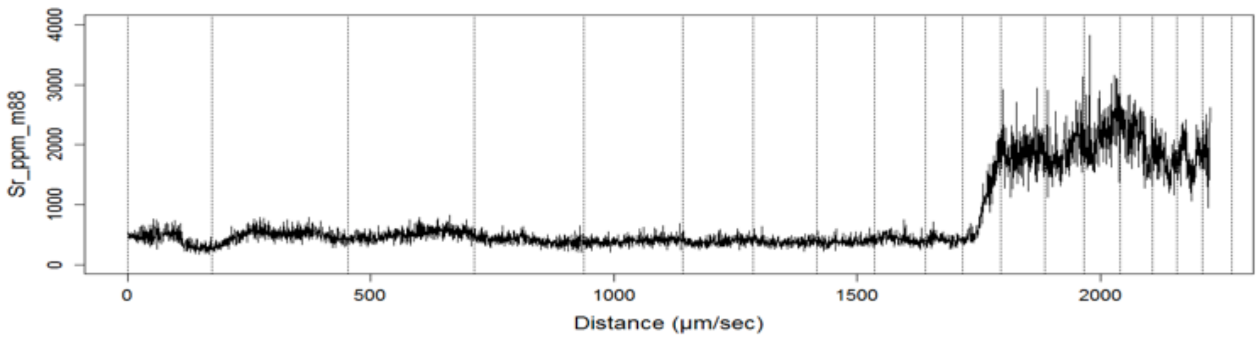


Figure 4. Median increment values of lake trout otolith [Sr] ppm for life history 1 and 2 (n=23 individuals, solid black circle ●) and life history 3 (n= 1 individual, open square □) Husky Lakes, NT. (Increment 1 represents the time before hatch (age 0), increment 2 is year 1, increment 3 is year 2, and so forth).

Figure 6. Diagram showing breadth of knowledge shared by local experts during Traditional Knowledge interviews on the topics of important ecosystem areas, important fishing locations, lake ice and lake water conditions, fish health, effects of outside influences on fish, and human health associated with fish consumption.

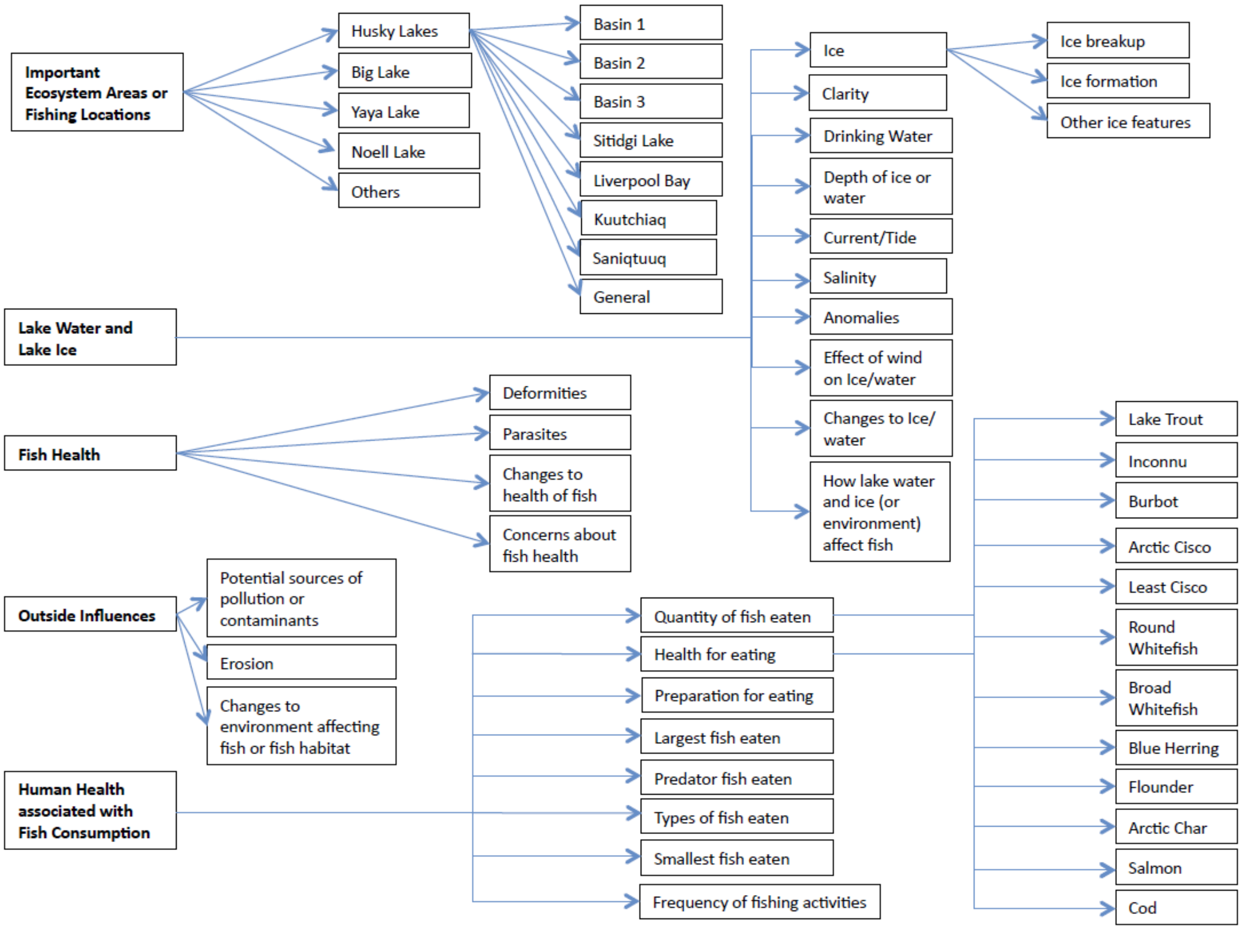
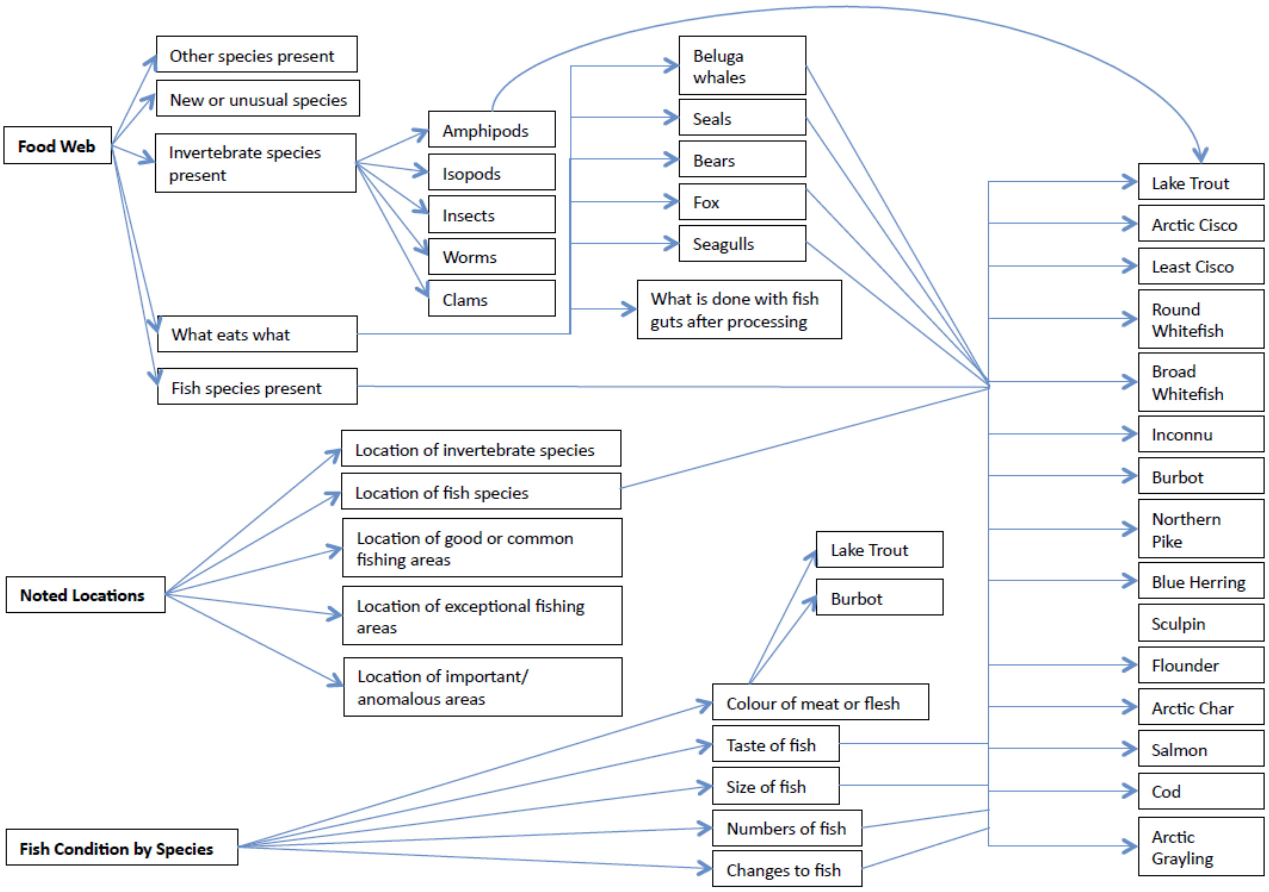


Figure 7. Diagram showing breadth of knowledge shared by local experts during Traditional Knowledge interviews on the topics of important locations in the Husky Lakes, conditions of fish, and understandings of the food web structure in the Husky Lakes. Note: a higher quality version of this figure is available for final publication.



Paulatuk beluga whales: Health and knowledge

Bélugas de Paulatuk : Santé et connaissance

- **Project Leader:**
  Paulatuk Hunters and Trappers Committee (PO Box 39, Paulatuk, NT X0E 1N0 Ph: (867) 580-3004 Fax: (867) 580-3404) Diane Ruben, Resource Person, Tony Green, President and Lawrence Ruben, MPA Member
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Abstract

Recent changes in climate and ice in Darnley Bay have changed and increased the frequency of beluga hunts by the community of Paulatuk in the Inuvialuit Settlement Region. The community of Paulatuk has many questions about the beluga being harvested, in regards to their health and how similar or different they are to whales monitored at Hendrickson Island in Mackenzie Estuary. This summer, two monitors from Paulatuk collected samples from seven harvested whales. The hunters and monitors noted the challenges in changes with the ice and weather that hampered harvests. Length measurements were taken, along with jaws for ageing and tissues for mercury and stable isotope analyses. Whales were larger and

Résumé

Les récents changements sur le plan du climat et de l'état des glaces dans la baie Darnley ont modifié et ont fait augmenter la fréquence de la chasse au béluga par la collectivité de Paulatuk, dans la région désignée des Inuvialuit. Les membres de la collectivité de Paulatuk se posent de nombreuses questions sur les bélugas qui sont capturés, notamment en ce qui concerne leur santé et la mesure dans laquelle ils sont similaires ou différents de ceux qui font l'objet d'une surveillance près de l'île Hendrickson, dans l'estuaire du fleuve Mackenzie. Cet été, deux contrôleurs de Paulatuk ont prélevé des échantillons sur sept baleines capturées. Les chasseurs et les contrôleurs ont noté les difficultés liées au changement de l'état des

older than those taken in 2005 and comparable to whales sampled at Hendrickson. Similar mercury concentrations to Hendrickson whales were measured in skin and muscle. However the liver levels remained much lower than Hendrickson whales. Comparisons with both Hendrickson whales and historical whales taken in Paulatuk suggest a possible shift in diet in recent years. However, given the low sample size (e.g. 7) it is difficult to conclude on such observations. Future efforts will be placed on increased observational information collected along with harvest samples.

glaces et des conditions météorologiques qui nuisent aux captures. Ils ont mesuré la longueur des spécimens, examiné les mâchoires pour déterminer l'âge de ces derniers, et prélevé des échantillons de tissus aux fins d'analyses ciblant le mercure et les isotopes stables. Les baleines étaient plus grosses et plus vieilles que celles capturées en 2005, et étaient comparables à celles échantillonnées près de l'île Hendrickson. Les concentrations de mercure mesurées dans la peau et les muscles étaient similaires à celles mesurées chez les baleines capturées près de l'île Hendrickson. Toutefois, les concentrations dans le foie étaient bien inférieures à celles observées chez les baleines capturées près de l'île Hendrickson. Les comparaisons de ces baleines, tant avec celles capturées près de l'île Hendrickson qu'avec celles capturées à Paulatuk, laissent croire que l'alimentation des bélugas a changé au cours des dernières années. Toutefois, vu la petite taille de l'échantillon (p. ex., 7), il est difficile de tirer des conclusions à partir de ces observations. Lors des activités de recherche futures, on s'efforcera de recueillir davantage de données d'observation et davantage d'échantillons.

Key Messages

- Due to early open water in Darnley Bay and high winds the beluga occurrence and hunts were different than 2011. Two beluga whale monitors (one stationed at Browns Harbour-northern tip of Darnley Bay, and one mobile monitor) sampled 7 harvested whales.
- Samples were sent to Fisheries and Oceans Canada to estimate age (teeth growth layer groups), measure the contaminant mercury (muscle, liver and skin), and evaluate the diet indicators, stable isotopes to better define diet and diet drivers of mercury levels.
- Preliminary results revealed muscle mercury levels were similar to those measured in Hendrickson Island beluga whales and higher than those measured previously in 2005. Conversely liver mercury levels were lower than those measured in Hendrickson

Messages clés

- Vu la saison des eaux libres hâtive dans la baie Darnley et les forts vents, l'occurrence des bélugas et de la chasse différaient par rapport à 2011. Deux contrôleurs (l'un posté à Browns Harbour, à l'extrémité nord de la baie Darnley, et l'autre mobile) ont échantillonné sept baleines capturées.
- Les échantillons ont été envoyés à Pêches et Océans Canada pour estimer l'âge des spécimens (groupes de couches de croissance des dents), mesurer les concentrations de mercure (dans les muscles, le foie et la peau), et évaluer les indicateurs du régime alimentaire, les isotopes stables, en vue mieux définir le régime alimentaire et les éléments de ce dernier qui influent sur les concentrations de mercure.

Island belugas. We are evaluating the drivers of short term (muscle) and longer term (liver) mercury accumulation in Paulatuk belugas

- Les résultats préliminaires ont révélé que les concentrations de mercure dans les muscles étaient similaires à celles mesurées chez les bélugas capturés près le l'île Hendrickson, et plus élevées que celles mesurées en 2005. À l'inverse, les concentrations de mercure dans le foie étaient inférieures à celles mesurées chez les bélugas capturés près de l'île Hendrickson. Nous évaluons les facteurs responsables de l'accumulation de mercure à court terme (dans les muscles) et à long terme (dans le foie) chez les bélugas capturés près de Paulatuk.

Objectives

- Move from an early pilot phase to a strengthened community lead beluga monitoring program for the community of Paulatuk in the ISR.
- Build community capacity in monitoring and research on beluga whales and health
- Determine contaminant levels in beluga whales and the overall health of the whales in context with the Hendrickson Island beluga whales, as well as use the data to establish a baseline for future long term monitoring
- Link program with Hendrickson and other ISR beluga hunts sites as well as link with other ecosystem monitoring (e.g. offshore BREA fish program under BREA).
- Engage community youth in analysis of samples at the DFO (FWI)

Introduction

Inuvialuit lead subsistence lifestyles which include harvesting beluga whales. As such there is concern over their health and contaminant levels. As the environment changes at the global scale (climate change) and the local scale (industrial activities) we suspect beluga may be exposed to more stressors and more contaminants that require ongoing monitoring. Establishing a baseline at this time will assist with future monitoring and management.

The community of Paulatuk hunts beluga whales in the summer. The hunts are limited by sea ice conditions that have been changing over the years. More open water earlier in the summer has changed the beluga occurrence and the hunts. Hunters have had concerns and questions about the health and well being of the beluga whales and their supporting ecosystems. While these are whales from the same population as those harvested at Hendrickson Island, previous research from 2005 showed differences in mercury concentrations, diet markers and other biological measurements (Loseto et al., 2008).

Previous work has shown whales collected at Hendrickson have similar mercury concentrations as those collected at other nearby monitoring sites (Kendall Island, East Whitefish) that are located in the Mackenzie Estuary. The habitat near Paulatuk is very different than the Mackenzie Estuary. How habitat is used differs, and may reflect different diets and processes among the whales. Including the Paulatuk harvest location as a satellite monitoring site to Hendrickson will not only address community questions on health but will also enhance our understanding of these beluga on a larger scale.

Activities in 2012-2013

Field and Local observations:

The PHTC hired on Jody Illasiak and Brandon Green as the 2012/13 Beluga Monitors from funding that came from Northern Contaminants Program (NCP), Fisheries Joint Management Committee (FJMC) and World Wildlife Fund (WWF), where the majority came from NCP. Team involved Lisa Loseto of DFO, Diane Ruben of PHTC, with support coming from other departments to such as FJMC.

Jody was hired as the mobile monitor, moving where harvesters go and Brandon Green was placed at Green's (Egg) Island where majority of harvesters camped. With the weather being a major factor of inability to get to the whales when they were seen, the harvesters had struggles to make their hunt a success. Jody followed the harvesters to the North (Brown's Harbour) in the second weekend of July, where four belugas were harvested and were successfully sampled.

Due to weather, Brandon sampled three belugas on his last day of monitoring on August 7, 2012. The whales were spotted by Tony Green and family that are stationed at their camp in Tippi doing the DFO Blue Char Project on that day and the harvesters were notified by Trapper radios. Seven boats left for the site(s) and were successful in harvesting 5 whales. And on August 8, 2 more whales were harvested west of the community and were shared with those who were unable to harvest.

A total of eleven whales were harvested this year, with unpredictable weathers, it is hard to tell when or how long they will be in our area in the future. The water temperatures have been warmer this year right through August. As in the past, the water temperature usually drops to -3° to -5° by mid-August. In June the weather have been very hot, higher than usual, it could be a number 2 factor with the behaviour of the Beluga. That is another question we seek to find in future monitoring.

It seemed this year that whales observed in the Darnley Bay area have migrated around the area when winds were strong around 50-70km/hr. This was new to the observers. They pass along the coast ranging from about 30 feet to100 feet from nearshore (Tippi camp).

All equipment have been returned by the Beluga Monitors and the trapper radio will be sent back to FJMC and the log books, data sheets will also be sent as well.

Laboratory:

Samples were sent to FWI for analyses. Ages of whales were determined from a thin section of tooth and counting individual growth layers at the Freshwater Institute (Stewart et al. 2006). Liver, skin and muscle were analyzed for total Hg cold vapor atomic absorption spectroscopy (CVAAS) following an acid digest.

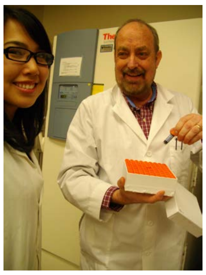
Stable isotope analyses on liver and muscle samples were carried out at the University of Waterloo using ion-ratio, mass spectrometry (CF-IRMS). Lipids were removed from samples using a 2:1 chloroform:methanol wash for carbon readings.

Youth

We had a Youth Summer Student, Bessie Lennie out on the field with Jim Johnson of DFO then later transferred to the Beluga Monitor site at Green's Island with Brandon Green. We linked the Invertebrate Project and Summer Student Program to this Beluga Program, which were all a success. She went down to Winnipeg FWI with a chaperone in mid-January during the DFO/FJMC Meeting. Diane has arranged the travel for January 11th to 18th. During her week at the FWI L. Loseto has arranged a week of exposure to programs and laboratory work related to her field season. Bessie worked with E. Choy (L. Loseto's PhD student) to learn methods of fatty acid analysis on beluga blubber, O. Nielsen and learned methods on beluga disease work, J. Delronde and learned Hg methods and T. Loewen who taught her how fish are dissected and prepared for all analyses. In addition there was 1.5 days spent listening to science presentations with the FJMC-DFO workshop. Bessie will provide a report back to the PHTC on her experience and present a power point presentation to the school about her experience.

Excerpt from Bessie Lennie's Field report Beluga Monitoring

This year I was stationed in Egg Island in Argo Bay with whale monitor, Brendan Green. As we all know the Beluga Whale arrived late this year and with not as much numbers as we hoped. This amazing creature is very important to us as a people which makes me grateful to see that this step has been taken to protect them. Much like the fish survey, samples of the whales have been taken for further research. Hopefully in further studies we can find out what drives them to keep coming back to this area each year.



Results

Here we place our findings from 2012 in context with work conducted in 2005 and 2011, in addition we make comparison to results from the Hendrickson Island beluga program.

Length and Age

The sample size of seven is small and difficult to assess trends with. Whales hunted in 2012 were generally larger than those historically taken and ranged in length from 3.7m to 4.6m (averaging = 4.3m). These whales were significantly larger than those harvested in 2005 (average = 3.6m; P=0.03) and not significantly different than 2011 (average 4.0m). Relative to whales taken at Hendrickson Island that averaged 4.0m in length, the whales from Paulatuk were larger (P=0.05). This is the reverse of what was observed in 2005 and in 2011 there were no significant differences in length (Figure 1). In whales harvested in 2012 length and age were positively related (r=0.8, p=0.03).

Belugas were older in 2012 and 2011 relative to those harvested in 2005 averaging just over 27 years (P=0.03, table 1). And the 2012 and 2011 whales were similar in age to those harvested at Hendrickson Island (P=0.85, Figure 2).

Table 1

	2012		ANOVA output	
	Mean	St Dev	P	r
Morphometrics				
Length	430.7	32.1	0.029	0.48
Age	27.7	7.0	0.028	0.48
Mercury				
Liver	16.8	14.2	0.079	0.43
Muscle	1.5	0.6	0.001	0.66
Skin	0.7	0.3	0.002	0.63
Methylmercury				
Liver	0.9	0.6	n/a	n/a
Stable Isotopes				
Nitrogen Muscle	17.3	0.4	0	0.81
Nitrogen Liver	17.7	0.4	0.662	0.18

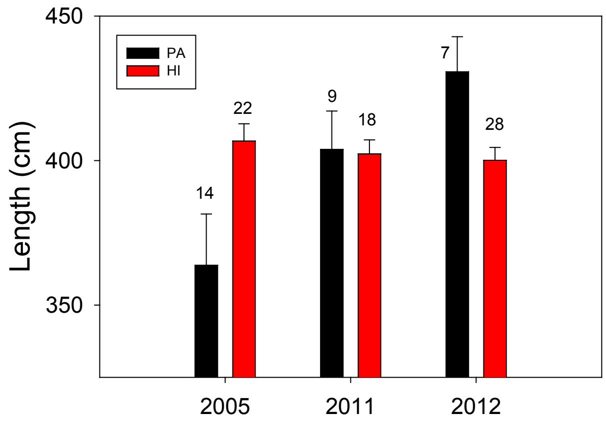


Figure 1. Beluga length (cm) from three years harvested at Hendrickson Island (red) near Tuktoyaktuk and near Paulatuk (black). Whaled did not differ in length among sites in 2011. Those from Paulatuk were significantly shorter in 2005 relative to other years. Sample sizes are noted in text above bars.

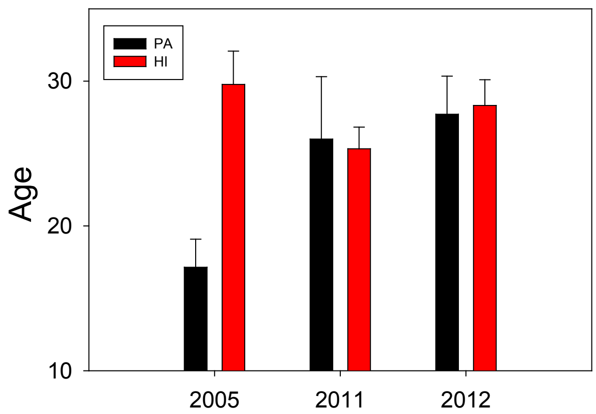


Figure 2. Estimated Beluga age (1 GLG) from three years harvested at Hendrickson Island (red) near Tuktoyaktuk and near Paulatuk (black). Belugas from Paulatuk taken in 2005 were significantly younger than those taken at Hendrickson and near Paulatuk in subsequent years.

Mercury Trends

Concentrations of Hg in muscle ranged from 0.9 to 2.5ug/g (ww) and averaged 1.5ug/g. These concentrations were significantly higher than those observed in 2005 (average = 0.7ug/g; P=0.01) and similar to 2011 (average 1.2ug/g; P = 0.2) (Table 1). The concentrations of Hg in 2012 whales were similar to those measured in whales from Hendrickson Island (1.2ug/g) (Figure 3). Trends for skin Hg concentrations were similar to muscle, showing an increase in 2012 (average = 0.65ug/g) from levels in 2011 (0.46ug/g) and 2005 (0.25ug/g) (Table 1).While liver Hg also showed an increase in 2012 (average = 16.0ug/g) relative to 2005 and 2011, the concentrations remained lower than those measured at Hendrickson Island (average = 27.3ug/g) (P=0.1, Table 1, Figure 4).

Muscle Hg positively related to length (r = 0.81, p=0.03) and age (r = 0.79, p=0.03). Liver Hg was positively related to age, near significance (r = 0.71, p=0.08).

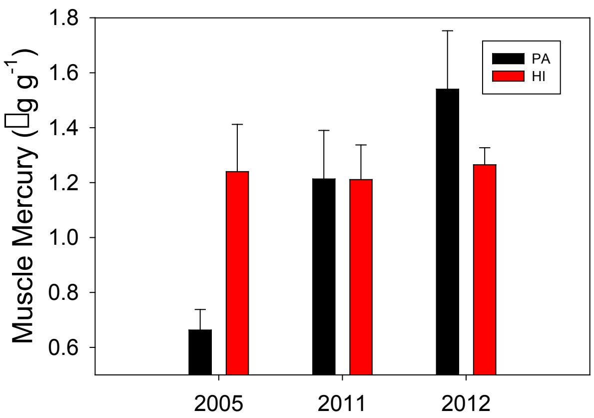


Figure 3. Concentrations of Hg in muscle (ug-g-1 ww) from three years harvested at Hendrickson Island (red) near Tuktoyaktuk and near Paulatuk (black). Belugas from Paulatuk taken in 2005 were significantly lower than those taken at Hendrickson and near Paulatuk in subsequent years.

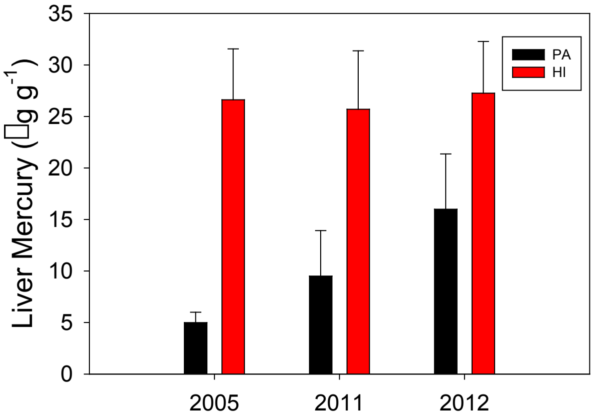


Figure 4. Concentrations of Hg in liver (ug-g-1 ww) from three years harvested at Hendrickson Island (red) near Tuktoyaktuk and near Paulatuk (black). Belugas from Paulatuk taken in 2005 were significantly lower than those taken at Hendrickson and near Paulatuk in subsequent years.

Stable Isotopes

Isotopes were used as a means to interpret beluga feeding preferences driving the contaminant levels. Trends in δ15N differed among muscle and liver whereby liver levels did not differ from 2005 to 2012 ($P=0.6$), and muscle levels did ($P<0.001$) (table 1). Liver is thought to reflect recent diet as it has faster turnover rates relative to muscle δ15N that has slower turnover rates and may represent a longer accumulation of diet signals. In comparison to δ15N in Hendrickson Island belugas, the muscle and liver were similar to Paulatuk whales in 2011 and 2012. Results for δ13C are pending as samples were submitted to have lipids removed.

For whales collected in 2012 δ15N demonstrated positive trends for both length ($r = 0.81$, $p=0.01$) and age ($r = 0.77$, $p=0.04$). Examining trends with Hg, δ15N was positively related to both muscle ($r = 0.74$, $p=0.05$) and skin ($r = 0.87$, $p=0.01$).

Discussion and Conclusions

Results presented include reference to previous work in 2005 and 2011 as well as to findings from Hendrickson Island. As noted earlier caution is taken with the interpretation of results due to the small sample size obtained for 2012.

The 2012 harvest year was a unique one as weather and ice conditions changed. Ice cleared out of Darnley Bay early, and while this made the bay accessible for hunting, the high winds and associated waves made it dangerous to be out hunting. As such only 7 whales were landed and later in the season from July 14 to Aug 06 4 more were harvested. Hunts in 2005 and 2011 occurred between July 14-25, not significantly earlier than 2012. While the whales were not harvested significantly later than previous years it is suspected whales are arriving to the Beaufort sooner due to changes in ice and open water, thus timing association with the size of whales requires further investigation. The local observations on the whales differ by size, the smaller ones comes in first to feed in the shallow water while the bigger ones comes about 1 – 2 weeks later to molt in shallow. There has been success in sampling sizes from 9’ to 14’ whales at two different times. While the earlier whales are the smaller sizes from 9’ – 11’ and the larger whales are later in early August ranging from 12’ to over 14’. Collecting more local observations and TEK will better help us to understand the behavior and why they tend to travel at different times. This is a new program but the past observations are a learning experience of why they migrate different times. Understanding how changes in whale size, age, behavior, diet relate to habitat changes are important to understanding links to climate change and further how those changes will influence contaminant loads.

Mercury in muscle and skin are both largely comprised of methyl mercury and reflect dietary exposure of mercury. The increased Hg concentration in muscle to levels similar to and higher than those at Hendrickson was unexpected given results from 2005 (Loseto et al. 2008b). Given that these whales were larger than those in 2005 and that muscle reflects recent diet sources that is related to size (Loseto et al. 2008a) the observations are then fitting. The relationship with muscle Hg concentrations with length supported the size relation observed previously (Loseto et al. 2008b). This supports that the larger whales continue to feed in offshore areas where prey may have higher Hg levels. Why the apparent difference in whales from 2005 and 2012 may partially reflect the low sample sizes collected in 2012.

On the other hand liver Hg concentrations are reflective of long term accumulation of Hg as Hg:Se overtime in the liver and thus tends to relate strongly with age. While liver Hg concentrations were also higher than those in 2005 they remained lower than concentrations measured in whales landed at Hendrickson Island. This was surprising given that the whales from both locations were similar in age.

The rise in muscle Hg that is associated with increase in size that is comparable to Hendrickson Island along with the low liver Hg despite similar age classes to Hendrickson whales suggest a shift in Hg exposure and associated changes liver accumulation.

Stable isotope results of δ15N were used to evaluate the trophic level of feeding of beluga, with the general trend of higher trophic level species having higher Hg concentrations. Carbon will be evaluated at a later date (data pending). Previously liver δ15N was found to reflect recent diet given the faster turnover rate of this tissue (e.g. (Loseto et al. 2008b)) whereas muscle represents a longer term turnover (find another reference). Here Liver δ15N was more closely related to length supporting the recent dietary linkage whereas muscle δ15N more closely related to age (as observed in other studies). While linkages on defining drivers are being teased out with some of the isotope work more analyses are required to better understand the recent observations, however given the general low sample size efforts on collecting LEK/TEK and observations will assist with the interpretation of results received thus far.

Acknowledgments

Please note that the NCP must be acknowledged in a formal way in all presentations and other communications products (including papers) related to activities funded by the NCP and their results.

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Tlicho Aquatic Ecosystem Monitoring Project

Projet de surveillance de l'écosystème aquatique de la Première Nation des Tlicho

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Abstract

The project builds on a community-driven aquatic ecosystem monitoring project carried out in 2010 and 2011 as a means of addressing community concerns related to observed changes in the environment. The project engaged local community members to collect samples and record a standard set of observations using both Tlicho and western scientific knowledge to address the question "are the fish and water safe to consume?" As a community- driven project, it meaningfully involved community members in all aspects of conducting contaminants related research, including in the actual pursuit of monitoring and research objectives.

Résumé

Le présent projet s'appuie sur un projet communautaire de surveillance des écosystèmes aquatiques mené en 2010 et 2011 pour répondre aux inquiétudes des collectivités à l'égard des changements environnementaux observés. La participation de membres des collectivités locales a été sollicitée pour ce projet afin de prélever des échantillons et de consigner un ensemble normalisé d'observations au moyen des connaissances Tlicho et scientifiques occidentales en vue de répondre à la question suivante : « Les poissons et l'eau sont-ils sécuritaires pour la consommation humaine? ». Comme il s'agit d'un projet communautaire, la participation importante de membres des collectivités pour tous les aspects des travaux de

A monitoring camp was held on Snare 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 to Elders and youth the methods for collecting fish tissues for analysis. A results workshop was held in Wek'weètì 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 Lake Trout. Lake Trout are predatory fish and as such bioaccumulate mercury as they consume prey. Small to moderate sized Lake Trout and Lake Whitefish were within Health Canada guidelines for Commercial Sale of Fish and do not pose a health risk.

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.

recherche sur les contaminants, y compris en ce qui touche l'atteinte des objectifs de surveillance et de recherche, est nécessaire.

Un camp de surveillance a été mis sur pied au lac Snare, un lieu fortement utilisé par les Autochtones pour la pêche de subsistance. L'eau, les sédiments et les poissons ont été 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 ont montré aux aînés et aux jeunes les méthodes employées pour prélever les tissus aux fins d'analyse. Un atelier a été organisé à Wek'weètì pour présenter les résultats de l'analyse des tissus ainsi que des échantillons d'eau et de sédiments. En outre, les membres des collectivités ont reçu de l'information sur la concentration des contaminants dans les poissons qu'ils sont susceptibles de consommer, et on leur a expliqué que ces aliments demeuraient sains, mais peut-être sous certaines réserves.

L'analyse des tissus des poissons montre que les concentrations de mercure étaient relativement faibles, sauf chez les touladis de très grande taille et très âgés. Le touladi est un poisson prédateur, et les proies qu'il consomme entraînent chez lui une bioaccumulation du mercure. Les concentrations relevées chez les touladis et les grands corégones de taille petite à moyenne étaient conformes aux lignes directrices de Santé Canada pour la vente commerciale de poisson, et ne posaient donc pas de risques pour la santé.

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 principaux objectifs de surveillance à long terme, qui consistent à déceler les changements temporels et spatiaux.

Key Messages

- The fish tissue analysis showed that mercury levels are relatively low except in very large and very old individuals of Lake Trout.
- The water and sediment quality sampling results show that Snare Lake is typical of other lakes in the area; low levels of nutrients, dissolved metals and moderate suspended sediment.
- The traditional knowledge forms an invaluable baseline against which we can measure change. Wek'weètì elders have observed many changes in water temperature and levels as well as increases parasites and cysts in fish.

Messages clés

- L'analyse des tissus des poissons a révélé que les concentrations de mercure étaient relativement faibles, sauf chez les touladis de très grande taille et très âgés.
- Les résultats de l'analyse des échantillons d'eau et de sédiments indiquent que le lac Snare est comparable aux autres lacs de la région (faibles quantités de nutriments et de métaux dissous, et 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 Wek'weètì ont observé de nombreux changements sur le plan de la température et des niveaux de l'eau, de niveaux, de même qu'une augmentation du nombre de parasites et de kystes chez les poissons.

Objectives

- Document and combine traditional knowledge of fish in the Wek'weètì area with conventional fish sampling methods;
- Obtain baseline data on mercury levels in fish consumed by Wek'weètì residents;
- Evaluate mercury levels found in fish in terms of species and size/age relationships, habitat use, trophic status;
- Long-term objective is to establish a monitoring program to identify contaminant levels and changes in levels through time for fish in the Tlicho region as part of a larger Aquatic Ecosystem monitoring program.

Introduction

There is a paucity of traditional knowledge and science on the aquatic ecosystems that supports subsistence fisheries in the Tlicho 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. Tlicho 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. Further, Lockhart et al[1] report

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.

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 Tlicho 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 Tlicho region would broaden the geographic coverage for this parameter as recommended in the INAC State of Knowledge Report[2].

Activities in 2012-2013

The project focused on the fisheries, water and sediment components of the aquatic environment and used Tlicho measures of healthy fish as well as scientific data on contamination in key fish species to help better understand the state of the aquatic environment in the Tlicho 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. Snare Lake was selected due to concerns of contamination from sewage discharged after filtering through a wetland and the close proximity of the community dump to the lake shore. Elders also discussed the concept of indicators and how they assess the health of the ecosystem.

Monitoring Camp

A five-day camp in September 2012 was held which provided a valuable experiential learning opportunity in Tlicho 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 Tlicho 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 Wek'weètì community members, fish tissue samples were collected from two fish regularly consumed (Lake Trout and Lake Whitefish). 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'. Four Lake Trout exceeded guidelines for consumption but Lake Whitefish samples and the remaining 16 Lake Trout were below the guideline for mercury (Figure 1). One large Lake Trout had a mercury measurement of 3.39mg/kg wet weight and is not show on the chart. This fish was 27 years old and weighed 7.5 kg. It was significantly larger than the other Lake Trout and can be considered an extreme outlier.

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). Overall water quality is good. CCME Guidelines for the Protection of Aquatic Life were not exceeded at any site. Further, Escherichia Coli (E. coli), the best indicator of fecal contamination[3] was not detected at D1 near the sewage lagoon, suggesting that the lagoon and wetland treatment system is working well.

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 Working Group. Updated November 2009. (original version February 2002, updated 2007)

3 Health Canada (2012). Guidelines for Canadian Drinking Water Quality. http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/2012-sum_guide-res_recom/index-eng.php.

Figure 1 - Mercury levels in Lake Whitefish and Lake Trout tissue sampled from Snare Lake. Twenty samples of each species were analysed and are shown except for one outlier, a Lake Trout that had a value of 3.39 mg/kg wwt.

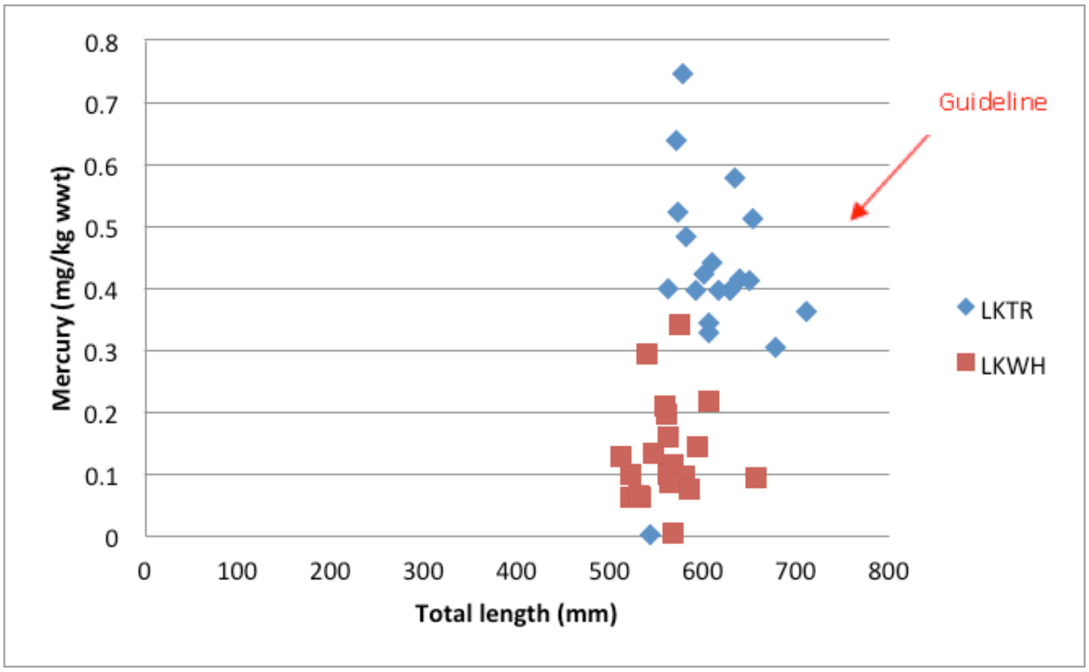

Figure 2 - Species and number of fish captured on Snare Lake

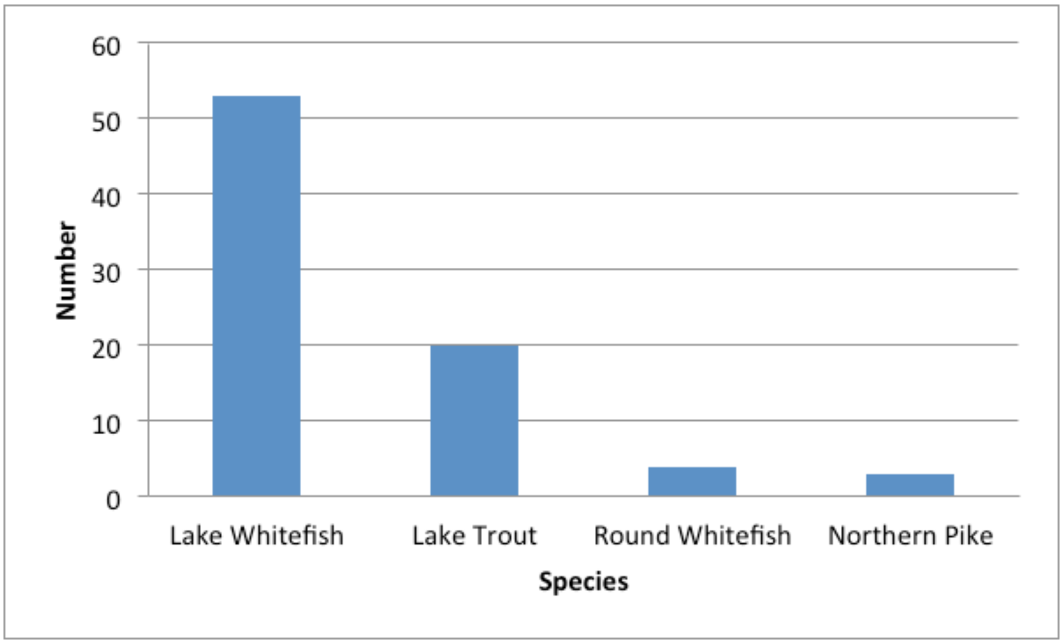

Table 1 - Selected Nutrient and Physical Parameters of Water Samples

Parameter	Units	D3	D2	D1	D1-R	U1	U2
Organic Carbon, Dissolved	mg/L	6.4	6.5	5.9	5.9	5.5	5.7
Organic Carbon, Total	mg/L	7	7.1	6.7	7	6.6	6.9
Phosphorous, Dissolved	mg/L	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Phosphorous, Total	mg/L	0.005	0.013	0.01	0.007	0.008	0.011
Alkalinity, Total (as CaCO3)	mg/L	7.6	7.9	7.2	7.4	6.6	6.8
Conductivity, Specific (@ 25°C)	μS/cm	23.7	23.8	23.3	23	21.6	21.1
pH	pH units	7.18	7.17	7.04	7.04	7.15	7.09
Solids, Total Dissolved	mg/L	18	18	16	10	12	16
Solids, Total Suspended	mg/L	< 3	< 3	< 3	< 3	< 3	8
Turbidity	NTU	0.39	1.22	0.57	0.56	0.93	1.13
Calcium	mg/L	3.7	4	3.9	3.8	3.7	4
Chloride	mg/L	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
Hardness	mg/L	14.5	16	15.8	15.3	15	15.7
Magnesium	mg/L	1.3	1.4	1.4	1.4	1.4	1.4
Silica, Reactive	mg/L	0.617	0.687	0.65	0.65	0.568	0.803
Sulphate	mg/L	2	1	1	1	1	1
Escherichia coli	MPN/ 100mL			< 1		< 1	

Sediment sampling used methods outlined in the Metal Mining Guidance Document for Aquatic Effects Monitoring4 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 January 2013 to report the results back to all project participants as well as an evening public meeting for community members ranging from school aged youth to elders.

Capacity Building

Tlicho 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.

4 Environment Canada. 2011. Metal Mining environmental Effects Monitoring Technical Guidance Document

Communications

Communication was achieved primarily through workshops and meetings with project participants and the public.

Traditional Knowledge Integration

Under the guidance of Tlicho Government traditional knowledge researchers, youth worked with Elders, using the Tlicho Aquatic Ecosystem Monitoring Protocol, 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.

Expected Project Completion Date:

completed

Acknowledgments

This project has been guided by many elders from the community of Wekweètì: Joseph Judas, Madeline Judas, Jimmy Kodzin, Noella Kodzin, Marie-Rose Boline, John Smallgeese, Marie Adele Football, and Isadore Washee. It has also been supported by many other community members including: Joseph Dryneck, Kathy Dryneck, Nick Lamouelle, Bessie Pea'a, Noel Quitte, Pamela Lamouelle, Bobby Pea'a, and William Quitte. We give many thanks for their dedication to the project and their patience in sharing their advice and knowledge over the past year. Adeline Football and Grace Angel provided logistical planning support in the community that was very much appreciated.

The Wek'èezhìi Renewable Resources Board and Tlicho Government thank those organizations that have provided technical support on this project: Fisheries and Ocean Canada (DFO), Wek'èezhìı Land and Water Board and Golder Associates. We also thank those agencies that generously provided financial support: DFO, Northern Contaminants Program (NCP), Cumulative Impact Monitoring Program (CIMP) and Tlicho 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 most rapid route for organic contaminants to enter Arctic ecosystems is through the atmosphere. 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 continued at the

Résumé

L'atmosphère est le chemin le plus rapide emprunté par les contaminants organiques pour pénétrer dans les écosystèmes de l'Arctique. Le projet porte sur la mesure de ces contaminants dans l'air de l'Arctique. Il fait partie d'un programme continu de surveillance qui a débuté en 1992. La mesure des quantités et des types de contaminants exige la collecte de volumes importants d'air au moyen de filtres. Les échantillons filtrés sont ensuite analysés en laboratoire. Les résultats de ce projet en cours servent à négocier des accords internationaux de lutte contre les contaminants et à en évaluer l'efficacité, ainsi qu'à faire l'essai de modèles atmosphériques qui expliquent le déplacement des contaminants à partir de points d'origine

baseline site of Alert, Nunavut, but only one out of four weekly samples were analyzed for routine trend analysis. The remaining samples were extracted and archived for future exploration of notable transport episodes and for emerging priority chemicals. Starting in Dec 2005, we have extended the program to screen for emerging chemicals, such as current-use pesticides, brominated flame retardants and stain-repellent-related perfluorinated compounds, in Arctic air at Alert. Air monitoring for organic pollutants have also been re-started at Little Fox Lake, Yukon, starting August 2011, using a passive flowthrough sampler (FTS).

situés au sud de l'Arctique. À cette étape du projet, on continue à prélever des échantillons toutes les semaines au site de référence d'Alert, au Nunavut, mais seulement un échantillon hebdomadaire sur quatre fait l'objet d'une analyse de routine afin d'établir une tendance. Les échantillons restants ont été 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. La surveillance des polluants organiques de l'atmosphère a repris au lac Little Fox, au Yukon, en août 2011, à l'aide d'un échantillonneur d'air à écoulement continu.

Key messages

- The decline in air concentration of lindane measured at Alert has accelerated after its deregistration in Canada followed by worldwide ban.
- Most banned organochlorine pesticides (OCs) show consistent and continuous declining trends up to the end of 2009.
- Year-long on-site comparison between the newly developed passive flowthrough sampler (FTS) and the super high volume air sampler at Alert shows that the FTS is a reliable and cost-effective method to measure semivolatile organic contaminants in ambient environment with very low concentrations, such as in the Arctic.

Messages clés

- La diminution de la concentration atmosphérique du lindane mesurée à Alert s'est accélérée après le retrait de l'homologation du produit au Canada, suivi de son interdiction à l'échelle mondiale.
- Jusqu'à la fin de 2009, la plupart des pesticides organochlorés interdits affichent une tendance à la baisse constante.
- L'analyse comparative sur place menée sur une année entre le nouvel échantillonneur d'air à écoulement continu et l'échantillonneur d'air à très grand volume à Alert révèle que le premier offre un moyen fiable et rentable de mesurer les contaminants organiques semi-volatils dans les environnements ambiants à très faibles concentrations, comme dans l'Arctique.

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 POPs 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 persistent organic pollutants (POPs) have been conducted at Alert, Nunavut, since 1992. The atmosphere is the major and fastest route of transport for many priority pollutants to the remote Arctic. Monitoring for organic pollutant levels in arctic air can be used for evaluating time trends of atmospheric contaminant input, to determine contaminant source regions and to evaluate global long-range transport models.

Emerging priority pollutants detected in Arctic air may indicate long-range transport potential which is one of the criteria for classifying chemicals as POPs that may be subjected to global control. Current-use pesticides (CUPs), neutral perfluorinated compounds (PFCs) and new flame retardants (FRs) were included in Arctic air measurements at Alert since 2006.

In this report, updated time trends of organochlorine pesticides (OCs) measured at Alert up to 2009 are given.

In 2004-2005, a flowthrough air sampler (FTS), which does not require a power supply to operate and suitable for use under cold environments, was developed. This sampler continued to be deployed at Alert in 2010-2011 to compare its performance in parallel with the conventional super-high-volume air sampler (superhivol). In this report, the air concentrations of OCs, PBDEs and new FRs measured by the FTS was compared with those by the superhivol to assess its feasibility for deployment under Arctic conditions.

Activities in 2012-2013

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 (superhivol). Measurements involve routine weekly sample collection, extraction, analysis as well as archiving. Samples are currently being analyzed in the National Laboratory for Environmental Testing (NLET, Burlington). Starting from 2009/10, only one out of four weekly samples were analyzed to maintain the long-term temporal trends while reducing costs. Gas and particle phases were separately analyzed to assess partitioning properties. The samples that were not analyzed were routinely extracted (with hexane for vapour phase fraction and dichloromethane for the particle phase fraction) and the extracts were archived, giving us the opportunity to analyze the skipped weeks if necessary. Analysis of 2011/12 samples from Alert is currently ongoing.

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 PFCs, new FRs and 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 superhivol, the sample has not been split and no archive has been retained. The sample has been sent to the National Water Research Institute (NWRI, EC) in Burlington for analysis. Drs. Derek Muir and Camilla Teixeira's laboratory analyzed for current-use pesticides. An interlaboratory comparison for CUPs is being conducted between Dr. Camilla Teixeira and Dr. Liisa Jantunen (EC) aiming at transferring the continued analysis of these samples to Dr. Jantunen in FY2013/14. Drs. Mahiba Shoeib and Tom Harner (EC) analyzed these samples for PFCs.

A site audit (funding from Environment Canada) was conducted at Alert in November 2012. Site audit reports for the superhivol and the PS-1 sampler are available upon request.

A newly-developed flow-through sampler (FTS) was installed at Alert in September 2007 and monthly samples have been collected using this sampler until September 2011. Comparable air concentration results measured using the FTS and the superhivol were obtained and an article has been published (Xiao et al., 2012).

As funding became available in mid-2011, an 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. Samples from the FTS installed at Little Fox Lake collected between August 2011 and September 2012 are currently under analysis in the Organics Analysis Laboratory (OAL) located in Downsview (EC).

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

1. Sampling at the Little Fox Lake station in Yukon was restarted in August 2007 and superhivol sampling ended October 2009. Flowthrough air sampling started August 2011 under NCP.

2. Two articles related to results from this project have been published:

    a. (a) Perrie et al. (2012) Selected topics in arctic atmosphere and climate. Climatic Change (August 2, 2012) p. 1-24, DOI:10.1007/s10584-012-0493-6.
    b. (b) Westgate, J. N., Sofowote, U. M., Roach, P., Fellin, P., D'Sa, I., Sverko, E.,

Su, Y., Hung, H. and Wania, F. (2013) In search of potential source regions of semi-volatile organic contaminants in air in the Yukon Territory, Canada from 2007 – 2009 using hybrid receptor models. Environmental Chemistry, 10 (1), 22 - 33.

Communications and Capacity Building

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.

We continued to work 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. In May 2012, project P.I.s Hayley Hung and Sandy Steffen participated in a Whitehorse Air Quality Workshop and presented on our NCP work conducted at the Little Fox Lake station. The workshop was attended by representatives from the EC Pacific and Yukon Region, the Yukon Government, Government of the Northwest Territories and local communities. This workshop was followed by a field trip to the Little Fox Lake station by workshop participants.

In February 2013, we conducted a lecture at the Yukon College for students of the B.Sc. and Renewable Resource programs (which use NCP-based curriculum) followed by a public seminar at the Beringia Center. During the same visit, we also met the Yukon Contaminants Committee to discuss future outreach activities; and colleagues at the Yukon College and Laberge Environmental to discuss the POPs and mercury passive air sampling project (new NCP Project M03) and the Little Fox Lake database.

Following the comments and suggestions from the Niqiit Avatittinni Committee (NAC) for last year’s proposals, we have initiated a communication and capacity building plan in Nunavut. With the assistance of NAC, we have distributed the Alert communication brochures to 73 organizations in 25 communities and 2 outpost camps in Nunavut.

Hayley and Sandy also guest lectured to students in the Environmental Technology Program at the Nunavut Arctic College on January 28, 2013 about Arctic air monitoring and research of organic contaminants and mercury. After the lecture, they met with the NAC to discuss potential outreach activities in Nunavut.

In May 2012, Hayley was invited to guest lecture at the University Center on Svalbard (UNIS) for 1 week on a graduate course titled “Arctic environmental pollution: atmospheric distribution and processes (AT-331)”. Air monitoring and trend analysis for organic pollutants under NCP and AMAP was included as part of the teaching material. Student evaluations from 2012 showed that her contributions were “among the best organized and presented with among the most useful content of all lecturers”.

A Research Note titled “Toxic Contaminant Measurements in Arctic Air” by Hayley Hung, Alexandra Steffen and Amanda Cole has been published in the fall issue of Northern Public Affairs to inform the public about recent findings under these two NCP projects.

Traditional Knowledge

At this time, traditional knowledge (TK) is only indirectly related to this project. 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 of OCs measured in air at Alert have been updated (Figure 1). Trends and seasonal cycles were derived using the digital filtration method (Hung et al., 2010) and apparent first order halflives are given in Table 1. Long-term trends and seasonal cycles were developed between 1993 and 2009 while halflives (Table 1) are calculated separately between 1993 and 2001 and between 2002 and 2009, due to the laboratory change in 2002 from the Freshwater Institute to NLET.

Discussion and Conclusions

Temporal Trends of OCs in Air at Alert (1993-2009)

Heptachlor epoxide, a- and g-HCH showed consistent and continuous declining trends from 1993 to 2009. Lindane (consists of almost pure g-HCH) has been included in the Stockholm Convention of POPs for global control as of May 2009. Canada, a major user of lindane in North America, has deregistered its use on canola seeds in July 2001 and a ban was introduced in 2004 (Becker et al. 2008). It is apparent that the air concentration decline of lindane in Arctic air has accelerated between 2002 and 2009 (t1/2, 02–09=3.9 y) compared to between 1993 and 2001 (t1/2, 93–01=7.3 y). A slightly decreasing trend for a-endosulfan was observed at Alert for the first time in 2006-2009 with a halflife of 6.1 years (2002-2009). Such a trend is further confirmed by the FTS measurements (Figure 2). The results given by the two sampling techniques both show similar values and declining trends. In 2010, the U.S. EPA announced that all uses of endosulfan in the U.S. will be cancelled and it was just added to the Stockholm Convention in 2011, with exemptions listed for India and Uruguay. Endosulfan is scheduled to be phased out in the U.S. and Canada by 2016 (Federal Register, 2010; Health Canada Pest Management Regulatory Agency, 2011). It can be expected that the air concentrations of a-endosulfan would continue to decline in the Canadian Arctic after the ban.

No discernable declining trends were found for trans-chlordane and cis-nonachlor in air at Alert. Cis-chlordane and trans-nonachlor showed extremely slow declining trends (halflives of 20 and 74 years, respectively, from 2002-2009). This observation is consistent with the fact that technical chlordane has been banned for almost 20-30 years in most western industrialized countries; the decline in air concentrations might have started to level off.

DDT-related compounds were usually found at low levels at Alert. Consistent long-term trends were usually not distinguishable in Arctic air.

Table 1. First order apparent halflives of various POPs at Alert

OCs	1993-2001[a]		2002-2009	
	$t_{1/2}$ (y)[b]	r^2	$t_{1/2}$ (y)[b]	r^2
HCB	N.D.	-	21	0.67
α-HCH	5	0.81	6.1	0.99
γ-HCH	7.3	0.71	3.9	0.92
trans-chlordane	4.9	0.82	N.D.	-
cis-chlordane	6.7	0.75	20	0.24
trans-nonachlor	5.1	0.89	74	0.029
cis-nonachlor	4.4	0.71	N.D.	-
α-Endosulfan	62	0.024	6.1	0.77

a Halflives are reported for Alert between 1993 and 2001 before the laboratory change. See text for details.
b t1/2=halflife, calculated as ln 2/slope. Compounds that do not show a consistent declining trend (i.e. greatly fluctuating or steady or slightly increasing trends) are indicated as N. D. = not determinable

Field Evaluation of a Flow-through Sampler for Measuring Pesticides and Brominated Flame Retardants in the Arctic Atmosphere

A flow-through sampler (FTS) was co-deployed with a superhivol between October 2007 and November 2008 to evaluate its ability to determine the ambient concentrations of pesticides and FRs in the Canadian High Arctic atmosphere (Xiao et al., 2012). Nine pesticides and eight FRs, including three PBDE replacement chemicals, were frequently detected in the samples. Atmospheric concentrations determined by the two systems showed good agreement. Concentrations for pesticides are normally within a factor of 3 of each other. The FTS tends to generate higher PBDE concentrations than the superhivol presumably because the former's configuration does not prevent the entrainment of blowing snow/ice crystals or large particles. Taking into account uncertainties in analytical bias, sample volume and breakthrough estimations, the FTS is shown to be a reliable and cost-effective method, which derives seasonally variable concentrations of semivolatile organic compounds (SVOCs) at extremely remote locations that are comparable to those obtained by conventional high volume air sampling. Moreover, the large sampling volumes captured by the FTS make it suitable for the screening of new and emerging chemicals in the remote atmosphere where concentrations are usually low. This type of sampler is currently deployed at the Little Fox Lake station, Yukon, to determine atmospheric concentrations of SVOCs in the western Canadian Arctic.

This project provides long-term time series of organic pollutants in air at Alert for evaluating temporal trends of atmospheric contaminant input, to determine contaminant source regions and to validate global long-range transport models. The measurements re-started at Little Fox Lake using the FTS allow for the assessment of long-range transport from the Pacific rim to the western Canadian Arctic. With the addition of emerging priority chemicals, e.g. PFCs, CUPs and FRs, to the target analytical list, this project provides data to demonstrate the probability of Arctic contamination as a result of long-range transport, which is one of the criteria for enlisting a chemical as a POP that may be subjected to global control. Measurements will continue at Alert and Little Fox Lake in 2013/14.

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; and to the Canadian Forces Station Alert for supporting data collection. 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 au lac Little Fox

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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. Trend analysis reveals there to be less of a decreasing trend in the high Arctic than at more southerly locations. Mercury continues to show a distinct seasonal drop in gaseous elemental mercury (GEM) in the spring. Seasonal patterns in shorter-lived mercury species (reactive gaseous mercury, or RGM, and particle-bound mercury, PHg) have been analyzed with patterns in mercury deposited in snowfall events. This analysis has shown a peak in PHg during early spring and a peak in RGM in late spring, with

Résumé

Le mercure (Hg) est un polluant d'intérêt 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). 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. On observe toujours une diminution saisonnière distincte du mercure élémentaire gazeux (MEG) au printemps. Les schémas saisonniers des espèces de mercure à vie courte (mercure gazeux réactif, ou MGR, et mercure particulaire, Hgp) ont été analysés avec ceux du mercure déposé lors des chutes

the highest snow Hg concentrations reported in late spring. GEM measurements continue to be collected in the Yukon at Little Fox Lake but more years of data are still required to produce a valid trend.

de neige. Cette analyse a révélé un pic de Hgp au début du printemps et un pic de MGR à la fin du printemps, et la plus forte concentration de Hg dans la neige a été détectée à la fin du printemps. On continue à mesurer le MEG au Yukon, au lac Little Fox, mais il faudra recueillir des données sur plusieurs années encore pour définir une tendance valable.

Key Messages

- Eighteen years of atmospheric mercury measurements at have been collected at Alert, Nunavut and five years of atmospheric mercury measurements have been collected at Little Fox Lake, Yukon.
- The long term measurements are done to establish levels over time and predict future trends in long range transport of mercury to these Arctic regions
- Time trends of these data were compared to other Arctic, sub-Arctic and mid-latitude sites and showed that the levels of GEM in the Arctic have not gone down as much as the non-Arctic levels
- Analysis of RGM and PHg measurements at Alert reveal that PHg is the dominant short-lived species in early spring while RGM dominates in late spring. The highest levels of Hg in snow are most often in May.

Messages clés

- Le mercure atmosphérique est mesuré depuis 18 ans à Alert, au Nunavut, et depuis 5 ans au lac Little Fox, au Yukon.
- Les mesures à long terme servent à établir les concentrations au fil du temps et à prédire les tendances futures concernant le transport du mercure sur de longues distances vers ces régions arctiques.
- Les séries chronologiques de valeurs mesurées ont été comparées à celles d’autres sites des régions arctique, subarctique et de latitude moyenne, et les résultats révèlent que la concentration de MEG a moins diminué dans l’Arctique que plus au sud.
- L’analyse des mesures du MGR et du Hgp à Alert révèle que le Hgp est l’espèce à courte vie qui prédomine au début du printemps, tandis que le MGR prédomine à la fin du printemps. C’est généralement en mai que la neige contient les plus fortes concentrations de Hg.

Objectives

- Establish long-term baseline concentrations, patterns and trends of mercury in the Canadian high Arctic air. This information will be crucial in the development of Canadian strategies for national and international pollution control objectives such as through the UNEP Minamata Convention on 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 provides long term data on the temporal trends and contributes to understanding the spatial variability of mercury in the High Arctic air and assesses 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 (Streets et al., 2011). 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. Alert is a coastal site and thus is subject to intense atmospheric chemical reactions in the springtime that convert Hg in the air so that it can more easily deposit to surfaces. Alert also reports increased levels of GEM in the summer season (a unique feature to the high Arctic). Neither of these phenomena is 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. 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 2012-2013

Research activities

Ground-based continuous atmospheric measurements of GEM, reactive gaseous mercury (RGM) and particulate mercury (PHg) continued at Alert. Site visits for maintenance and calibration of all mercury instruments at Alert were made in April and November 2012, on top of regular checks by the onsite operator. Continuous measurements of GEM at Little Fox Lake were also carried on through 2012-2013. Through a partnership with P. Roach and the Yukon College, the contractors visit the LFL site on a weekly basis to check the instrument, download the data and do minor repairs to the instrument on site. Site visits from Environment Canada technicians for instrument maintenance/replacement, supplies, and calibrations were made in February and September 2012.

Data from both sites have been reviewed and finalized through the end of 2011 for all species and submitted to the Canadian National Atmospheric Chemistry (NAtChem) database and the Arctic Monitoring and Assessment Programme (AMAP). The data for 2012 have been collected and processed through the quality control program and are awaiting finalization before submitting to NAtChem and AMAP. Monthly reviews of all atmospheric mercury data were initiated in July 2012 to assist in noting and correcting instrumental issues as they arise.

Snow samples continued to be collected on weekly samples (ground) and on a per event basis (table). All snow samples collected up to the end of 2011 have now been analysed in the laboratory; 2012 samples are currently stored pending analysis at NWRI.

Long-term trends of mercury species at Alert, including speciated mercury, were included in a 2013 journal publication comparing long-term GEM trends at Arctic sites with those at mid-latitude sites (Cole et al., 2013). The results showed that GEM in Arctic air has not been decreasing as quickly as GEM at lower latitudes, with some reasons proposed for the difference including changes in ocean-atmosphere exchange. This paper also included the first publication of trends in RGM and PHg, reporting increases in these species during the springtime.

A comparison of data quality control protocols for atmospheric mercury speciation measurements was published in 2012 (Steffen et al., 2012) and used the Alert data and Alert data protocols to assess the comparability of the US and Canadian networks. These protocols will be proposed to be used for effectiveness evaluation for monitoring under the Minimata agreement.

Analysis of a small set of particulate samples for different isotopes of Hg - a project led by collaborator B. Berquist (U. of Toronto) - determined that the method needs improvement but that we can collect enough sample to measure different Hg isotopes in PHg.

Results from Alert and Little Fox Lake have also been included in atmospheric mercury chapters in two recent national assessment reports. The third Canadian Arctic Contaminants Assessment Report (CACAR III) published in Spring 2013, and the Canadian Mercury Science Assessment (atmospheric chapter) has been externally reviewed and is expected to be published in late 2013 or early 2014.

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. In May 2012, project P.I.s Hayley Hung and Sandy Steffen participated in a Whitehorse Air Quality Workshop and presented on our NCP work conducted at the Little Fox Lake station.

The workshop was attended by representatives from the EC Pacific and Yukon Region, the Yukon Government, Government of the Northwest Territories and local communities. The workshop was followed by a field trip to the Little Fox Lake station by workshop participants. We travelled to Iqaluit in January 2013 to give a guest lecture at the Arctic College and discuss future collaborations. In February 2013, we presented a lecture at Yukon College in Whitehorse. We continue to work with the Yukon college for data collection and storage efficiencies and for the development of a mercury passive sampling project.

Communications

With the assistance of Natalie Plato and Gayle Kabloona, we distributed the Alert communication brochures to 73 organizations in 27 communities in Nunavut. Also, while in Whitehorse in February 2013 we presented a public lecture at the Beringia Centre which was advertised in the Yukon News. When possible, our work is disseminated to the media and others as requested. For example, a Research Note titled "Toxic Contaminant Measurements in Arctic Air" by Hayley Hung, Alexandra Steffen and Amanda Cole was published in the fall issue of *Northern Public Affairs* to inform the public about recent findings under these two NCP projects.

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 have 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 1 shows a comparison of time series of GEM at six sites, including two Arctic and one sub-Arctic, along with the trend line for 2000-2009. The time series of GEM at Little Fox Lake is shown in Figure 2. Figure 3 shows the average annual patterns of RGM, PHg, and the mercury in tabletop snow samples (normalized to the area covered by the sample) for all data collected to the end of 2011. Discussion of these results follows.

Discussion and Conclusions

In recent years, it has become clear that GEM concentrations in the air at Alert have decreased since the start of continuous measurements in 1995 (Cole and Steffen, 2010). We recently published a paper (Cole et al., 2013) comparing time trends in GEM from 2000 to 2009 at Alert, another Arctic site at Ny-Alesund, Spitsbergen, Norway, a sub-Arctic site at Kuujjuarapik, QC, Canada, and three mid-latitude Canadian sites at St. Anicet (Québec), Kejimkujik (Nova Scotia) and Egbert (Ontario). As shown in Figure 1, it was found that mercury levels in the Arctic did not decrease as quickly as levels at the sub-Arctic and mid-latitude sites. Further, the two Arctic sites also differed from the other sites in that these trends varied by season, with mercury concentrations in some months increasing over the decade. Seasonal processes that uniquely affect mercury in the Arctic air, such as springtime oxidation chemistry and summer emissions from the increasingly open Arctic Ocean, may be changing at the same time as global mercury emissions and may account for the differences reported between the Arctic and other locations. The paper also presented trends in RGM and PHg at Alert, showing increases in both compounds during the spring when concentrations are highest, however the analysis is limited by the shorter data set (2002-2009) and high variability from year to year. Further monitoring of trends in oxidized mercury will aid in determining the cause of the long-term changes in mercury in Arctic air and whether deposition into the ecosystem is increasing or decreasing.

Figure 1: Long-term trends in GEM at six sites. Monthly median concentrations are shown along with the calculated trend lines. The value of each trend line, with confidence intervals, is also given for each site.

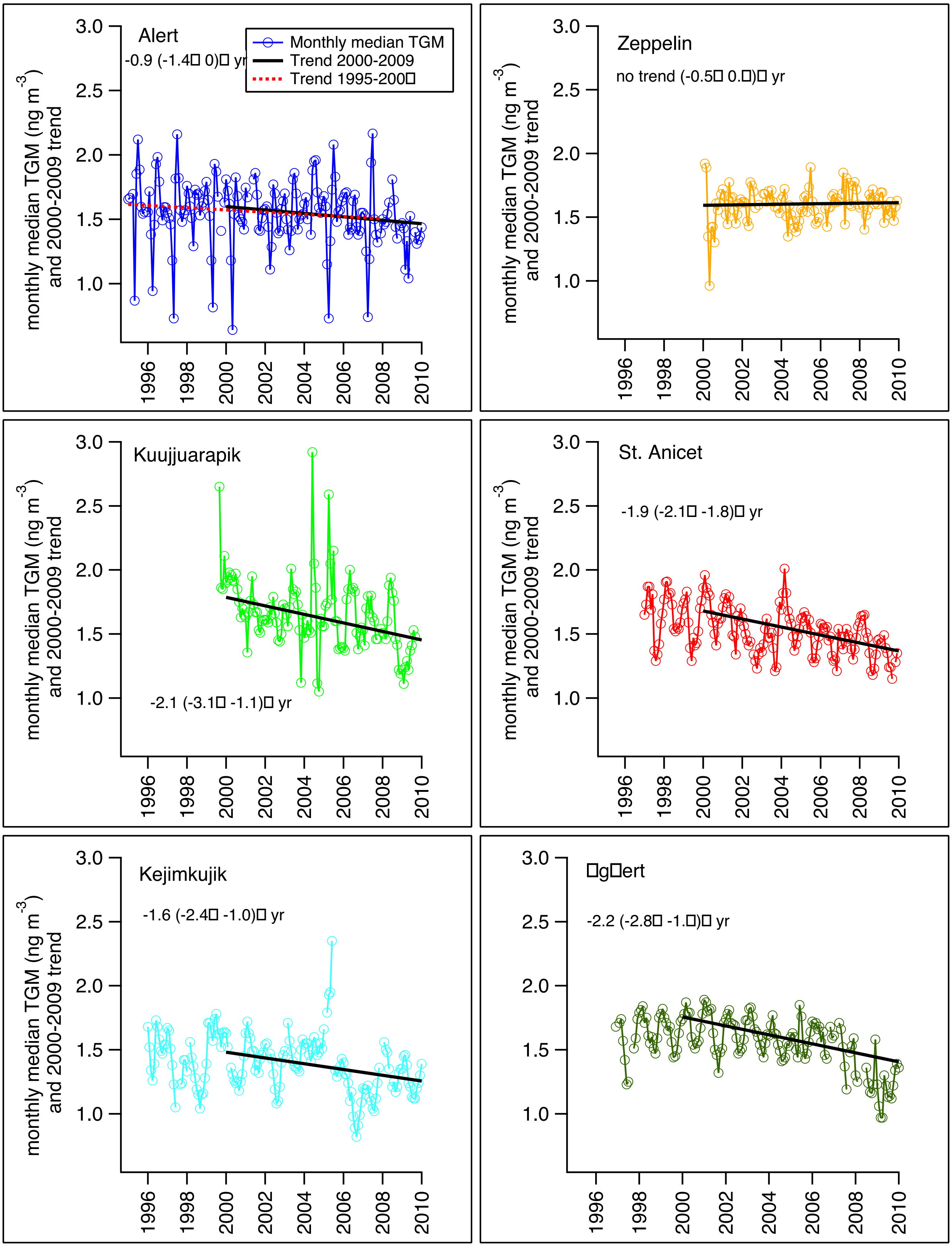


Figure 2: Hourly (red line) and mean monthly (black squares) GEM concentrations at Little Fox Lake, Yukon. Concentrations for 2012 are not finalized and are therefore shown in fainter colours.

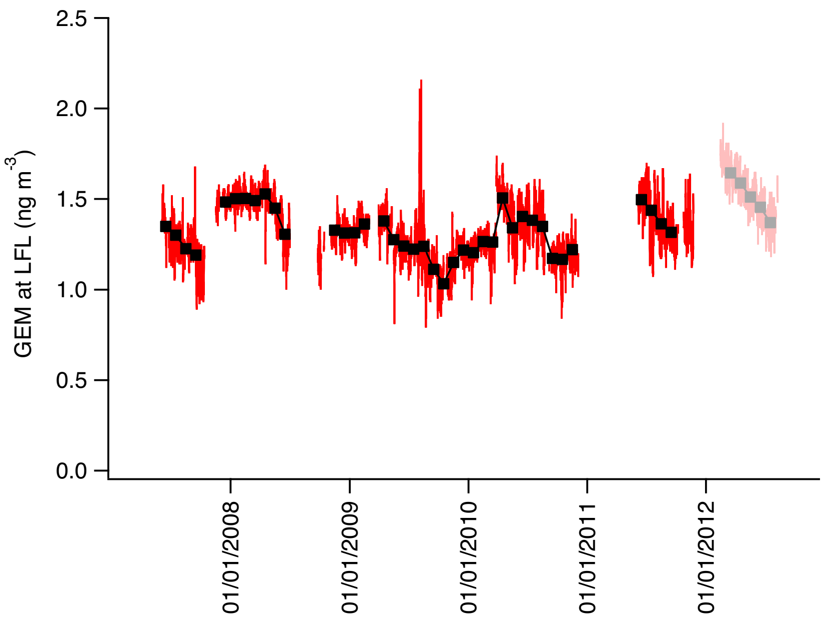
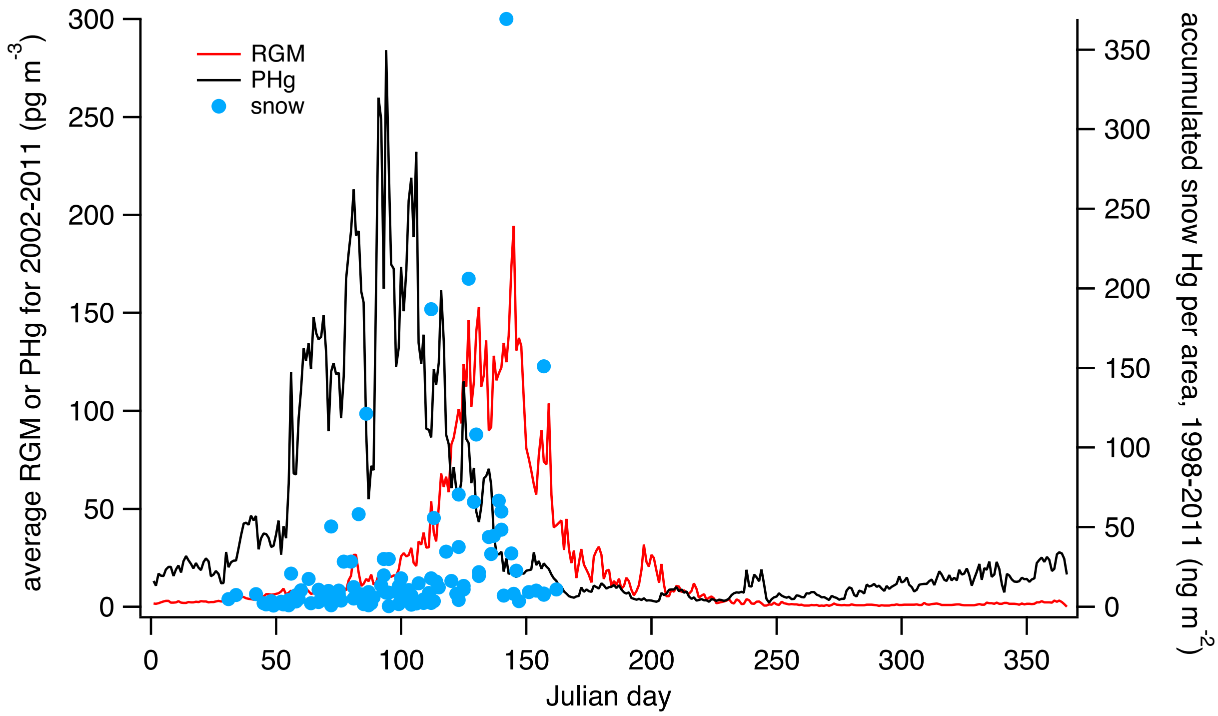


Figure 3: All RGM, PHg and collected snow data at Alert. RGM and PHg data are averaged by Julian day. RGM and PHg data averaged from 2002 to 2011 and snow from 1998 to 2011.



Continued monitoring at Little Fox Lake, which is not subject to AMDEs nor as affected by Arctic sea ice changes, will also help determine how much of the trend is due to these processes compared to how much is due to changes in global emissions and transport to the Arctic. The current record of GEM at Little Fox Lake now covers almost 5 years (Fig. 2). Because there are some gaps in the record due to technical issues, this is not quite enough to establish a trend. Ongoing monitoring at this site will continue to provide crucial validation data for mercury transport and deposition models in this undersampled area. The existing data also establish a baseline for GEM concentrations before the implementation of the UNEP Minamata Convention on Mercury.

The long record of speciation data at Alert was also analyzed in depth this year, with a manuscript describing the results currently in preparation. The analysis examines correlations between meteorological data, particle measurements, speciated mercury concentrations, and mercury in surface snow. For example, pooling the data from 2002 to 2011 for RGM and PHg has revealed a consistent seasonal pattern in which PHg dominates in late winter and early spring, while RGM dominates in late spring and early summer (Fig. 3). Also shown in Fig. 3 are measurements of the total amount of mercury collected from a sampling table during various snow events between 1998 and 2011 and sorted by Julian day. Though deposition amounts vary widely, the long time series of these measurements allows us to discern an overall pattern where the highest amounts of mercury in fresh snow occur in May, roughly coincident with the switch from PHg-dominant to RGM-dominant oxidized mercury. The mechanism for this timing is currently being explored through this analysis.

Expected Project Completion Date:

Ongoing

Acknowledgements

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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 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 2012 samples were collected by local hunters in the communities of Arviat, Nain, Resolute and Sachs Harbour. Chemical measurements were combined with results from previous years, including samples archived from the 1970s to examine the trends over time and geographical differences. Average mercury concentrations in seal liver collected

Résumé

Le présent projet a pour but de déterminer, chez le phoque annelé, les changements de concentrations de mercure et d'anciens contaminants, comme les BPC et d'autres polluants organiques persistants (POP). Tout l'échantillonnage est effectué avec l'aide de comités de chasseurs et de trappeurs dans chacune des collectivités visées, auxquelles on remet des trousses d'échantillonnage et des instructions à cet égard. En 2012, des échantillons ont été prélevés par des chasseurs dans les collectivités d'Arviat, de Nain, de Resolute et de Sachs Harbour. Des mesures chimiques ont été combinées aux résultats d'années antérieures, incluant des échantillons

in 2012 were similar to measurements made in previous years. However mercury in seal muscle has declined significantly at Arviat and Resolute since the mid 2000s. Trends of flame retardant chemicals in seal blubber varied among locations; they declined at Arviat but continued to increase in samples from Resolute and Sachs Harbour. Fluorinated chemicals also declined in seals from Arviat and Resolute but continued to increase slowly at Sachs Harbour.

prélevés à partir des années 1970, pour examiner les tendances au fil du temps et les différences géographiques. Les concentrations de mercure moyennes mesurées dans le foie des phoques en 2012 étaient similaires aux concentrations mesurées au cours des années antérieures. Les concentrations de mercure dans les muscles des phoques ont cependant diminué de manière significative à Arviat et à Resolute depuis le milieu des années 2000. Les tendances des concentrations de produits ignifugeants dans la graisse de phoque ont varié d'un endroit à l'autre; ces concentrations ont diminué à Arviat, mais ont continué d'augmenter à Resolute et à Sachs Harbour. Les composés fluorés ont également diminué dans les échantillons de phoque prélevés à Arviat et à Resolute, mais ont continué d'augmenter lentement à Sachs Harbour.

Key messages

- Mercury in seal muscle has declined significantly at Arviat and Resolute since the mid 2000s
- Trends of brominated and fluorinated chemicals, as well as legacy POPs such as PCBs are not the same across the Canadian arctic.

Messages clés

- Les concentrations de mercure dans les muscles des phoques ont diminué de manière significative à Arviat et à Resolute depuis le milieu des années 2000.
- Les tendances varient dans l'Arctique canadien en ce qui concerne les concentrations de composés bromés, de composés fluorés et d'anciens POP tels que les BPC.

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. The 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, Nunatsiavut, 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.

Our 2011-12 report focused on trends of “legacy POPs” and mercury in muscle. In this report we summarize trends in mercury and cadmium as well as BFRs and PFCs.

Activities in 2012-13

Sample collection

In 2012 ringed seal samples were successfully collected by hunters in the communities of Arviat (N=25), Sachs Harbour (25), Resolute Bay (N=25) and Nain (13). 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 -20oC and then shipped frozen to Burlington for processing. Large subsamples of all tissues were archived in walk-in freezers at -20 oC in sealed plastic bags (double bagged).

In 2012 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 2013 as part of communication and consultations. In February/ March 2013, project summaries were also sent to the Chair of the Nunavut Niqiit Avatitinni Committee.

Chemical analyses

Methodology for organochlorine pesticides (OCPs), PCBs, polybrominated diphenyl ethers (PBDEs) and PCNs and coplanar PCBs in seal blubber was changed in 2012. Analyses of OCPs and PCBs in the 2011 and 2012 samples was contracted to ALSGlobal (Burlington ON). Extraction and cleanup procedures followed the same general procedure as in previous years. Tissue samples were spiked with 13C12-PCB-133- prior to extraction. The tissues were mixed with anhydrous sodium sulphate and Soxhlet extracted overnight with dichloromethane (DCM). The extracts were cleaned by gel permeation chromatography to remove lipids and reduced to a 1mL final volume in DCM. A separate 50uL portion of each extract was removed for both OCP and PCB analyses. A suite of 13C labeled PCBs was added to the PCB extracts for target analyte quantification and retention time references. Similarly a suite of deuterium and 13C- labeled OCPs was added to the OCP extracts prior to instrumental analysis for target quantification. Sample extracts were then analysed directly by GC-high resolution mass spectrometry (GC-HRMS) for OCPs and by GC-Low resolution MS) for PCB congeners. All data were recovery corrected for extraction and clean up losses relative to 13C12 PCB-133 response. The suite of OCPs and PCBs analysed was identical previous suite analysed by the National Laboratory for Environmental Testing (NLET) organics lab.

PCNs were also determined by ALS Global by GC-HRMS on the same extracts. The raw DCM extract was cleaned with acid/silica followed by alumina column chromatography. The cleaned extracts were concentrated to small volume (40uL in toluene) prior to the addition of a 5uL solution of 13C- labeled PCN extraction standards. These final extracts were analyzed by GC/HRMS for 68 of the 75 possible PCN congeners. PBDEs and other PFRs as well as toxaphene and endosulfan isomers were analysed on the remaining extract using GC-negative ion LRMS by the NLET organics lab.

Total mercury in muscle was determined by Direct Mercury Analyser using EPA method 7473 (US Environmental Protection Agency 2007).

PFCs in liver were analysed for perfluorinated alkyl acids in the Muir labs at Environment Canada (Burlington) as described by Butt et al.(2008) with method modifications described in Mueller et al.(2011). Instrumental analysis was performed by liquid chromatography-tandem MS (LC-MS/MS) as described in Butt et al. (2008).

Thirty-two elements were determined in liver by Inductively Coupled Plasma- Mass spectrometry (ICP-MS) (NLET 2002). In brief, liver (1 g) was digested with nitric acid and hydrogen peroxide (8:1) in a high pressure microwave oven at 200 °C for 15 minutes. The digest was then analysed directly by ICP-MS. Mercury was analyzed from the same digest by using cold vapor atomic absorption spectrometry. Mercury II was reduced to elemental mercury in an automated continuous flow system by using stannous chloride.

Quality assurance and statistical analysis

Both NLET labs and ALSGlobal are certified by certified by Canadian Standards Association and have participated in the NCP Interlab comparisons. ALSGlobal Laboratory Group, Environmental Division in Burlington also participated succesfully in Phase 6 of the NCP QA program and submitted data for PBDEs, OCPs, PCBs, and PCNs to Phase 7 of the program.

PFCs were determined in the Muir lab at Environment Canada Burlington. This lab has participating in international interlab comparisons 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 log10 transformed to give coefficients of skewness and kurtosis <2 and geometric means (back transformed log data) were calculated. Temporal trends of PCBs, OCPs and PBDEs 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 2012 requested information on gender, girth, length, blubber thickness was provided for 80 of 88 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 and cadmium

Concentrations of mercury in seal muscle have declined significantly at Arviat and Resolute from the mid-2000s. At Resolute the decline (2004-2012) is 12 %/yr (significant at P=0.034) and at Arviat it is 8.9 %/yr (P=0.019). There is also an apparent decline at Sachs Harbour from 2006 to 2012 but this was not tested statistically due to limited sampling years. No change is evident at Nain but again fewer sampling years were available.

Mercury concentrations in seal liver continue to vary within a relatively narrow range at Resolute, Arviat and Nain and show no significant trends over time (Figure 1). A Sachs Harbour, liver mercury has declined from a high level in 2005. However, with limited sampling years (no seals were received in 2008 and 2009) we are waiting for additional data before assessing the trend statistically.

Cadmium concentrations in seal liver varied over a relatively narrow range at Sachs Harbour, Resolute and Nain but dropped sharply between 2011 and 2012 at Arviat. Further annual sampling at Arviat will be needed to assess whether this drop is part of a declining trend. Seal length (Figure 1) and carbon and nitrogen isotope ratios at Arviat (ages not yet available for 2012) did not change very much from 2011 so the drop in cadmium remains unexplained for the moment.

Trends of Legacy POPs

Measurement of all organic contaminants continued in 2012-13 but results for PCBs and other chlorinated organics including organochlorine pesticides, toxaphene, endosulfan, chlorinated paraffins and PCNs in samples collected in 2012 are pending. Temporal trends of legacy POPs to 2011 using the PIA program (Bignert 2007). As in previous years results from nearby communities were combined because most PCB/OCs concentrations were similar for nearby communities while differing significantly among regions (see footnote in Table 1). For 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 (-2.7 to -7.3 %/yr) > α-HCH (-1.9 to 9.2%/yr) > Σ10PCB (-0.54 to -5.4 %/yr). Declines were most rapid in Hudson Bay animals and least in the Beaufort Sea samples (Table 1). The trends of Σ10PCB, ΣDDT, ΣCHL and toxaphene in the Beaufort (Sachs Harbour/Ulukhaktok) were not statistically significant. Toxaphene also showed no trend at Resolute over the period 1972 to 2011 and concentrations have actually increased at Resolute over the period 2009 to 2011.

Trends of Newer POPs

Other contaminants determined in ringed seal blubber include those listed in the Stockholm Convention (Penta- and Octa-brominated diphenyl ethers), as well as a large suite of brominated flame retardant (BFR) chemicals.

Two newer BFRs routinely analysed in the project include the hexabromo-cyclododecane (HBCDD) and 1,2-Bis(2,4,6-tribromo-phenoxy) ethane (BTBPE). Consistent detections of HBCDD and BTBPE have been made since 2006. Overall, concentrations of HBCD have increased from 45 to 162 %/yr and BTBPE from 16 to 38%/yr during the period 2006-2011 (Table 1). These increases are not statistically significant because they reflect considerable variation among individual animals and levels close to detection limits.

ΣPBDEs (sum of congeners 17, 28/33, 47,49, 66, 85, 99, 100, 153, 154, 183, 190) have generally increased in the southern Beaufort (+9.2 %/yr) and in Lancaster Sound (10 %/yr) but are declining in Hudson Bay (-7.4% from 2002 to 2011, although the trend is not statistically significant (Table 1).

PFOS concentrations continue to decline in seals from Lancaster Sound and Hudson Bay over the period 2003 to 2011 after previous rapid increases (Butt et al. 2007). ΣPFCAs (sum of perfluorononanoic acid to perfluorodecanoic acids) are also declining in Lancaster Sound (-18 %/yr) and in Hudson Bay (-7.0 %/yr; not statistically significant) (Table 1). In the southern Beaufort Sea samples both PFOS and ΣPFCAs continue to increase (3.6 and 3.0 %/yr, respectively) 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 suggesting for the first time that concentrations have declined significantly since the mid-2000s. However, no decline was found for mercury in liver. Concentrations in liver are of special interest due to the recent advisory based on the Inuit Health Survey (Nunatsiaq online 2012). The decline of mercury in seal muscle at Resolute differs from observations mercury in eggs of thickbilled murre and northern fulmar at Prince Leopold Island in Lancaster Sound. The seabirds there may feed in the same marine waters as the seals. Mercury concentrations appear to have leveled off in these seabirds but currently show no significant declining trend (Braune et al. 2013).

Hunters are reporting earlier ice breakup and this may be influencing the diet of the seals. Gaden et al. (2009) reported that ringed seals attained higher mercury in muscle in short (2 months) and long (5 months) ice-free seasons. 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 HBCDD and BTBPE, 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. The results also show the effect of bans and phase outs of the PBDEs and PFOS, which are both declining in Hudson Bay. However, trends for these newer POPs as well as for legacy POPs vary widely across the Canadian arctic. Differences between the Beaufort Sea and the Hudson Bay animals are particularly striking as illustrated by declining β-HCH, PBDEs and PFOS in Hudson Bay and increases in the Beaufort animals. This may reflect the importance of ocean transport not only for HCHs but also for other contaminants as well as food web differences as has been noted for mercury in polar bears (St. Louis et al. 2011).

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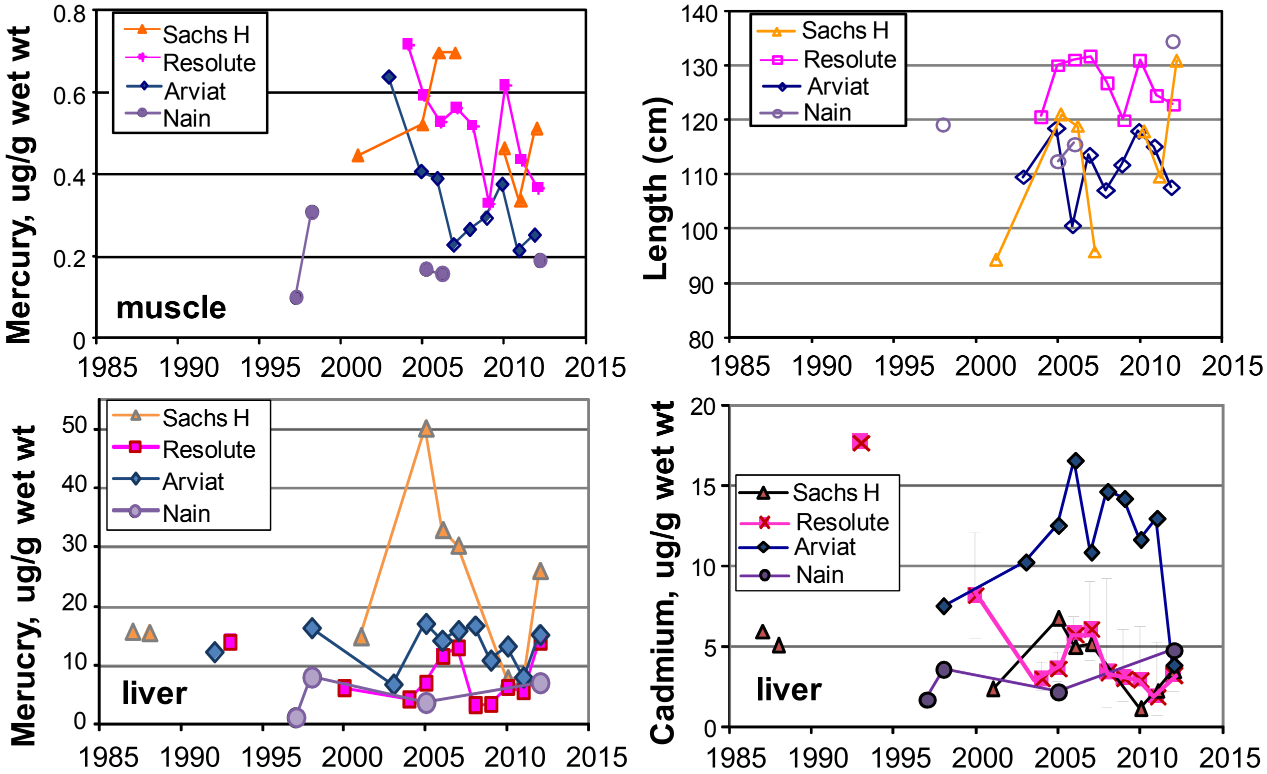

Figure 1. Time trends of mercury in seal muscle and liver and cadmium in liver along with average length of the seals from Sachs Harbour, Resolute, Arviat, and Nain. Symbols represent geometric mean concentrations for animals ≥5yrs of age. Error bars are omitted for clarity.

Table 1. Time trends of POPs in female ringed seals – statistically significant % annual change in bold

Region [1]	yrs [2]		a-HCH	b-HCH	HCB	S10PCB	SDDT	SCHL	Toxa-phene	SPBDE (02-11)	HBCDD (07-11)	BTBPE (06-11)	PFOS (02-11)	PFCAs (02-11)
Hudson Bay	13	%/yr	-9.2	-2.7	-2.8	-5.4	-7.3	-7.4	-6.1	-7.4	+100	+16	-9.0	-7.0
1986-2011		R^2	0.78	0.10	0.52	0.58	0.71	0.65	0.64	0.27	0.16	0.27	0.26	0.23
Lancaster	17	% /yr	-4.3	+4.5	-0.87	-2.2	-3.0	-1.2	+0.30	+10	+162	+19	-21	-18
1972-2011		R^2	0.61	0.57	0.18	0.48	0.65	0.17	0.01	0.24	0.94	0.49	0.56	0.70
Beaufort Sea	8	% /yr	-1.9	+5.4	-0.86	-0.54	-2.7	+0.32	-1.8	+9.2	+45	+38	3.6[3]	3.0[3]
1972- 2011		R^2	0.31	0.85	0.41	0.06	0.41	0.01	0.19	0.90	0.54	0.50	0.35	0.63

1 Hudson Bay = Arviat + Inukjuaq; Lancaster = Resolute Bay + Arctic Bay + Grise Fiord; Beaufort Sea = Sachs Harbour + Ulukhaktok (2001, 2006, 2010)

3 Sachs Harbour PFOS and PFCAs for the period 1972 to 2011

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 food web. Legacy and emerging contaminants were monitored, as well as new POPs discovered, in the liver or fat of polar bears collected in 2012-2013 from the two territorial management zones in southern and western Hudson Bay in Nunavut. This contaminant monitoring is ongoing and focuses on inter-year temporal trends over the longer term. As of 2011, for western Hudson Bay bears, generally the levels for SPCBs, SDDTs, SCHLs, a-HCH, b-HCH and SClBzs are similar to those in samples from 2007. That is, in 2011 SPCBs and SCHLs continue to remain at high ppm levels, SClBzs

Résumé

L'ours blanc (Ursus maritimus) est le superprédateur de l'écosystème et du réseau alimentaire marins de l'Arctique. Les contaminants anciens et émergents, ainsi que les nouveaux polluants organiques persistants (POP) découverts dans le foie ou la graisse d'ours blancs abattus en 2012 et 2013, font l'objet d'une surveillance dans deux zones de gestion territoriale du sud et de l'ouest de la baie d'Hudson, au Nunavut. Cette surveillance est continue; elle est axée sur les tendances temporelles à long terme d'une année à l'autre. En 2011, pour les ours de l'ouest de la baie d'Hudson, la SBPC, la SDDT, la SCHL et la SClBz, ainsi que les niveaux de a-HCH et de

remained at the 200 to 400 ng·g-1 (lipid weight (lw)) levels, SDDTs and a-HCH continue to decline, and b-HCH continues to follow an increasing concentration trend. Based on two- and three-point temporal comparisons back to 2001-2002, the levels for S4PBDEs in the southern Hudson Bay bears appears to have decreased. For western Hudson Bay the S4PBDE levels are roughly unchanged. Our analysis of 2011 fat samples from Hudson Bay bears showed that BDE-209 and eighteen non-PBDE replacement BFRs were almost completely non-detectable. Generally, the levels for PFOS in both the western and southern Hudson Bay bears appears to have decreased in 2011 relative to 2007-2008. We presently conclude that as of 2011 international regulations are effective as legacy and emerged (i.e. PBDE and PFOS) POP levels continue not to be increasing or appear to be decreasing in polar bears from Hudson Bay and other Canadian subpopulations, relative to historical levels.

b-HCH, étaient en général semblables à ceux relevés dans les échantillons prélevés en 2007. En d'autres termes, en 2011, les SPCB et les SCHL (en ppm) ont continué d'être élevées, la SClBz est demeurée entre 200 à 400 ng g-1 (poids des lipides [pl]), la SDDT et le niveau de a-HCH ont continué à diminuer, et le niveau de b-HCH a continué à suivre une tendance à la hausse. D'après des comparaisons temporelles de deux points et de trois points à partir de 2001-2002, la S4PBDEs chez les ours du sud de la baie d'Hudson semble avoir diminué. Dans le cas des ours de l'ouest de la baie, la S4PBDE est demeurée à peu près inchangée. Notre analyse des échantillons de graisse prélevés en 2011 chez des ours de la baie d'Hudson a révélé que le BDE209 et 18 PIB de remplacement sans PBDE étaient presque complètement non décelables. En général, les niveaux de PFOS chez les ours du sud et de l'ouest de la baie d'Hudson semblent avoir diminué en 2011 par rapport à 2007-2008. Nous avons actuellement conclu que la réglementation internationale est efficace car les niveaux de POP (c.àd. PBDE et PFOS) anciens et émergents continuent de ne pas augmenter ou semblent en baisse chez les ours blancs de la baie d'Hudson et d'autres sous-populations canadiennes par rapport aux niveaux historiques.

Key Messages

- As of 2011, for western Hudson Bay bears, generally the levels for SPCBs, SDDTs, SCHLs, a-HCH, b-HCH and SClBzs are similar to those in samples from 2007.
- As of 2011, SPCBs and SCHLs continue to remain at high ppm levels, SClBzs remained at the 200 to 400 ng·g-1 lw levels, SDDTs and a-HCH continue to decline, and b-HCH continues to follow an increasing concentration trend.
- Based on two-point temporal comparisons, 2011 and 2007-2008, the levels for S4PBDEs in the southern Hudson Bay bears appears to have decreased, and for western Hudson Bay the S4PBDE levels are roughly unchanged.
- Generally, the levels for PFOS in both the western and southern Hudson Bay bears appears to have decreased in 2011 relative to 2007-2008.

Messages clés

- En 2011, les SPCB, les SDDT, les SCHL, les SClBz et les concentrations de aHCH et de bHCH chez les ours de l'ouest de la baie d'Hudson étaient semblables à celles chez les échantillons prélevés en 2007.
- En 2011, la SPCB et la SCHL (en ppm) sont demeurées à des niveaux élevés, la SClBz est demeurée entre 200 à 400 ng g-1 pl, la SDDT et le niveau de aHCH ont continué de diminuer, alors que le niveau de b-HCH a continué à suivre une tendance à la hausse.
- D'après des comparaisons temporelles de deux points (2011 et 2007-2008), la S4PBDE chez les ours du sud de la baie d'Hudson semble avoir diminué, alors que chez les ours de l'ouest de la baie, elle demeure à peu près inchangée.
- En général, les niveaux de PFOS chez les ours du sud et de l'ouest de la baie d'Hudson semblent avoir diminué en 2011 par rapport à 2007-2008.

Objectives

- To determine the spatial and ongoing inter-year temporal trends of legacy and emerging POPs (e.g., flame retardants (FRs) and perfluoroalkyl substances (PFASs)) 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) 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 screen and determine new and emerging, chlorinated, brominated and/or fluorinated POPs that may bioaccumulate in polar bears. Such POPs may persist in the tissues of polar bears but are not necessarily listed as a NCP, LRTAP or Stockholm Convention priority POP. New POPs may also include congeners, isomers and/or precursors and degradation products.

Introduction

Mercury (Hg) and a growing array of chlorinated, brominated and fluorinated persistent organic pollutants (POPs), since the late 1800s and 1960s, respectively, have proven to be anthropogenic contaminants that have been transported to the Arctic and accumulate in biota (AMAP 2004; Letcher et al. 2010). These bioaccumulative POPs (and/or their precursors and degradation products) and Hg are transported via global atmospheric and/or oceanic pathways and processes that result in deposition in the Arctic, and are found in Arctic endothermic top predators, and in particular in polar bears. Most known legacy and emerging POPs are lipophilic to some degree, and because lipids constitute an important energetic factor in polar marine food chains, POPs are biomagnified in the long Arctic marine food chains. As a result, POP and Hg levels are very high in polar bears in spite of their relatively high ability to bio-transform compounds via liver enzymatic processes, which can lead to excretion but also to the formation of POP metabolites (AMAP 2010, 2011; Letcher et al. 2010; McKinney al. 2011a; Routti et al. 2011, 2012; Gebbink et al. 2008; Verreault et al. 2005).

Polar bears are distributed throughout the circumpolar region, have unquestionable importance to northerners both culturally and economically, and thus provide important sentinel or monitoring species for legacy and emerging POPs and Hg. The fact that levels of POPs are generally high in the polar bear, and are an ideal wildlife receptor for the biomonitoring of spatial and temporal trends, distribution, dynamics, fate, biomagnification and potential effects of Hg and legacy and emerging POPs.

Based on samples collected up to the early to mid-2000s, several investigations and assessments compiled temporal and spatial data on levels of legacy organochlorine compounds (OCs) in polar bears. Whereas levels of some legacy POPs such as PCBs seem to decrease (Verreault et al. 2005), a number of emerged environmental pollutants, such as polybrominated diphenyl ethers (PBDEs) and perfluoroalkyl substances (PFASs; in particular the highly bioaccumulative perfluorooctane sulfonate (PFOS)) were reported, and in some cases for the first time, in the liver, fat and other tissues of polar bears (Greaves et al. 2012, 2013; Muir et al. 2006; Smithwick et al. 2005, 2006; Dietz et al. 2008). Temporal trends up the mid-2000s had predicted that tissue concentrations of e.g. PBDE and PFOS would continue to rise into future years.

Arctic ecosystems face multiple challenges at local and regional scales, among them changes and the potential stress of changes in climate and exposure to anthropogenic chemical contaminants proven to be POPs. More recently the warming of the Arctic has been signaled by loss of multi-year sea ice and thawing of permafrost and accelerated coastal erosion (Olsen, 2011). The significance of the conversion of ice to water is that it affects physical and biogeochemical pathways of POPs and other contaminants. This results in an alteration of animal behaviour such as habitat use and diet as well as ecosystem structure including the introduction of new species and loss of existing species of biota. More recent research has shown that Arctic warming and changes in sea-ice means change in exposure to POPs and Hg to Arctic biota and particularly in the polar bear (i.e. Canadian Hudson Bay and East Greenland subpopulations) (Dietz et al. 2013a, 2013b; McKinney et al. 2009, 2010, 2013; Gaden et al. 2009).

Among polar bear sub-populations, we have shown that the relative effect of dietary differences versus the regional geographical influence the legacy and emerged POP accumulation and exposure patterns and in particular for Hudson Bay (McKinney et al. 2011b). Dietary variation between Alaska, Canada, East Greenland, and Svalbard subpopulations was assessed by muscle nitrogen and carbon stable isotope (δ15N, δ13C) and adipose fatty acid (FA) signatures relative to their main prey (ringed seals). Western and southern Hudson Bay signatures were characterized by depleted δ15N and δ13C, lower proportions of C20 and C22 monounsaturated FAs and higher proportions of C18 and longer chain polyunsaturated FAs. East Greenland and Svalbard signatures were reversed relative to Hudson Bay. Alaskan and Canadian Arctic signatures were intermediate. Subpopulation dietary differences predominated over inter-annual, seasonal, sex, or age variation. Among various brominated and chlorinated contaminants, diet signatures significantly explained variation in adipose levels of polybrominated diphenyl ether (PBDE) flame retardants (14-15%) and PCBs (18-21%)

(McKinney et al. 2011b). However, dietary influence was contaminant class specific, since only low or nonsignificant proportions of variation in OC pesticide (e.g., chlordane (CHL)) levels were explained by diet. Hudson Bay diet signatures were associated with lower PCB and PBDE levels, whereas East Greenland and Svalbard signatures were associated with higher levels. We concluded that understanding diet/food web factors in polar bears is important to accurately interpret contaminant trends, particularly in a changing Arctic.

Based on fat samples collected over the period of 1991-2007, we also recently showed linkages between changes in sea-ice, dietary changes and organohalogen compound (OHC) contaminant patterns for legacy OCs and newer PBDE POPs in polar bear from the western Hudson Bay subpopulation. In McKinney et al. (2009), we reported on recent changes in feeding ecology (1991-2007) in polar bears from the western Hudson Bay subpopulation that have resulted in increases in the tissue concentrations of several chlorinated and brominated contaminants. Differences in timing of the annual sea ice breakup explained a significant proportion of the diet variation among years. As expected from climate change predictions, this diet change was consistent with an increase in the consumed proportions of open water-associated seal species compared to ice-associated seal species in years of earlier sea ice breakup.

From 2007 and up to the present 2012-2013 period, the monitoring activities of this NCP project continue to examine the inter-year temporal trends of various legacy, emerging and recently discovered POPs and Hg (and other trace metals/elements) in western and southern Hudson Bay polar bears.

Activities in 2012-2013

Sample collections and analysis

In addition to having a valid 2012 Nunavut Wildlife Research Permit (NWRP), in late 2012, we successfully applied for and obtained a 2013 Nunavut Wildlife Research Permit (NWRP) for polar bear sample collections during the harvests in western and southern Hudson Bay. The 2012 and 2013 NWRPs were evaluated in collaboration with communities via the Nunavut Department of Environment (NDE; M. Dyck and A. Coxon). In late winter/early spring 2012, from the quota of permitted polar bear harvests, fat, liver and muscle tissue samples were obtained from n=10 southern Hudson Bay bears and n=10 western Hudson Bay bears.

Analytical methods

For the sample sets collected in 2012, we very recently completed the analysis of various POPs currently being monitored (e.g., PCBs, DDTs, CHLs, ClBzs, HCHs, PCP, PBDEs, various other FRs (e.g. OPFRs), PFASs and Hg (and other elements/metals) in fat or liver samples). Legacy POPs were determined according to NWRC Method No. MET-CHEM-OC-06B. Analyses of the 14 standard PBDE congeners and various other HFRs including total-α-HBCD were carried out according to NWRC Method No. NWRC-MET-OCRL-BFR-ver. 7 (May 2010). PCP was determined according to Method No. MET-ORGRES-multi-residue-OHC-08. PFASs were determined according to NWRC Method No. MET-ORGRES-PFC-08. For DP-like, norbornene derivatives, fat samples were analyzed by Dr. Reiner's lab at the Ontario Ministry of the Environment (OMOE) in Toronto. SCCP screening and quantification are currently underway in Dr. Sverko's lab at EC's NLET in Burlington, ON. Quality assurance/ quality control (QA/QC) is monitored by NWRC Laboratory Services and the OCRL. Both the NWRC and the OCRL laboratories have participated in the NCP's QA/QC Program (recent NCP III-Phase 7 round in 2012-2013). FA analyses were completed by Lab Services, NWRC. The analysis of SIs of nitrogen and carbon for the recently collected liver and muscle samples are currently being 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 2013, which is done by the Nunavut Department of Environment (A. Coxon, M. Dyck).

Capacity building

Starting in 2009, Dr. Letcher had previously established with Dr. S. Atkinson (Government of Nunavut, Dept. of Environment) a 5-year Agreement of Cooperation and Contribution, which embodies this research Environment Canada-Government of Nunavut partnership. In 2012-2013, this project cooperated in building expertise in scientific sampling during the late winter/early spring 2012 harvests in Hudson Bay. In this research year, the four participating communities and HTOs were directly involved and led in the organization and collection of fat, liver and muscle samples. As detailed in the valid 2012 NWRP, and in cooperation with Markus Dyck and Angela Coxon in the Department of Environment, Government of Nunavut, Dr. Letcher arranged and sent directly to Angela Coxon 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. These sampling kits were distributed to the participating communities. For the hunters in each community, and via the HTO, each sampling kit 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).

Communications

For new POP data that had become available in 2012-2013, presentations and dissemination were not possible for the 2012 NCP Results Workshop. This workshop was to be held in Inuvik, NWT, and in late September 2012, but was cancelled. Numerous oral or poster presentations were made in 2012-2013 as listed in the NCP performance indicator section. With the completion of journal publications and reports, 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 and the NAC. The PI also made every reasonable effort to communicate in person with the RCC representatives and COs and hunters in each participating community.

In 2012-2013, the PI was committed to travel to at least one Nunavut community in 2012-2013 to interface with our major northern research partner (M. Dyck) and individuals in the NDE (e.g., A. Coxon), and to communicate study findings and discuss with community and HTO representatives. Although it was not possible to arrange such a visitation to a Hudson Bay/ Nunavut community, in spring 2013, the PI did travel to the Cambridge Bay and Gjoa Haven communities in Nunavut. Letcher joined Dr. Peter van Coeverden de Groot (Dept. of Biology, Queens University). Letcher met with many community leaders, hunters and HTO members in both communities. In Gjoa Haven, Letcher gave a presentation on Arctic contaminants in wildlife to the Gjoa Haven HTO, and to grade 7 to 12 students and teachers at the Gjoa Haven school. Both presentations were well received and with much discussion, and thus was an effective and important outreach and communication activity. Letcher, or when necessary via M. Dyck or A. Coxon, continued to circulate any copies of presentations, reports or journal papers to the NAC.

Annual reports of the results to date are made to the NCP each year and results will continue to be published in peer-reviewed scientific journals. Several papers were published in 2012-2013, including on PFASs and precursors and tissue distribution studies in the whole body and brain of polar bears (see Greaves et al. 2012, 2013), multi-decadal temporal trends of PCBs, OCs and PBDE in East Greenland bears (Dietz et al.

2013a, 2013b), and also spatial trends and the influence of carbon and lipid source in the diet on Hg and other trace elements in bears from Alaska, Canadian Arctic and East Greenland (McKinney et al. 2013, Routti et al. 2011, 2012).

Traditional knowledge

It can be a challenge to incorporate new traditional knowledge on an annual basis into an ongoing contaminants monitoring program, and in particular for polar bears. However, as in past sampling for this core monitoring project, the 2012-2013 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 HTOs 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. It should be noted that polar bears are consuming country food at similar trophic levels as people in the communities. The inclusion of traditional knowledge has also facilitated the researcher's/PI's understanding of changing trends (diet and habitant), despite the link to shared resources (e.g. contaminant exposure from seal). This supports a two-way integration of knowledge. As mentioned, in spring 2013, Letcher travelled to the Cambridge Bay and Gjoa Haven communities. With Dr. Peter van Coeverden de Groot, Letcher joined three Inuit hunters on a snowmobile trek to Gateshead Island in the M`Clintock Channel and about 300 km north of Cambridge Bay. Although there has not been a polar bear harvest quota for Cambridge Bay since 2002, the purpose of this trek was to ferry building supplies and bear hair and feces sampling materials. This gave Letcher the opportunity to learn and directly communicate with Inuit hunters who know and have experiences in the field and with polar bears.

Results

Temporal trends of legacy POPs in Hudson Bay polar bears

The 1991-2007 temporal trends of the geometric mean concentrations (lw corrected) of ΣPCBs, ΣDDTs, ΣCHLs, α-HCH, β-HCH and ΣClBzs in the fat of polar bears from western Hudson Bay are shown in Figure 1. These data were published recently in McKinney et al. (2009, 2010). New concentration data is also shown for 2011-collected fat samples. We only recently completed sample analysis for 2012-collected samples and thus this and other POP data cannot be reported at this time. Data generation has also been completed for fat and liver samples collected in 2009 and 2010, and will be presented in 2013-2014 as part of a more resolved inter-year assessment of temporal trends.

Spatiotemporal trends of emerged POPs in Canadian polar bears

Over eleven years and up until 2011, two- and three-point temporal comparisons were examined of the geometric mean concentrations (lw corrected) of Σ_4PBDE in fat (Figure 2) and PFOS in liver (Figure 3) of polar bears from seven Canadian subpopulations. For BDE-209 and for eighteen non-PBDE replacement BFRs, these were almost completely non-detectable in the 2011-collected fat samples from all Hudson Bay bears. Thus, based on the sensitivity of our method, the levels are these non-PBDE BFRs are sub-ppb if accumulated at all. As of 2011, generally the levels (wet weight (ww) corrected) for PFOS in both the western and southern Hudson Bay bears appears to have decreased (Figure 3).

Targeted and new POPs discoveries in Hudson Bay polar bears

Polar bear fat and liver sample pairs from 2011-collected polar bears from the southern Hudson Bay were screened for a suite of fifteen organophosphate flame retardants (OPFRs) using the method of Chen et al. (2012). That is, tris(2-chloroethyl)phosphate (TCEP), tripropyl phosphate (TPrP), tris(2-chloroisopropyl) phosphate (TCPP), tris(1,3-dichloro-2-propyl) phosphate (TDCPP), triphenyl phosphate (TPP), tris(2,3-dibromopropyl)phosphate (TDBP), tributyl phosphate (TBP), tricresyl phosphate (TCP), 2-ethylhexyl-diphenyl phosphate (EHDPP), tris(2-butoxyethyl) phosphate (TBEP), tris(2-bromo-4-methylphenyl)phosphate (T2B4MP), tris(4-bromo-3-methylphenyl)phosphate (T4B3MP), tris(3-bromo-4-methylphenyl)phosphate (T3B4MP), tris(2-ethylhexyl)phosphate (TEHP), tris(tribromoneopentyl)phosphate (TTBP).

Both the liver and fat samples contained low- to sub-ppb (wet weight (ww)) concentrations of TCEP, TCPP, TBP, TPP and/or TBEP. Detection and quantification was much less frequent in the fat relative to the liver sample pairs. TCPP and TBEP were at the highest levels at 7.2±8.2 and 4.8±5.1 ng·g-1 ww, respectively, in the fat, and 3.7±3.4 and 5.6±4.5 ng·g-1 ww, respectively, in the liver. There were no obvious fat to liver ratio relationships for any quantifiable OPFR.

Hudson Bay fat samples collected in 2011, were screened for several DP-like, norbornene derivatives, as well as re-analyzed for syn- and anti-Dechlorane Plus (DP) flame retardant and structurally related mirex and photomirex. Similar to the OCRL analysis, syn- and anti-DP were not detectable in any of these samples. However, DP-602 and DP-603 were quantifiable and at levels of 2.5±2.4 and 0.3±0.2 ng·g-1 lw, respectively. These concentrations were the same as those of the legacy POP mirex (2.8±2.5 ng·g-1 lw) and a little less than that of photomirex (11±9 ng·g-1 lw).

Discussion and Conclusions

As of 2011, for western Hudson Bay bears, generally the levels for SPCBs, SDDTs, SCHLs, a-HCH, b-HCH and SClBzs are similar to those in samples from 2007 (Figure 1) (McKinney et al. 2009, 2010, 2011c). That is, in 2011 SPCBs and SCHLs continue to remain at high ppm levels, SClBzs remained at the 200 to 400 ng·g-1 lw levels, SDDTs and a-HCH continue to decline, and b-HCH continues to follow an increasing concentration trend. We also previously examined temporal trends of levels and congener patterns of PCBs, OCs, PBDEs, and emerging HBCD, PBBs and other current-use BFRs, both on an individual and sum-(Σ-) contaminant basis in bear fat samples from western Hudson Bay (McKinney et al. 2010). Over this longer-term 17-year period (1991-2007), ΣDDT also decreased (−8.4%/year), α-HCH also decreased −11%/year, β-HCH also increased +8.3%/year, and ΣPCB and ΣCHL, both contaminants at highest concentrations in all years, also showed no distinct trends, and even when compared to previous data for this subpopulation dating back to 1968 (Norstrom et al. 1998). ΣClBz levels also did not significantly change over the 1991-2007 period.

As we reported in McKinney et al. (2010) for western Hudson Bay bears, increasing Σ4PBDE levels (+13%/year) over the period of 1991-2007 matched increases in the four consistently detected congeners, BDE-47, BDE-99, BDE-100 and BDE-153. Our present findings for 2011, and based on two- and three-point temporal comparisons back to 2001-2002 (from McKinney et al. 2011c; Muir et al. 2006), the levels for S4PBDEs in the southern Hudson Bay bears appears to have decreased (Figure 2). For western Hudson Bay the S4PBDE levels are roughly unchanged, which appears to be a change from the upward trend up to 2007 that we reported in McKinney et al. (2010). The downward trend of the Hudson Bay bears is consistent with the general decreasing S4PBDE level trend for all subpopulations in 2007-2008 relative to 2001-2002 (Figure 2). Furthermore and overall, S4PBDE concentration in fat remain under 100 ng·g-1 lw, and are much lower compared to SPCBs and SCHLs (Figure 1).

Our analysis of 2011 fat samples from Hudson Bay bears showed that BDE-209 and eighteen non-PBDE replacement BFRs were almost completely non-detectable. For coincidentally analyzed non-PBDE BFRs and BDE-209, these 2011 findings are consistent with McKinney et al. (2011c), where thirty-seven PBDE congeners, HBCD, two PBBs, pentabromotoluene, pentabromoethylbenzene, hexabromobenzene,

Figure 1. Temporal trends of the geometric mean concentrations (+95% CI) of legacy PCBs and organochlorines in fat tissue of polar bears from western Hudson Bay and collected in 1991-2007 (McKinney et al. 2009, 2010) and 2011 (light blue bars, this study). The 2011 data is not corrected for sex, age or diet (if applicable).

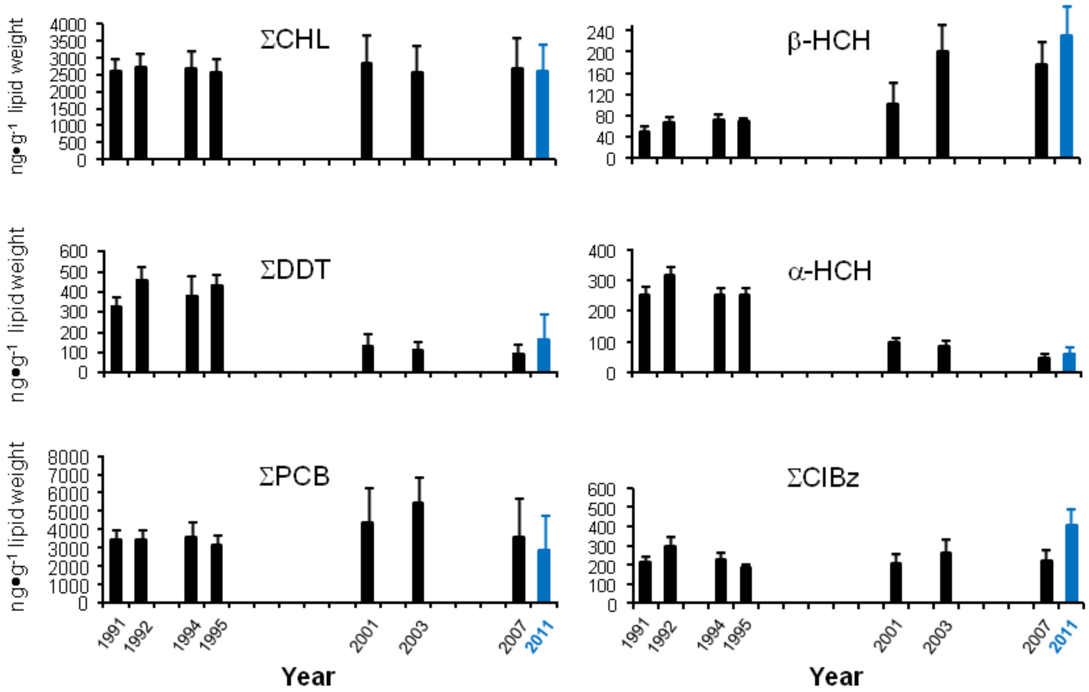
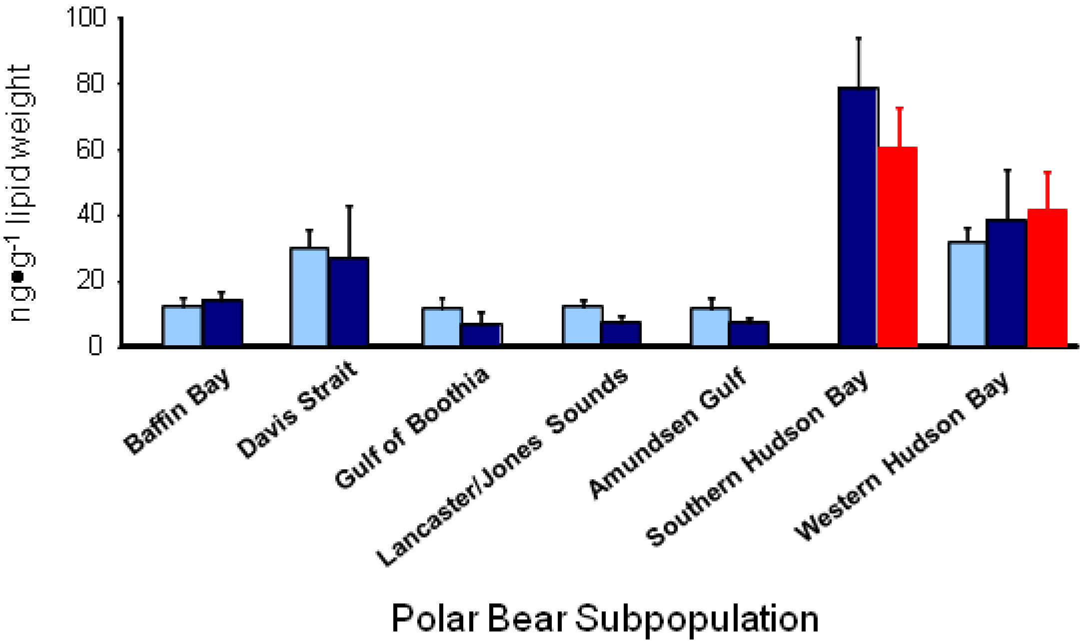


Figure 2. Two- and three-point temporal comparisons of the geometric mean (+95% CI) concentrations of Σ4PBDE (sum of BDE-47, -99, -100 and -153) in fat of seven polar bear subpopulations between 2001-2002 (light blue bars, Muir et al. 2006; southern Hudson Bay data not available), 2007-2008 (dark blue bars, McKinney et al. 2011a), and 2011 (red bars, this study; and only for western and southern Hudson Bay). The 2011 data is not corrected for sex, age or diet (if applicable).



1,2-bis (2,4,6-tribromophenoxy(ethane) and decabromodiphenyl ethane were screened, but only four PBDE congeners (BDE-47, -99, -100 and -153), HBCD and BB153 were consistently found. Polar bears possess a relatively high ability (compared to other Arctic mammalian and avian wildlife) to bio-transform compounds including bioaccumulative POPs via liver enzymatic processes, which can lead to excretion but also to the formation of POP metabolites, e.g. oxychlordane from cis- and trans-chlordane and MeSO2-PCBs from PCBs (Letcher et al. 2010; Gebbink et al. 2008; Verreault et al. 2005). Metabolism and rapid depletion and/or metabolite formation has also be shown for BFRs such as BDE-209 and decabromodiphenyl ethane (DBDPE) in an in vitro microsomal depletion assay based on polar liver (McKinney et al. 2011a), and also for recent PBDE replacements such as α- and β-isomers of 1,2-dibromo-4-(1,2-dibromoethyl) cyclohexane (TBECH) using a similar mammalian (rat) microsome based in vitro assay (Chu et al. 2012).Thus, it is likely that many of the non-PBDE BFRs that could bioaccumulate in polar bears from their prey diet (e.g. ringed seals), are not highly persistent in bears due to efficient metabolism by polar bears. As reported in McKinney et al. (2011c) for Canadian subpopulations, geometric mean ΣPBDE and BB153 levels were highest in East Greenland, Svalbard and western and southern Hudson Bay. This is consistent with our present 2011 findings for southern Hudson Bay (Figure 2). McKinney et al. (2011c) also reported that ΣPCB and ΣCHL levels were high relative to BFRs as well as other legacy contaminants, again consistent with our 2011 findings for Hudson Bat bears (Figure 1).

Generally, the levels for PFOS in both the western and southern Hudson Bay bears appears to have decreased in 2011 relative to 2007-2008, and also relative to 2001-2002 for the southern Hudson Bay subpopulation only (Figure 3). Like S4PBDEs (Figure 2), this is consistent with the general decreasing trend for all subpopulations where PFOS decreased in 2007-2008 relative to 2001-2002 (Letcher et al. 2009; Houde et al. 2011). This is a departure from the increasing trends for PFOS for Baffin Bay and East Greenland bears (liver) up to the early to mid-2000s (Smithwick et al. 2005, 2006; Dietz et al. 2008). It was concluded in the mid-2000s that for temporal trends, (liver) tissue concentrations of PFOS would continue to rise into future years.

We presently conclude that international regulations continue to be effective as legacy and emerged (i.e. PBDE and PFOS) POP levels continue not to be increasing or appear to be decreasing in polar bears from Hudson Bay and other Canadian subpopulations, relative to historical levels. However, slow or stalling declines of certain historic pollutants like PCBs, and the complex mixture of "new" chemicals continue to be of concern with respect to polar bear exposure and health, and that of their arctic marine ecosystems. For example, our finding in Hudson Bay bears of low but persistent levels of OPFRs and DP 602 and DP 603.

Expected Project Completion Date:

This is an ongoing monitoring program and a core NCP biomonitoring project.

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Mercury in from the Arctic; status in 2013

La situation du mercure dans l'Arctique en 2013

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Abstract

Samples of liver, kidney, muscle and muktuk of beluga whales collected in 2011 or 2012 were analyzed for total mercury and selenium. Levels of mercury remained similar to ranges established in previous years. Of the organs analyzed in this study, liver typically had the highest concentrations of mercury, followed by kidney, muscle and muktuk. For example, the mean concentration of total mercury in 29 liver samples of beluga from Hendrickson Island in 2012 was 27.3 ± 27.0 $\mu g \cdot g^{-1}$ while that of muktuk from the same animals was 0.59 ± 0.18 $\mu g \cdot g^{-1}$. Data from these samples were added to the growing database on concentrations of these elements in organs of arctic marine mammals. The database now contains information on

Résumé

Les concentrations de mercure total et de sélénium dans des échantillons de foie, de reins, de muscles et de muktuk de béluga prélevés en 2011 ou 2012 ont été analysées. Les concentrations de mercure sont semblables aux plages du paramètre établies au cours des dernières années. 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. Par exemple, la concentration moyenne de mercure total dans 29 échantillons de foie prélevés en 2012 chez des bélugas de l'île Hendrickson s'élevait à 27,3 ± 27,0 µg g-1 alors que celle dans le muktuk des mêmes animaux s'élevait

over 1300 arctic beluga from several locations over the period from 1977 to 2012. Mercury content varies among species, among individual animals, and among organs within an animal. This variation makes rigorous detection of differences among animals, places and times statistically difficult. Detection of differences among samples is further complicated by the fact that mercury accumulates with age so that older animals usually have higher levels than younger ones from the same location. Consequently comparison of mercury levels among different groups of beluga requires adjustment for differing ages; accurate age data are essential. The additional samples obtained each year improve the chances of detecting differences if they are real and reduce the chances of reporting apparent differences if they are not real. Usually the chemical analyses are completed prior to the age determinations and so there is a lag in interpretation of the data.

à 0,59 ± 0,18 µg g-1. Les données issues de ces échantillons ont été ajoutées à la base de données sans cesse grandissante sur les concentrations de ces éléments dans les organes de mammifères marins de l'Arctique. La base de données contient maintenant de l'information sur plus de 1 300 bélugas de l'Arctique capturés à plusieurs endroits au cours de la période allant de 1977 à 2012. Le contenu en mercure varie entre les espèces, entre les individus et entre les organes d'un animal. Vu cette variation, la détection rigoureuse de différences entre les animaux, les lieux et les périodes est difficile sur le plan statistique. Le fait que le mercure s'accumule au fil du temps dans l'organisme des animaux, ce qui fait que les individus âgés présentent habituellement des niveaux plus élevés que les jeunes animaux d'un même lieu, vient compliquer davantage la détection de différences entre les échantillons. Par conséquent, la comparaison des niveaux de mercure chez les différents groupes de bélugas demande un rajustement du fait des différences d'âges et des données précises sur l'âge sont essentielles. Les échantillons additionnels prélevés chaque année améliorent les chances de détecter des différences si elles sont réelles et réduisent les chances de signaler des différences apparentes si elles ne sont pas réelles. Habituellement, les analyses chimiques se font avant la détermination de l'âge, ce qui entraîne un délai dans l'interprétation des données.

Key Messages

- New data were obtained on total mercury and selenium in organs of beluga from Hendrickson Island, Kendall Island, Paulatuk, Arviat and Sanikiluaq.
- Mean concentrations of total mercury in liver of the whales from the Mackenzie Delta exceeded 25 µg·g-1 while those from Paulatuk averaged 16.8 µg·g-1. The comparable values for liver from Arviat and Sanikiluaq were 12.7 µg·g-1 and 11.8 µg·g-1 respectively.

Messages clés

- De nouvelles données sur les niveaux de mercure total et de sélénium dans les organes de bélugas de l'ile Hendrickson, de l'île Kendall, de Paulatuk, d'Arviat et de Sanikiluaq ont été recueillies.
- Les concentrations moyennes de mercure total dans le foie des bélugas du delta du Mackenzie dépassaient 25 µg g-1 alors que celles des individus de Paulatuk s'élevaient en moyenne à 16,8 µg g-1. Les niveaux pour les bélugas d'Arviat et de Sanikiluaq se situaient à 12,7 µg g-1 et 11,8 µg g-1 respectivement.

- Concentrations of total mercury in liver were much higher than those in the other organs analyzed. The second highest concentrations were found in kidney, followed by muscle and muktuk.
- Concentrations of selenium often correlated with those of mercury. Evidence is growing indicating that the complex between mercury and selenium is a means by which the toxicity of mercury is reduced. Normally selenium and mercury are present in roughly a 1:1 atomic ratio but selenium in muktuk was in much higher excess over mercury.

- Les concentrations de mercure total dans le foie étaient beaucoup plus élevées que celles dans les autres organes analysés. Les reins venaient au deuxième rang, suivis des muscles et du muktuk.
- Les concentrations de sélénium étaient souvent corrélées à celles de mercure. Il devient de plus en plus évident que le complexe entre le mercure et le sélénium est un moyen par lequel la toxicité du mercure est réduite. Le sélénium et le mercure sont normalement présents dans un rapport atomique d'environ 1:1, mais la concentration de sélénium dans le muktuk était de loin supérieure à celle du mercure.

Objectives

- To provide incremental information on concentrations of mercury and selenium in organs of beluga, narwhal and walrus from selected locations in the Canadian Arctic
- To present new data in the context of previous data from the same species and locations
- To maintain a database of this information that will enable the more rigorous assessment of temporal and spatial changes of mercury in these animals

Introduction

Interest in levels of mercury in arctic marine mammals derives from; 1) Mercury in these unique animals as examples of mercury as a global pollutant AND; 2) Dietary intakes of mercury by northern people who consume these animals and the possible health implications for the people. Recently a new factor has been discovered, namely a linkage between exposure to mercury in young adulthood and the development of diabetes later in life (He et al., 2013); this will likely foster additional interest in the intakes of mercury by northern people.

The levels of mercury in several organs of marine mammals from the Canadian Arctic have been relatively high (Wagemann et al. 1996; Lockhart et al. 2005), exceeding levels in commercial fish analyzed by the Canadian Food Inspection Agency. Health Canada has published an updated evaluation of the risks of mercury in fish for human health (Health Canada, 2007) but Health Canada did not address consumption of marine mammals. One table (Appendix III, Health Canada 2007) lists species of fish for which at least some individuals have levels over 0.5 µg·g-1. If the marine mammal organs reported here were to be included in the Health Canada tables, they would fall in this group with levels over 0.5 µg·g-1. However, mercury in fish is almost all in the toxic form of methylmercury; in marine mammals that is not the case. Recent analyses have shown that marine mammals organs vary in the way they store mercury; in liver, kidney and brain only about one quarter of the mercury is methylmercury but in muscle, most of it is methylmercury (Lemes et al, 2011).

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). Sediment core studies in arctic lakes (Hermanson, 1993; Lockhart et al., 1998) have suggested that mercury inputs have increased over the past few decades but those studies do not discriminate between inputs due to imported mercury transported by the air and inputs due to mercury already in watersheds and mobilized by, for example, climate warming. Mercury has increased in teeth from modern beluga from the Mackenzie Delta but not in teeth of walrus from Igloolik (Outridge et al., 2002). Previously, Outridge et al. (2000) showed that mercury in teeth correlates with those in liver, kidney, muscle and muktuk, and so trends in teeth were likely mirrored by trends in other organs. It is not clear what proportion of the mercury supporting these increases derives from mercury already present in the Arctic or from mercury imported into the Arctic from elsewhere.

Several recent studies have suggested that decreased ice cover has resulted in altered feeding behaviour in some arctic marine mammal populations (Stern and Macdonald, 2005; Gaden et al., 2009; Gaden and Stern, 2010) and that this influences intakes of mercury. Loseto et al. (2008) have begun to look at biological variables that reflect feeding habits of Beaufort Sea beluga to help explain their mercury content.

Selenium often correlates with mercury in various organs of marine mammals and it is hypothesized to offer protection from mercury poisoning. Recent studies by Huggins et al. (2009) have described the forms of selenium in organs of beluga from the Mackenzie Delta. In liver, the amount of selenium present as HgSe ranged from 38 to 77 per cent, while in pituitary the range was 85 to 90 per cent. These authors suggested that HgSe can serve as a bioindicator of non-toxic mercury in these animals.

The raw data from this investigation have been produced at the Freshwater Institute and are archived in an Access database maintained within the project. The data currently comprise records of mercury and often selenium in organs of over 1300 arctic beluga, 285 walrus, 413 narwhal, 3 bowhead and over 1000 ringed seals.

Activities in 2012-2013

The NCP-funded activities have been mostly the analysis of the samples at the Freshwater Institute for total mercury and selenium. The project also provides partial support for collection/shipping of samples and for age determinations. All new samples reported this year were of Beluga whales collected at Hendrickson Island, Kendall Island, Paulatuk, Arviat or Sanikiluaq. These whales were taken by local hunters as part of their subsistence harvests and samples of body organs were collected by trained collectors present at the hunt.

Results

New samples of beluga were obtained and analyzed in 2012 and some ages for beluga reported previously also became available. The new data available for 2012 were:

- Age data on 18 beluga from Hendrickson Island in 2011
- Organ samples and ages of 29 beluga from Hendrickson Island in 2012
- Organ samples but no ages of 25 beluga from Kendall Island in 2011
- Organ samples but no ages of 16 beluga from Kendall Island in 2012
- Age data on 14 beluga of Paulatuk in 2005
- Organ samples and ages of 9 beluga from Paulatuk in 2011
- Organ samples and ages of 7 beluga from Paulatuk in 2012
- Organ samples but no ages of 16 beluga from Arviat in 2012
- Organ samples but no ages of 12 beluga from Sanikiluaq in 2012.

No new samples or age data for other species were obtained. The new information on ages, lengths and genders of beluga are shown in Table 1. A noteworthy aspect of these samples is the preponderance of males over females in most of the collections.

The mean concentrations (µg·g-1 wet weight) of mercury and selenium in liver, kidney, muscle and muktuk are listed in Tables 2 and 3 respectively.

Hendrickson Island 2012

Collections from Hendrickson Island are one of the most extensive with 367 samples from 16 collections taken every year since 1993 with the exception of a gap between 1996 and 2001. Ages were added for the Hendrickson Island beluga reported for 2011 and new samples were obtained from 29 whales in 2012. The mean level of mercury in liver samples in 2012 was 27.6 µg·g-1 (range 5.2 to 111.2 µg·g-1) (Table 2). The mean age of these same whales was 28.3 years. There was a significant statistical relationship between age and untransformed mercury levels in liver (r=0.56, p=0.002). Levels of mercury in kidney (mean 5.81 µg·g-1, range 1.18 to 19.5 µg·g-1) were much lower than those in liver. The relationship between age and mercury in kidney fell short of the usual criterion for statistical significance (r=0.34, p=0.072). Mercury in muscle was lower than that in liver or kidney with a mean concentration of 1.27 µg·g-1 (range 0.67 to 2.33 µg·g-1). In spite of the lower values in muscle, all of them still exceeded 0.5 µg·g-1, the concentration long used to regulate the sale of commercial fish in Canada. Mercury in muscle was not related statistically to the ages or lengths of the whales. Of the four organs analyzed, muktuk contained the lowest levels of total mercury with a mean of 0.59 µg·g-1 and a range of 0.29 to 0.99 µg·g-1. About two thirds of the samples (19 of 29) exceeded 0.5 µg·g-1.

Comparing mercury levels among the different organs, mean levels declined from liver to kidney to muscle to muktuk. A matrix of correlations among organs is shown in Table 4. There was no statistical relationship between mercury in liver and that in kidney but there were between liver and muscle and between liver and muktuk. Kidney mercury did not correlate to that in muscle and only weakly to that in muktuk. The strongest inter-organ statistical relationship was between muscle and muktuk (r=0.856, p=0.000000).

The relationships between mercury and selenium differed from organ to organ.

Selenium values in liver ranged from 3.81 to 39.4 6 µg·g-1 with a mean of 13.8 µg·g-1 (Table 3) and these correlated strongly to levels of mercury (r=0.91, p=0.000000). The average selenium concentration was 13.8 µg·g-1 which can be expressed as 0.175 µmol· g-1, taking the atomic weight of selenium as 78.96 µg·µmol-1. With an average mercury concentration of 27.6 µg·g-1, the corresponding micromolar concentration is 0.138 µmol g-1, taking the atomic weight of mercury as 200.59 µg·µmol-1. The molar ratio of selenium to mercury then was about 0.175/0.138 = 1.27. That is, on average the livers contained about 1.27 atoms of selenium for each atom of mercury. The levels of both mercury and selenium in kidney were lower but the correlation between them remained very strong (r=0.79, p=0.000001). The correlation between them was much weaker in muscle (r=0.32, p=0.094) where levels of both were again lower than in liver or kidney. The relationship between these elements was quite different in muktuk in which the average level of mercury was 0.59 µg·g-1 or 0.0029 µmol g-1 and the average level of selenium was 3.49 µg·g-1 or 0.0442 µmol g-1. In muktuk, then there were about 15 atoms (0.0442 /0.0029) of selenium for each atom of mercury. The correlation between mercury and selenium was negative (r = -0.30. p=0.120) although it fell short of statistical significance.

We have accumulated mercury measurements in 367 samples of liver from Hendrickson Island beluga on 16 occasions dating from 1993. Earlier collections are available from other locations nearby. For those specifically from Hendrickson Island, the highest mean value was 44 µg·g-1 in 1995 (N=18) and the lowest was 16.3 µg·g-1 in 2010 (N=20). A graph showing median values for mercury levels in these samples is shown in Figure 1. The median is a relatively

Table 1. New information on beluga whales added to the data archive in 2012/2013. Means are shown with standard deviations (SD) and the number of samples (N)

Location	Year	Age (years)			Length (cm)			Gender
		Mean	SD	N	Mean	SD	N	
Hendrickson	2011	25.3	6.32	18	402	20.7	18	17 M, 1 F
Hendrickson	2012	28.3	9.41	28	400	24.0	28	24 M, 4 F
Kendall	2011				386	27.5	25	14 M, 10 F
Kendall	2012				417	25.4	16	11 M, 5 F
Paulatuk	2005	17.1	7.27	13	364	66.3	14	12 M, 2 F
Paulatuk	2011	26	12.8	9	404	39.9	9	6 M,.1 F
Paulatuk	2012	27.7	6.97	7	431	32.1	7	7M, 0 F
Arviat	2012				380	63.5	12	12 M, 3 F
Sanikiluaq	2012				368	49.9	11	6M, 4 F
Missing data accounts for discrepancies in numbers of samples.								

Table 2. Concentrations of total mercury in organs of beluga for which some new data became available in 2012. Concentrations are shown in µg·g-1 wet weight followed by standard deviations and the number of samples (N).

Location	Year	Liver	Kidney	Muscle	Muktuk
Hendrickson	2011	25.7 ± 24.0 (18)	3.92 ± 2.69 (18)	1.21 ± 0.54 (18)	0.54 ± 0.25 (18)
Hendrickson	2012	27.3 ± 27.0 (29)	5.81 ± 3.26 (29)	1.27 ± 0.33 (28)	0.59 ± 0.18 (29)
Kendall	2011	26.1 ± 38.4 (25)		1.41 ± 0.82 (25)	
Kendall	2012	29.0 ± 28.7 (15)	5.06 ± 2.66 (16)	2.02 ± 1.46 (16)	0.74 ± 0.39 (16)
Paulatuk	2005	4.99 ± 3.66 (13)		0.66 ± 0.27 (13)	0.25 ± 0.13 (13)
Paulatuk	2011	9.51 ± 12.5 (8)		1.21 ± 0.53 (9)	0.46 ± 0.27 (9)
Paulatuk	2012	16.8 ± 13.5 (7)	3.27 ± 1.13 (3)	1.54 ± 0.56 (7)	0.65 ± 0.26 (7)
Arviat	2012	12.7 ± 10.3 (14)	4.94 ± 6.40 (13)	1.31 ± 0.96 (15)	0.48 ± 0.43 (12)
Sanikiluaq	2012	11.8 ± 9.44 (12)	3.61 ± 1.79 (12)	0.91 ± 0.40 (12)	0.45 ± 0.19 (12)

Table 3. Concentrations of selenium in organs of beluga for which some new data were obtained in 2012. Concentrations are shown in μg·g^{-1} wet weight followed by standard deviations and the number of samples (N).

Location	Year	Liver	Kidney	Muscle	Muktuk
Hendrickson	2011	13.2 ± 7.47 (18)	3.65 ± 1.40 (18)	0.36 ± 0.05 (18)	3.40 ± 1.01 (18)
Hendrickson	2012	13.8 ± 8.61 (29)	4.06 ± 1.14 (29)	0.36 ± 0.04 (29)	3.49 ± 0.85 (29)
Kendall	2011	14.8 ± 12.3 (25)		0.44 ± 0.05 (24)	
Kendall	2012	14.4 ± 8.64 (15)	4.31 ± 1.46 (16)	0.51 ± 0.37 (16)	4.11 ± 1.39 (16)
Paulatuk	2005				3.57 ± 0.61 (19)
Paulatuk	2011	7.19 ± 5.74 (8)		0.44 ± 0.07 (9)	4.37 ± 1.20 (9)
Paulatuk	2012	12.7 ± 7.80 (7)	3.51 ± 1.01 (3)	0.36 ± 0.06 (7)	3.56 ± 1.49 (7)
Arviat	2012	5.81 ± 3.27 (14)	3.06 ± 1.42 (13)	0.29 ± 0.04 (15)	3.73 ± 1.73 (12)
Sanikiluaq	2012	7.22 ± 3.44 (12)	3.24 ± 0.84 (12)	0.35 ± 0.07 (12)	2.56 ± 0.68 (12)

Table 4. Correlations among untransformed concentrations of mercury (μg·g-1 wet weight) in organs of 28 beluga whales from Hendrickson Island in 2012. Correlation coefficients (r) are given with probabilities that the correlations are due to chance in parentheses.

	Liver Hg	Kidney Hg	Muscle Hg	Muktuk Hg
Liver Hg	1.0	r = 0.287 (0.139)	r = 0.647 (0.000198)	r = 0.467 (0.0105)
Kidney Hg		1.0	r = 0.266 (0.172)	r = 0.351 (0.062)
Muscle Hg			1.0	r = 0.859 (0.000000)
Muktuk Hg				1.0

conservative statistic and visual inspection of the plot shows a number of statistical outside points but these have little influence on the medians. The data have not been transformed or adjusted for differing ages but there is no consistent trend obvious from this mode of presentation. A more detailed statistical analysis with adjustments for ages is warranted but that is beyond the scope of this report.

Figure 1

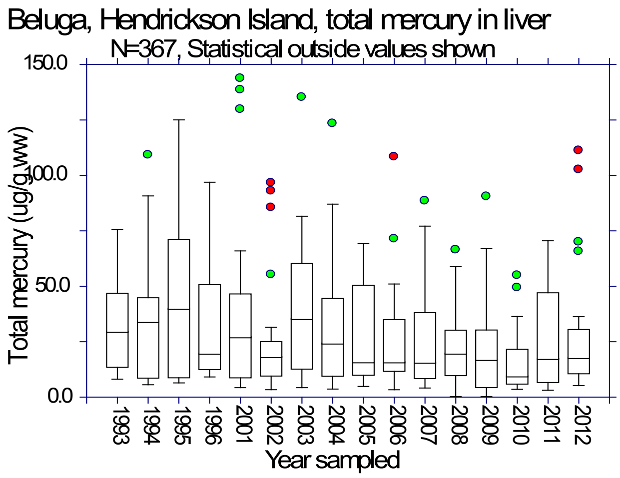


Figure 1. Box plots of median mercury levels (μg·g-1 wet weight) in liver of beluga whales from Hendrickson Island from 1993 to 2010. The horizontal line in each box represents the median value while the box itself represents the range from the 25th to the 75th percentile or the interquartile range (IQR). 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 outside values; mild outside values are not unusual but severe outside values are.

Kendall Island 2012

We have additional data on mercury (Table 2) and selenium (Table 3) in beluga taken at Kendall Island in 2011 and 2012, although ages are still unavailable. Kendall Island is in the Mackenzie Delta region and the values obtained might be expected to bear some similarities to those from Hendrickson Island (Tables 1-3). Curiously, the numbers of males and females are more balanced in these samples than in any others listed in Table 1. The mean mercury level in liver from Kendall Island in 2011 (26.1 μg·g-1) has a high standard deviation because of the influence of one extreme value of 177.4 μg·g-1. We have neither kidney nor muktuk values for that individual but its level of mercury in muscle fell within the range of others in the same collection. Lacking age data, no tests for relationships between mercury and age were possible but there was not a significant relationship between liver mercury and length. However, mercury in muscle in 2011 was statistically related to whale length ($r=0.58$, $p=0.0022$). In 2012 also, age data were not available and so tests for relationships to length were made but there was no correlation between levels of mercury in any of the organs with length ($p>0.05$ in all pair comparisons).

The data for 2011 include only liver and muscle and mercury levels in those two organs were not related statistically. In 2012, we have mercury values for all four organs with only one missing measurement in liver. Unlike the whales from Hendrickson Island, mercury levels in all four organs were correlated strongly with each other (liver/kidney, liver/muscle, liver/muktuk, kidney/muscle, kidney/muktuk, and muscle/muktuk).

In 2011 mercury and selenium in liver were correlated strongly ($r=0.90$, $p=0.000000$) and the same was true for muscle although the linkage was not as tight ($r=0.61$, $p=0.0014$). In 2012 mercury and selenium were again strongly correlated in liver ($r=0.91$, $p=0.00000$) and kidney ($r=0.80$, $p=0.00000$), but only weakly in muscle ($r=0.32$, $p=0.094$) and weakly negatively in muktuk ($r= -0.295$, $p=0.120$).

We have only three collections from Kendall Island plus data on two whales from a collection in 1977 reported by Beak Consultants (1978). The mercury levels in liver on those occasions are shown in Figure 2. The medians are less sensitive than means to the outside values found in some samples in 2011. Based on these few data, the pattern seems to be one of little change or no change at all in mercury levels over the interval.

Figure 2:

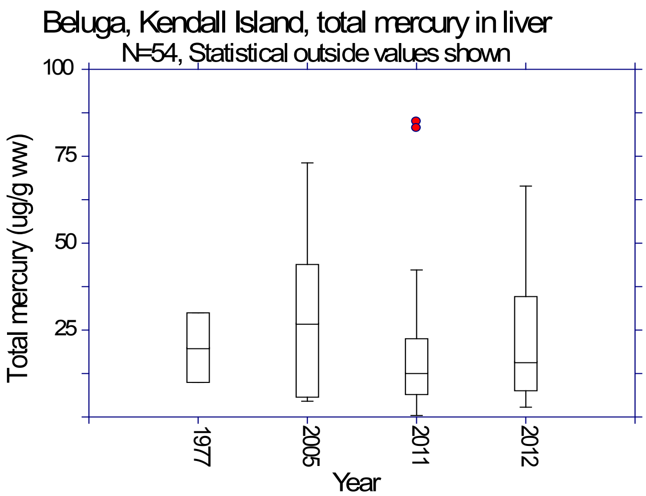
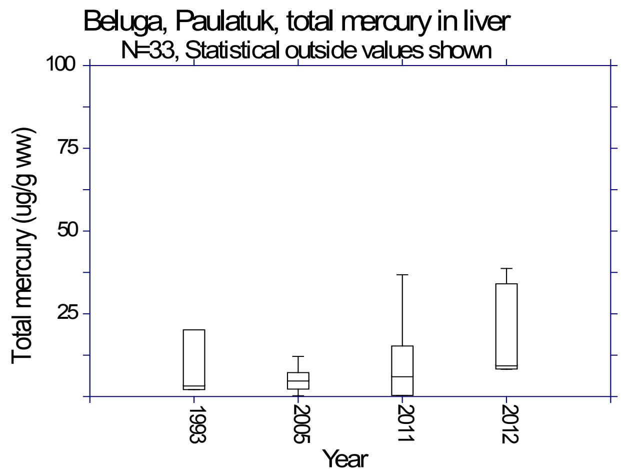


Figure 2. Box plots of median mercury levels (µg·g-1 wet weight) in liver of beluga whales from Kendall Island on four occasions from 1977 (N=2) to 2012. The horizontal line in each box represents the median value while the box itself represents the range from the 25th to the 75th percentile or the interquartile 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 outside values; mild outside values are not unusual but severe outside values are. In addition to the two outside values shown for 2011, there was an additional one not shown unless the vertical scale is extended.

Hendrickson Island and Kendall Island data in the context of other Mackenzie Delta data

We have information on whales taken at a few other areas within the Mackenzie Delta region, and the new data from Hendrickson Island and Kendall Island can be viewed as parts of the larger data on whales from the Delta. Figure 3 shows the results from the pooled unadjusted data on 496 beluga taken at locations in the Delta over the period from 1977 to 2012. This type of simple analysis shows no obvious temporal trend in the median levels of mercury over the interval.

Figure 3:



Paulatuk

We have records of four small collections of beluga from Paulatuk with a total of 33 animals, mostly males, taken over four occasions in 1993, 2005, 2011 and 2012. The mean ages for all but the collection in 1993 are given in Table 1. The whales in 2005 were the youngest animals reported with an average age of 17 years. That may be the reason for the low concentrations of total mercury in liver from that year (4.99 ± 3.66 µg·g-1, Table 2). One individual from 2005 was aged at zero years but still had liver mercury (5.39 µg·g-1) slightly greater than the group mean. In this same collection there were two teen-aged whales with liver mercury levels under 1 µg·g-1 causing one to wonder how these animals could have such low levels of mercury. The ages of the whales in 2011 (average 26 years, Table 1) were about the same as the beluga from Hendrickson Island at that time and yet the levels of mercury in liver were still relatively low (mean 9.51 ± 12.5 µg·g-1, Table 2). The average age was about the same again in 2012 (27.7 years, Table 1) but the mercury levels were considerably higher at 16.8 ± 13.5 µg·g-1 (Table 2). Perhaps some of these unusual observations will be explained when mercury levels are adjusted for age effects.

We do not have kidney samples from 2005 or 2011 but those in 2012 had mercury levels (3.27 µg·g-1) about 20 per cent of corresponding levels in liver (16.8 µg·g-1), consistent with other collections (Tables 2 and 3). Muscle levels of mercury were lower still with averages for the three years being: 0.66 µg·g-1 in 2005, 1.21 µg·g-1 in 2011, and 1.54 µg·g-1 in 2012. As with other collections, mercury in muktuk was lowest of all (Table 2). The highest mean level in muktuk was 0.65 µg·g-1 in 2012 and the lowest was 0.25 µg·g-1 in 2005.

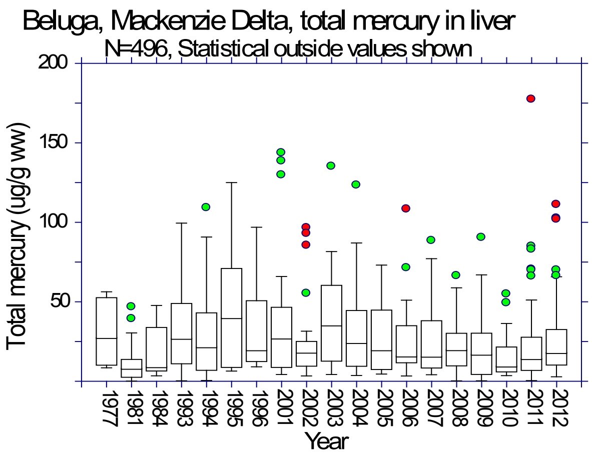
Selenium measurements are available in muktuk for three years of Paulatuk samples (Table 3). The levels are very similar to those from Hendrickson Island and Kendall Island so that the molar excess of Se over Hg would be of the same order as that calculated above for Hendrickson Island.

All four samples from Paulatuk, including the three whales in 1993 are included in Figure 4 in which the distributions of unadjusted mercury concentrations are shown for each collection period. Given the small numbers of samples and the relatively young ages of the whales in 2005 it would be premature to suggest any trend at this location.

Arviat

The nine collections from Arviat comprise 188 beluga taken on occasions dating from 1984. The 2012 collection consisted of samples from 16 animals (Table 1) most of which included all four organs. There were 12 males, 3 females and one for which no gender information was supplied. Ages for these animals are not available yet but lengths are listed in Table 1. Mercury in liver averaged 12.7 µg·g-1 with decreasing levels found in the other organs

Figure 4



(Table 2). The mean level of mercury in kidney was 4.94 µg·g-1 within the range of levels in kidney in the other collections listed in Table 2. However, mean values for mercury in kidney, muscle and muktuk were all influenced by unusually high values in one individual. The extreme value in kidney was 22.15 µg·g-1. Mercury in muscle averaged 1.31 µg·g-1 and fell within the range of other muscle samples even with the aberrant high value included in the calculation. Similarly with muktuk, the average of 0.48 µg·g-1 was close to other muktuk results even with the high outlier point included. When the correlations of mercury contents were calculated between pairs of organs, it was found the liver correlated significantly only with muktuk while kidney correlated strongly with muscle and muktuk and this latter pair correlated strongly with each other.

Selenium was measured in all four organs (Table 3) and this group had the lowest mean values in Table 3 for liver, kidney and muscle. There was a strong statistical relationship between mercury and selenium in liver (r=0.88, p=0.00002). Mercury and selenium were correlated also in kidney (r=0.70, p=0.007) but not in muscle or muktuk.

Median mercury in liver is shown for the nine collections since 1984 in Figure 5. Bearing in mind that these data have not been adjusted for differing ages of the whales, the appearance of the plot suggests the possibility of increasing levels of mercury since the early 2000s.

Figure 5:

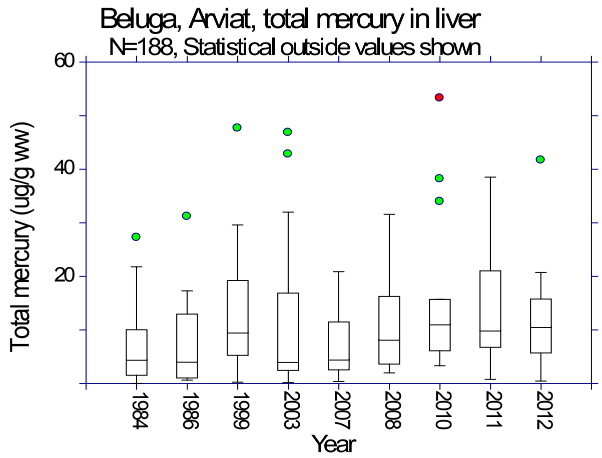
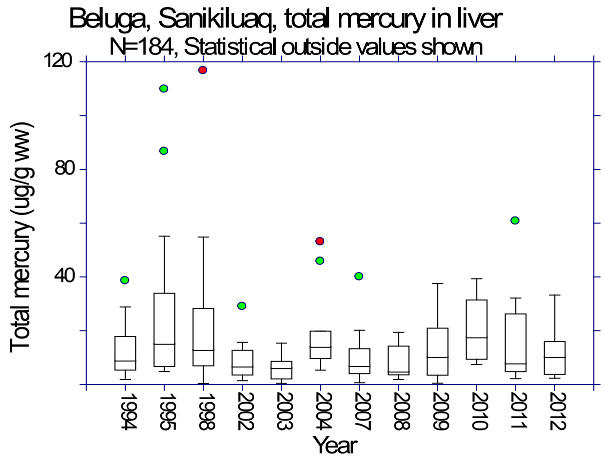


Figure 6:



Sanikiluaq

Twelve samples were obtained from Sanikiluaq in 2012, 6 males, 4 females and 2 of unknown gender. Lengths were obtained for 11 of them and these are included in Table 1. Total mercury levels found in the four organs analyzed are listed in Table 2. Mean mercury in liver was 11.8 µg·g-1, similar to the value of 12.7 µg·g-1 from Arviat. Both samples from Hudson Bay had averages for mercury in liver well below those from the Mackenzie Delta. Kidney levels were lower, with a mean of 3.61 µg·g-1 and mercury in muscle and muktuk were lower with still with corresponding means of 0.91 and 0.45 µg·g-1.

The comparisons between mercury among organs were unusual in the sense that their levels were not correlated strongly with each other in any of the organ pairs. The two strongest associations were between mercury in liver and kidney (r=0.54, p=0.068, just short of significance) and between muscle and muktuk (r=0.56, p=-.057, again just short of significance).

Mercury and selenium were related in liver (r=0.75, p=0.005), but not in kidney, or muscle; they fell just short of correlating in muktuk (r=0.55, p=0.065).

The pattern of median mercury levels in liver from 184 beluga from Sanikiluaq obtained on 12 occasions since 1994 is shown in Figure 6. There is no consistent pattern of change over time obvious from this type of presentation.

Discussion and Conclusions

Levels of total mercury in arctic beluga organs remain high when compared with fish commonly consumed by people. Of the four organs analyzed liver contains the highest mercury concentrations, followed by kidney, muscle and muktuk. Even with the lowest concentrations in muktuk, many of them still exceed 0.5 µg·g-1, the concentration long used to regulate the sale of fish for human consumption. The variation in the mercury concentrations is high with standard deviations often equalling or even exceeding means. This variation among animals makes it difficult to detect differences between locations at any one time or between times at any particular location. Ages of most of the beluga have been determined and it may help future statistical analysis to adjust mercury levels for varying ages. A more rigorous statistical analysis will have to be performed at some time to test for trends using appropriate transformations and age adjustments. The type of descriptive analysis done here has not revealed any clear, temporal trends in levels of mercury in liver. There do appear to be differences from place to place with the beluga from Hudson Bay having lower levels of mercury in body organs than beluga from the Mackenzie Delta.

The molecular speciation of mercury varies from organ to organ with liver, kidney and brain having only a small proportion present as methylmercury and muscle having most of the mercury present as methylmercury (Lemes et al, 2011). This raises the possibility that estimates of risks to consumers of these whales may have to be made organ by organ. It seems increasingly likely that selenium in the same organs as the mercury acts to protect the animals from mercury poisoning. In several organs selenium is present in approximately the same molar concentration as mercury but in muktuk the selenium exceeds mercury by several fold.

Performance Indicators

Western Arctic

- See 2010-11 NCP Synopsis report "Breanne Reinfort, Gary Stern, Feiyue Wang, Arctic contaminants: Exploring effective and appropriate communication between Inuvialuit communities and researchers. While this project was not funded by NCP in 2012-13, Breanne work in the community of Sachs Harbour is still on going.

- Loseto is in Tuktoyaktuk annually to discuss current research and findings with the HTO and the community.

- Breanne's presented poster and gave a talk on her current work with the community at the 2012 ArcticNet Science Meeting (ASM) held in Vancouver, Dec 12-14, 2013. **Breanne's poster won second place on the Social Sciences Category**

  – Talk tile - The overlooked importance of communication processes in disseminating contaminants research to Inuvialuit.

  – Poster title - It's not just what you say, it's how you say it – How relationships and trust influence perceptions and communication about Arctic contaminants in Sachs Harbour, NT.

While not funded by NCP, we have been conducting studies on temporal trend of contaminants in ringed sea from Ulukhaktok. John Alikamik (Olokhatomiut Hunters and Trappers Committee, Ulukhaktok, Northwest Territories) was collaborator in this study and the TEK he provided was absolutely essential to the success of the program As a result of this work, In. 2012 we published a paper in the high ranking peer reviewed journal Environmental Science and Technology. In recognition of his contribution John was included as a co-author (See citation 4, below)

Eastern Arctic

- Presentation made to the community of Sanikiluaq by Steve Ferguson on February 28, 2013. Title: "Beluga Research around the Belcher Islands and Hudson Bay"

Polar Data Catalogue (Metadata)

- CCIN 9750: Trends in beluga, narwhal and walrus mercury concentrations in Hudson Bay.

- CCIN 1697: Community perspectives on communicating contaminants research

Recent marine mammal related publications (2009-13)

1. Dietz, R. et al. 2013. What are the toxicological effects of mercury in Arctic biota? STOTEN, 443, 775-790.

2. Ostertag, S.K.; Stern, G.A.; Wang, F.; Lemes, M; Chan, L. 2013. Mercury distribution and speciation in different brain regions of beluga whales (*Delphinapterus leucas*). STOTEN. In press.

3. Frouin, H.; Loseto, L.L.; Stern, G.A.; Haulena, M.; Ross, P.S. 2012. Mercury toxicity in beluga whale lymphocytes: Limited effects of selenium protection. Aquatic Toxical., 109, 185-193.

4. 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.

5. Lemes, M,: Wang, F.; Stern, G.A.; Ostertag, S.K.; 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.

6. 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.

7. 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.

Expected Project Completion Date

This study has been ongoing for several years. Interest in this study seems likely to continue as long as whales and other marine mammals are hunted and eaten by northern people. The newly discovered linkage between intake of mercury by young people and incidence of diabetes later in life is likely to maintain interest in mercury in northern fish and marine animals that are eaten by northerners.

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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

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. Des 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

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 and perfluorinated carboxylic acids have increased. Levels of polybrominated diphenyl ethers (PBDEs), a group of brominated flame retardants, increased from 1975 to 2003 and now appear to be decreasing.

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 et d'acides perfluorocarboxyliques ont augmenté. 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.

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.
- Concentrations of total mercury (Hg) and perfluorinated carboxylates (PFCAs) have significantly increased 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 declining 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) et des carboxylates perfluorés (PBDE) ont considérablement augmenté depuis 1975 dans les oeufs de ces deux espèces d'oiseaux de mer de l'Arctique, dans 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 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 carboxylates (PFCAs) (Braune and Letcher 2013) and, up until 2003, the polybrominated diphenyl ethers (PBDEs). However, after 2003, ΣPBDE concentrations appear to be decreasing (Braune 2012).

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 brominated compounds such as the PBDEs and hexabromocyclododecane (HBCD), as well as polychlorinated dibenzo-p-dioxins (PCDDs), dibenzofurans (PCDFs), coplanar PCBs, and per- and poly-fluoroalkyl substances (PFASs) such as the PFCAs and perfluorooctane sulfonate (PFOS).

Activities in 2012-2013

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 Digges Island (62°33’N, 77°50’W) near Ivujivik in northeastern Hudson Bay. Attempts to collect eggs at Coats Island, our regular monitoring colony in northern Hudson Bay, were thwarted by poor weather conditions in 2012 preventing access to the colony during the egg-laying period. Therefore, with consent from the NCP Secretariat, murre eggs were collected from Digges Island instead. We have previous thick-billed murre egg collections from Digges Island with which to compare data.

Eggs were analyzed for the normal suite of legacy POPs (e.g. PCBs, DDT, chlordanes (CHL), chlorobenzenes (CBz), etc.), PBDEs, HBCD, and PFASs 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 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 (15N/14N) and carbon (13C/12C).

Analytical Methods

Analyses of the legacy POPs, PBDEs, HBCD, PFASs 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-a-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. PFASs are analyzed using HPLC/MS/MS in negative electrospray mode (ESI-) according to NWRC Method No. MET-WTD-ORG-RES-PFC-02. PFASs 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 were carried out by G.G. Hatch Stable Isotope Laboratory at the University of Ottawa in Ottawa, ON. All samples are archived in the National Wildlife Specimen Bank 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 2012, 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. Due to weather-related problems preventing access to Coats Island, we collected murre eggs from Digges Island instead in 2012. Two Inuit boat captains (Saima Mark, Johnny Luuku) were hired from Ivujivik to transport the field team to and from the field camp. Building on earlier successful collaborations between NWRC and the Arctic College program in Iqaluit, Nasivvik funds were used in March 2013 to send two graduate students to Iqaluit to work with Nunavut Arctic College (NAC) students to teach them the proper protocols for dissection of birds in the context of marine bird research including contaminants work using samples collected in 2012. A similar workshop was held in school classrooms in Cape Dorset in May 2012.

Communications

Presentations on the work that Environment Canada is doing related to arctic birds are given regularly in Resolute Bay, the closest community to Prince Leopold Island. Unfortunately, no one but the presenter (Mark Mallory) showed up for a meeting scheduled and confirmed for 23 July 2012 at the HTA office in Resolute Bay. However, a subsequent meeting with the

Resolute Bay HTA held in March 2013 was well-received. Presentations on marine bird research at Coats Island, East Bay and other areas in the region were previously given at the school and elsewhere in Coral Harbour every two years. Presentations were made by Grant Gilchrist to the Coral Harbour HTO in April 2011 and again in April 2013. At the request of the community, the frequency of the presentations will be increased. As part of our integrated approach to marine bird research (including contaminants) in the eastern Canadian Arctic, members of Grant Gilchrist's research team gave community presentations on marine bird research during Spring/Summer 2012 to the Nunavik Research Centre in Kuujjuaq, and the local HTOs in Cape Dorset, Iqaluit, Kangirsuk and Ivujivik. In July 2012, a presentation on marine bird research supported by the PCSP entitled "What we do after you drop us off" was made by Jennifer Provencher (graduate student) during the PCSP community open house in Resolute. Jennifer also made a presentation on the collaborative work of Environment Canada with the Nunavut Arctic College (NAC) in Iqaluit (see Capacity Building) at the Inuit Studies Conference in Washington, DC, in October 2012. Annual reports of the results to date are made to the NCP each year and results will continue to be published in a peer-reviewed scientific journals. A manuscript on temporal trends of perfluorinated compounds in seabird eggs was published in Environmental Science and Technology (see Braune and Letcher 2013), and a manuscript on How wildlife research can be used to promote wider community participation in the North has been accepted for publication in Arctic (see Provencher et al. in press). As well, the Coastlines newsletter, which contains plain-language summaries of our work, was sent to HTOs and NGOs as well as appropriate government environmental contacts in Nunavut in 2012.

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 (by Dominique Henri) which has been accepted at Oxford University and is being considered for publication as a book. In the mean time, a paper has been submitted to the journal Arctic for publication (see Henri and Gilchrist submitted). As well, the collaborative work of Environment Canada with the Nunavut Arctic College in Iqaluit demonstrating the utilization of marine bird dissections in research has been accepted for publication in Arctic (see Provencher et al. in press).

Results

Temporal Trends

The statistical program PIA (Bignet 2007) was used to analyze temporal trends of the major contaminants monitored in eggs of northern fulmars and thick-billed murres at Prince Leopold Island. Concentrations of most legacy organochlorines (e.g. SCBz, SCHL, SDDT, SPCB) have decreased significantly in eggs of both species at Prince Leopold Island between 1975 and 2011. In the murre eggs, SPCB showed the greatest percent annual decline followed by SCBz and SDDT, whereas in the fulmar eggs, SDDT showed the greatest annual percent decline followed by SPCB and SCBz. SCHL showed the lowest annual decline in both species (Table 1). Concentrations of SPCDD and SPCDF have also decreased significantly since 1975 with slightly greater annual declines seen in the fulmar eggs (Table 1). SPBDE increased in both species from 1975 to 2003 and then started to decline (Figure 1). Therefore, a log-linear analysis of the data over the whole time period resulted in a non-significant trend in both species (Table 1). Using PIA to analyze the SPBDE data for the two separate time periods, 1975-2003 and 2003-2011, resulted in a significant increasing trend in both species during 1975-2003 with annual increases of 7.2% and 8.9% in the murre and fulmar eggs, respectively, followed by significant decreasing trends in both species from 2003 to

2011 with annual decreases of 19% and 25% in the murre and fulmar eggs, respectively. PFOS has shown no consistent directional change over time whereas SPFCA has increased significantly between 1975 and 2012 with annual increases of 14% and 13% (Table 1). However, there is some indication that SPFCA levels may be starting to decline, particularly in the fulmars (Figure 2). Total Hg concentrations have increased significantly in eggs of both the murres and fulmars and at Prince Leopold Island between 1975 and 2012 at annual rates of 1.8% and 1.2% in murre and fulmar eggs, respectively (Table 1). However, annual sampling starting in 2005 indicates considerable inter-annual fluctuation in the data (Figure 3). The lowest detectable change in the current time series with a power of 80% ranges from 4.2% to 8% for the legacy organochlorines, SPCDD and SPCDF, 2.7-3.4% for total Hg, and 9.7-22% for PFOS and SPFCA (Table 1).

Digges Island

T-test analysis shows that there was no significant difference (p>0.05) in total Hg concentrations in eggs of thick-billed murres collected from Digges Island in 1993 (0.83 ± 0.07 mg g-1 dw, n=15 as 5 3-egg pools) and 2012 (0.80 ± 0.02 mg g-1 dw, n=15 as 5 3-egg pools). However, in 2012, total Hg was significantly lower (p<0.001) in the murre eggs collected from Digges Island (0.80 ± 0.02 mg g-1 dw) than from Prince Leopold Island (1.18 ± 0.07 mg g-1 dw).

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 as well as the PCDDs and PCDFs have decreased in eggs of thick-billed murres and northern fulmars monitored at Prince Leopold Island since 1975 (Table 1). 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).

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 SPBDEs 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 1). An increase in SPBDE 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). The annual rate of decrease of SPBDE after 2003 was more than double the annual rate of increase between 1975 and 2003 which likely reflects a rapid response to the phasing out of Penta-mix BDE usage in North America after 2005 (de Wit et al. 2010).

The increase in SPFCA concentrations in both murre and fulmar eggs is consistent with observed increases in other arctic species including herring gull eggs from northern Norway (Verreault et al. 2007), polar bears from Alaska and Baffin Island (Smithwick et al. 2006), ringed seals from the Canadian Arctic (Butt et al. 2007) and beluga whales from Alaska (Reiner et al. 2011). Despite the manufacturing phase-out of PFOS by the 3M Company between 2000 and 2002 (Butt et al. 2010), PFOS in the murre and fulmar eggs at Prince Leopold Island showed no significant change over time (Table 1). This is in contrast with several studies showing recent declines in PFOS levels in response to the phase-out (Butt et al. 2010, Houde et al. 2011). Braune and Letcher (2013) proposed that increased productionof PFOS in China may have offset the 3M phase-out with respect to the exposure of some arctic biota to PFOS.

Total Hg concentrations have been increasing in seabird eggs from Prince Leopold Island since 1975 (Table 1). 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

Table 1. Analysis of time trends for eggs of thick-billed murres and northern fulmars at Prince Leopold Island using PIA program (Bignert 2007). Percent annual decline or increase is significant ($p < 0.05$) unless otherwise noted.

	Thick-billed Murre				Northern Fulmar			
Year range of monitoring	1975-2011				1975-2011			
Parameter[1]	# years sampled	Total # samples[2]	% annual decline or increase	LDC[3] (%)	# years sampled	Total # samples[2]	% annual decline or increase	LDC[3] (%)
SCBz	15	65	-2.6%	6.1%	14	66	-2.6%	5.6%
SCHL	15	65	-1.2%	4.5%	14	66	-1.5% ns	5.4%
SDDT	15	65	-2.5%	4.2%	14	66	-4.7%	4.6%
S_{69}PCB	15	65	-4.0%	4.7%	14	66	-3.8%	6.1%
SPCDD	13	36	-3.4%	6.7%	12	34	-5.4%	8.0%
SPCDF	13	36	-2.6%	5.7%	12	34	-4.6%	6.8%
SPBDE	12	48	+3.0% ns[4]	18%	12	48	+2.4% ns	24%
	1975-2012				1975-2012			
PFOS	12	55	-0.51% ns	11%	12	57	-0.01% ns	9.7%
SPFCA	12	55	+14%	10%	12	57	+13%	22%
Hg	16	70	+1.8%	3.4%	15	71	+1.2%	2.7%

[1] SCBz = Sum Chlorobenzenes (tetra-, penta- & hexachlorobenzene); SCHL = Sum Chlordanes (oxychlordane, *cis-* & *trans-*nonachlor, *cis-* & *trans-c*hlordane, heptachlor epoxide); SDDT = Sum *p,p'*-DDE, *p,p'*-DDD and *p,p'*-DDT; S_{69}PCB = Sum of 69 congeners; SPBDE = Sum BDE 17, 28, 49, 47, 66, 100, 99, 85, 153, 138, 183; SPFCA = Sum C6 to C15.

[2] Number of 3-egg pools for all but SPCDD and SPCDF which were analyzed as 5-egg pools, and SPBDE which were analyzed as 5-egg pools 1975-2003 and as 3-egg pools 2005-2011.

[3] Lowest detectable change in current time series at power of 80%.

[4] ns = no statistically significant log-linear change ($p > 0.05$) in mean concentrations over time using the PIA program (Bignert 2007).

pattern of increasing Hg trends in seabirds in the Canadian high Arctic 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 and natural emissions coupled with environmental and biological (e.g. food-web) processes which may also be affected by climate change. In contrast, no significant difference was found for total Hg concentrations in eggs of thick-billed murres collected from Digges Island in 1993 and 2012. Total Hg levels in 2012 were significantly higher in murre eggs from Prince Leopold Island than from Digges Island which supports the observation of a latitudinal gradient for Hg as previously observed for seabirds in the Canadian Arctic (Braune and Scheuhammer 2008, Braune et al. 2002) as well as for Greenland species (Dietz et al. 1996). No significant difference was found for the legacy organochlorines and total Hg in eggs of thick-billed murres sampled from Coats Island and Digges Island in 1993 (Braune et al. 2002) suggesting that contaminant data for murres from those two colonies may be comparable. However, this needs to be confirmed with more recent samples.

Expected Project Completion Date

This is an ongoing monitoring program and a core NCP biomonitoring project.

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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

We are investigating contaminant trends in sea-run Arctic char from Ekaluktutiak (Cambridge Bay) and Mittimatalik (Pond Inlet). Sea-run char are being investigated because of their importance in the domestic fisheries for most coastal communities and to provide supporting information to the benefits of including these fish in country food diets. Mercury concentrations continue to be exceedingly 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 over 1977-2011 but not Pond Inlet where the temporal record is limited to 2005-2011. Persistent organic contaminant concentrations

Résumé

Nous examinons les tendances des contaminants chez l'omble chevalier anadrome à Ekaluktutiak (Cambridge Bay) et à Mittimatalik (Pond Inlet). Nous étudions ce poisson en raison de son importance pour les pêches de subsistance pratiquées dans la plupart des villages côtiers et pour recueillir des informations à l'appui des avantages d'inclure ce poisson dans les régimes d'aliments traditionnels. Les concentrations de mercure continuent d'être extrêmement faibles chez l'omble aux deux endroits 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 de 1977 à 2011, mais pas à Pond Inlet, pour lequel le dossier temporel se limite

were low with no trend evident over the 2004-2011 record. Limited measurements were made of contaminants concentrations in char from both locations in 1987. HCH and DDT concentrations were substantially lower in fish collected from both locations in the recent period than 1987; chlordane and CBz concentrations were lower at Cambridge Bay but not Pond Inlet. Overall, our study has determined that contaminant concentrations are low in sea-run char.

à la période de 2005 à 2011. Les concentrations de contaminants organiques persistants étaient faibles, et aucune tendance n'était évidente pour les données de 2004 à 2011. Des mesures limitées des concentrations de contaminants chez l'omble ont été effectuées aux deux endroits en 1987. Les concentrations de HCH et de DDT étaient considérablement plus faibles chez ces individus au cours de la période récente qu'en 1987, et les concentrations de chlordane et de CBz étaient moins élevées à Cambridge Bay mais non à Pond Inlet. Dans l'ensemble, notre étude a permis d'établir que les concentrations de contaminants chez l'omble chevalier anadrome sont faibles.

Key Messages

- Mercury concentrations were very low in sea-run char, i.e., well below the 0.5 mg/g guideline for the commercial sale of fish.
- There was a trend of mercury increase at Cambridge Bay (1977-2011) but not at Pond Inlet (2005-2011) where the monitoring period is shorter.
- Concentrations of legacy contaminants (DDT, CBz, HCH, and chlordane) were low.
- Most legacy organic contaminants occurred in substantially lower concentrations over 2004-2011 than 1987 for char from Cambridge Bay. At Pond Inlet, only HCH and DDT concentrations were substantially lower in 1987 than 2005-2011.
- Fish appear healthy.

Messages clés

- Les concentrations de mercure chez l'omble chevalier anadrome prélevé sont très faibles, soit 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 (1977-2011), mais non à Pond Inlet (2005-2011), où la période de surveillance était plus courte.
- Les concentrations de contaminants classiques (DDT, CBz, HCH et chlordane) étaient faibles.
- Les concentrations de la plupart des contaminants organiques classiques chez l'omble chevalier de Cambridge Bay étaient considérablement plus faibles en 2004-2011 qu'en 1987. À Pond Inlet, seules les concentrations de HCH et de DDT étaient considérablement plus faibles en 1987 qu'en 2005-2011.
- Les poissons semblent en santé.

Objectives

- 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.
- Investigate the role of factors such as fish age, trophic feeding, climate, and location in affecting contaminant body burdens and trends.
- 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.
- 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

The Northern Contaminants Program (NCP) includes arctic char in its monitoring design in order to provide communities with essential information on contaminant levels in their traditional foods. Char have a wide variety of life history forms, with some migrating to the sea in late spring, spending a few weeks feeding on benthos and forage fish before returning inland for the fall while others remain inland (resident and landlocked) throughout their lives (Ganter et al. 2010 a, b; Swanson and Kidd 2010, Swanson et al. 2010). 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. 2008 a, b) making them good food choices for those wishing to consume country foods while limiting contaminant intake.

NCP also is designed to track the decline of legacy persistent organic contaminants such as PCBs and DDT. With the reduced usage of these chemicals globally, 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. Furthermore, the cold and low productivity arctic environment hinders rapid degradation of these chemicals and their burial in newly-formed sediments. Mercury, a naturally-occurring metal, also is of concern; increasing amounts of mercury have been carried to northern Canada since the mid 1880s with the onset of the industrial revolution (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 North America and Europe have reduced 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); it has been argued that recent increases in mercury flux rates to subarctic and Arctic sediments is more a consequence of warming trends and increased productivity than increases in mercury reaching Canada's north via atmospheric pathways (Stern et al. 2005; Outridge et al. 2007; Carrie et al. 2009).

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. These studies determined that contaminant concentrations were uniformly low in these sea-run char (Evans and Muir 2008, 2009, 2010). In 2011, the monitoring was scaled back to three communities (Nain, Cambridge Bay, and Pond Inlet) and then 2012 when only Cambridge Bay and Pond Inlet contributed to the monitoring program (Evans and Muir 2011, 2012). 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.

Activities in 2012-2013

In fall 2012, 20 sea-run char were harvested by local fisherman from Cambridge Bay and Pond Inlet, frozen, and shipped whole 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. Contaminant analyses are ongoing.

Results of our research to date have been reported in Evans and Muir (2012); we also contributed to CACAR and CARA expert work groups. Two papers were published based on an investigation of the factors affecting differences in mercury concentrations between sea-run and resident/landlocked char populations (Van der Velden et al. 2013 a, b); this in turn was based on a Master's thesis with the research supported by Arctic Net and NCP.

Results and Discussion

Temporal variations in mercury levels

The data sets for investigating time trend analyses in sea-run char is limited with the monitoring program beginning at Cambridge Bay in 2004 and Pond Inlet in 2005; earlier data exist for Cambridge Bay from the commercial fishery (Lockhart et al. 2005). However, Cambridge Bay fish caught in 1978 were small (<500 mm and 455-665 g) and not suitable to include in time trend analyses. Mercury concentrations showed a trend of increase over 2005-2010 although concentrations declined in 2011 (Fig. 1). When all available data were considered, there was a significant trend of mercury increase for Cambridge Bay char with variations in mercury concentration also explained by fish length and weight ($R2 = 0.48$; $F= 7.47$, $p =0.0002$). Increases in mercury concentration have been observed in other biota in the central Arctic and subarctic with part of this increase related to warming trends (Carrie et al. 2010, Rigét et al. 2010).

Temporal variations in legacy POPs

Organic contaminant analyses are ongoing for sea-run char collected in 2012. Data for 2011 fish have been received and are reported here with the exception of PCBs; a commercial laboratory was used in 2011 and their PCB determinations are still being verified. Historic legacy organic contaminant data are also available for 1987 fish analyzed from both locations (Muir et al. 1990). Overall HCH concentrations over 2004-2011 were substantially lower than in 1987 (Fig. 2). This decrease could in part be related to declining concentrations of HCH in the atmosphere (Hung et al. 2010). Similar declines in HCH are being observed in landlocked char, Fort Good Hope burbot, and Great Slave Lake burbot and lake trout (Muir et al. 2012; Stern 2012; Evans and Muir 2012). DDT also is showing evidence of lower concentrations in the recent period at both locations than in 1987. Chlordane and CBz have declined in concentration at Cambridge Bay but not Pond Inlet.

Overall, the data base for assessing time trends in contaminants in sea run char is limited in the number of observations which limits the sensitivity to detect small change. 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 and trophic feeding and their response to the warming trend which has been observed in this region of the Arctic.

Spatial variations in mercury and legacy POP concentrations

Van der Velden (2012) recently completed a M.Sc. thesis comparing mercury concentrations in sea-run and non-anadromous char along a latitudinal gradient running from Pond Inlet in the north to Nain in the south. Her findings have been published in Van der Velden et al. (2013 a, b). Mercury concentrations were substantially lower in sea-run than (site range 20 - 114 ng/) than non-anadromous (site range 111-227 ng/g) char; there was no evidence of a latitudinal gradients in concentrations. Lower mercury concentrations in sea-run char were related to lower methyl mercury concentrations at the base of the food web, i.e., food and water in marine waters than fresh waters.

Sea-run char from Pond Inlet and Cambridge Bay can be compared with respect to life history characteristics and contaminant concentrations (Table 1). On average Cambridge Bay char were larger, younger and more lipid rich than Pond Inlet char suggesting a faster growth rate. Mercury concentrations were similar at both locations whereas persistent organic contaminants tended to be higher at Cambridge Bay, particularly PCBs. Sea-run char data also can be compared with lake trout (also a member of the Salmonidae family) from the West Basin of Great Slave Lake. While length of the sampled fish was similar for the three locations, West Basin lake trout had a slightly faster growth rate than the two char populations. Mercury concentrations were substantially higher than in sea-run char while legacy organic contaminants and PBDEs occurred in similar concentrations in char and lake trout.

Table 1. Mean life history characteristic and contaminant concentrations (fillet, wet weight) in serum char from Pond Inlet and Cambridge bay with comparisons with lake trout from the West Basin of Great Slave Lake. Means are based on collections made over 2004-2010.

	Sea-run char		Lake trout
Parameter	**Cambridge Bay**	**Pond Inlet**	**Great Slave Lake**
Fork Length (mm)	681.9 ± 78.6	629.9 ± 94.0	669.7 ± 32.3
Age (yr)	12.9 ± 2.3	13.6 ± 2.8	9.0 ± 4.1
% Lipid	10.90 ± 6.73	9.90 ± 4.10	9.4 ± 4.6
Mercury (µg/g)	0.07 ± 0.02	0.06 ± 0.02	0.20 ± 0.09
sChlordane (ng/g)	5.73 ± 3.73	3.90 ± 1.75	5.38 ± 4.76
sHCH (ng/g)	3.60 ± 2.64	2.07 ± 1.46	0.76 ± 1.10
sCBz (ng/g)	4.74 ± 2.57	2.60 ± 0.97	2.23 ± 1.48
sDDT (ng/g)	2.12 ± 1.29	1.91 ± 0.91	3.09 ± 2.94
Dieldrin (ng/g)	1.92 ± 1.42	1.73 ± 0.74	0.63 ± 0.70
sPCB (ng/g)	14.54 ± 8.43	7.61 ± 2.72	13.38 ± 12.57
sPBDEs (ng/g)	0.67 ± 0.56	0.57 ± 0.72	0.93 ± 0.68

Conclusions

Mercury and persistent organic contaminant concentrations were low in sea-run char. There may be a trend of increasing mercury concentrations in char at Cambridge Bay over 1977-2011 but not Pond Inlet over 2005-2011 where the data record is much shorter. However, mercury concentrations remain very low in these fish, i.e., ca. 10 times lower than the commercial sale guideline of 0.5 μg/g. Legacy persistent organic contaminant concentrations were low with evidence of lower concentrations over 2004-2011 than 1987 when the first measurements were made.

Expected completion date

This is core trend monitoring project with monitoring expected to continue with the NCP program.

Acknowledgements

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Figure 1. Time trends in fork length and mercury concentrations in fillet for sea run char from Cambridge Bay and Pond Inlet.

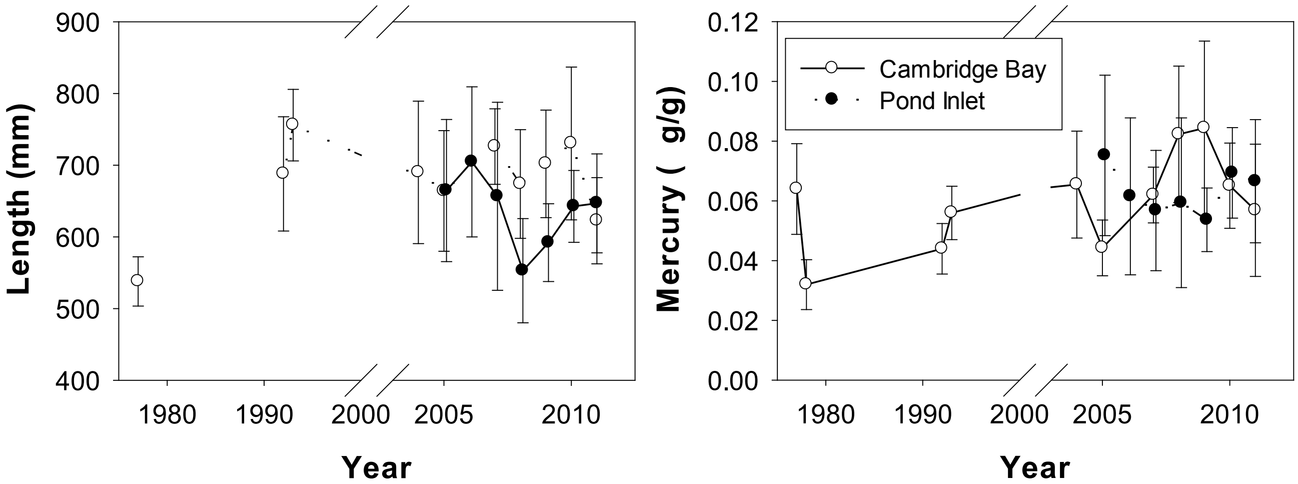
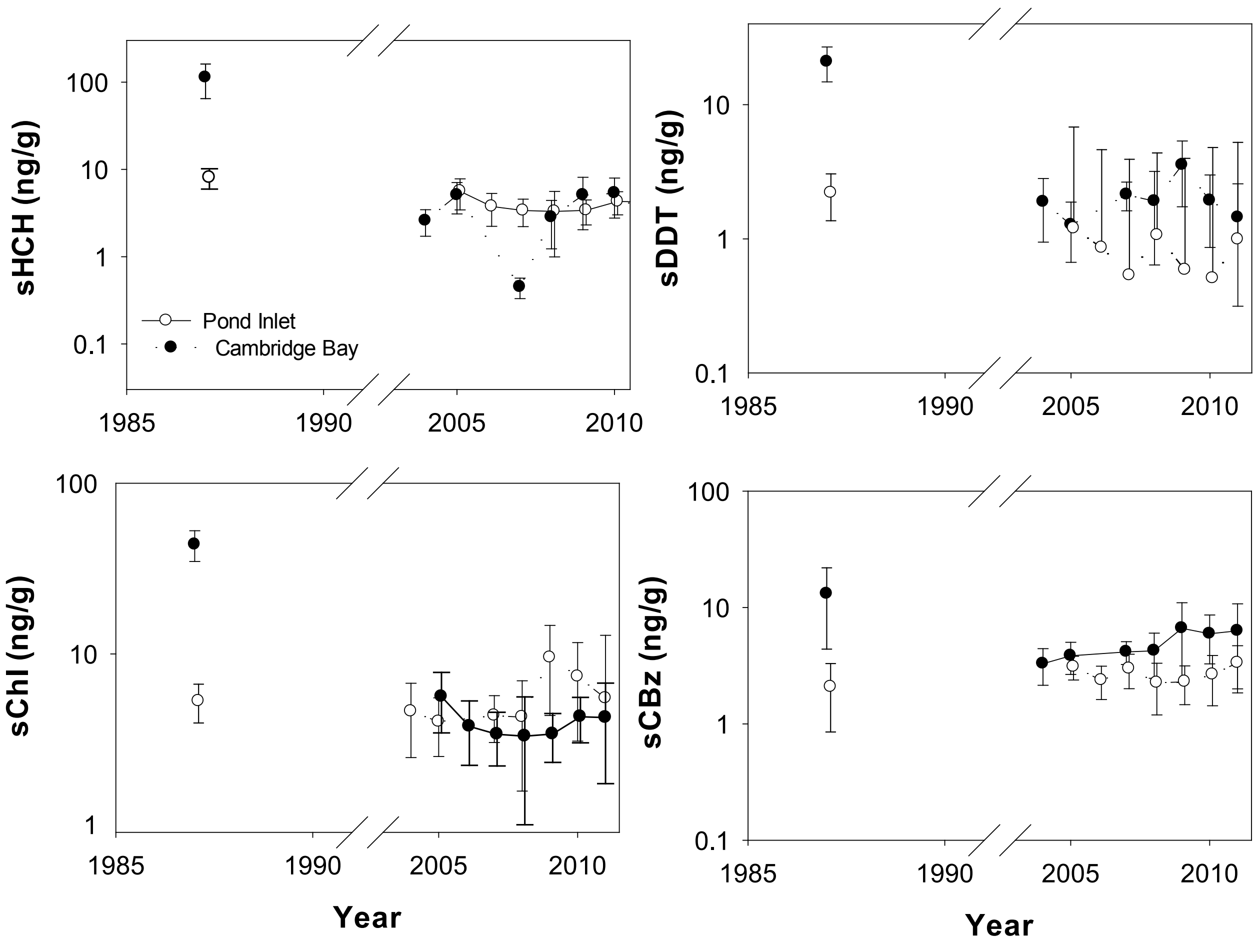


Figure 2. Time trends in HCH, DDT, Chlordane and CBz in in sea-run char at Cambridge Bay and Pond Inlet.



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 2012, 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 2012 we found significant declining trends of mercury in char in Amituk, Char and Resolute lakes. No change

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). Des échantillons sont recueillis annuellement 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 du Canada Quttinirpaaq, sur l'île d'Ellesmere. En 2012, nous sommes parvenus à recueillir des échantillons d'omble chevalier dans les quatre lacs. Afin d'évaluer les tendances temporelles, les résultats ont été combinés aux résultats

in mercury was found for char from Lake Hazen. Legacy POPs are declining in char in all lakes except in Resolute Lake where PCBs, DDT and chlordane-related chemicals continued to show no change while toxaphene has increased. Replacements for banned brominated flame retardants are increasing in Amituk, Char and Resolute lakes but is still below detection limits in Lake Hazen. Fluorinated chemicals are generally showing little change in concentration in Char and Hazen lakes but one group of these chemicals continues to increase in Amituk Lake.

antérieurs obtenus pour les mêmes lacs. Compte tenu des résultats de 2012, nous avons constaté des tendances à la baisse significatives pour ce qui est du mercure chez l'omble chevalier dans les lacs Amituk, Char et Resolute. Aucun changement n'a été observé pour ce qui est du mercure mesuré chez l'omble chevalier du lac Hazen. Les anciens POP sont à la baisse chez l'omble chevalier dans tous les lacs, sauf dans le lac Resolute; en effet, les concentrations de BPC, de DDT et de composés apparentés au chlordane sont demeurées stables, tandis que les concentrations de toxaphène ont augmenté. Les composés remplaçant les ignifugeants bromés qui ont été interdits sont en hausse dans les lacs Amituk, Char et Resolute, mais leurs concentrations sont toujours inférieures aux seuils de détection dans le lac Hazen. De façon générale, les concentrations de composés fluorés mesurées chez l'omble chevalier ont peu varié dans les lacs Char et Hazen, mais un groupe de composés fluorés est présent en concentrations de plus en plus grandes dans le lac Amituk.

Key Messages

- Concentrations of mercury concentrations in landlocked char from three of the four study lakes have declined since 2005
- While most legacy POPs such as hexachlorocyclohexanes, PCBs and DDT are declining some newer flame retardant chemicals are increasing.

Messages clés

- Dans trois des quatre lacs étudiés, les concentrations de mercure mesurées chez l'omble chevalier confiné aux eaux intérieures ont diminué depuis 2005.
- Les concentrations de la plupart des anciens POP, tels que l'hexachlorure de benzène, les BPC et le DDT, sont en déclin, mais les concentrations de certains produits ignifugeants plus récents sont à la hausse.

Objectives

- 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.
- Investigate factors influencing contaminant levels in landlocked char such as the influence of sampling time, water temperature, diet and climate warming.
- 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 (Köck et al. 2004; Power et al. 2008), landlocked char are good indicators of changes in inputs of methyl mercury, the toxic and bioaccumulative form of mercury. Research in the past 5 years has provided much new information on mercury in landlocked char populations and their food webs (Gantner et al. 2009; Gantner et al. 2010a; Gantner et al. 2010b), (Swanson and Kidd 2010), (Swanson et al. 2010), Chételat et al. (Chételat et al. 2008; Chételat et al. 2010) and (van der Velden et al. 2013a; Van der Velden et al. 2013b).

Many persistent organic pollutants (POPs) are known to have similar biomagnification potential as methyl mercury and accumulate in Arctic lake food webs as well (Rigét et al. 2010). 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.

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; 2011; 2012).

Activities in 2012-13

Sample collection

Char were successfully collected in July 2012 from Amituk, Hazen, Char, and Resolute lakes. In 2012, we were again challenged at Char Lake, with only 1 fish weighing over 200 grams. It appears that Char Lake is now dominated by a smaller “morphotype” of char with adult fish of 15 to 25 cm length rather than 25-60 in the other lakes. At Lake Hazen the collections were carried out by Parks Canada staff at Quttinirpaaq National Park.

In a related NCP project, graduate student Ben Barst collected landlocked char,from 6 lakes in the Resolute area including from Amituk, Char and Resolute lakes for studies on mercury toxicity (Drevnick 2012). 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

Methodology for organochlorine pesticides (OCPs), PCBs, polybrominated diphenyl ethers (PBDEs) and PCNs and coplanar PCBs in seal blubber was changed in 2012. Analyses of OCPs and PCBs in the 2011 and 2012 samples was contracted to ALS Global (Burlington ON). Extraction and cleanup procedures followed the same general procedure as in previous years. Tissue samples were spiked with 13C12-PCB-133- prior to extraction. The tissues were mixed with anhydrous sodium sulphate and Soxhlet extracted overnight with dichloromethane (DCM). The extracts were cleaned by gel permeation chromatography to remove lipids and reduced to a 1mL final volume in DCM. A separate 50uL portion of each extract was removed for both OCP and PCB analyses. A suite of 13C labeled PCBs was added to the PCB extracts for target analyte quantification and retention time references. Similarly a suite of deuterium and 13C- labeled OCPs was added to the OCP extracts prior to instrumental analysis for target quantification. Sample extracts were then analysed directly by GC-high resolution mass spectrometry (GC-HRMS) for OCPs and by GC-Low resolution MS) for PCB congeners. All data were recovery corrected for extraction and clean up losses relative to 13C12 PCB-133 response. The suite of OCPs and PCBs analysed was identical previous suite analysed by the National Laboratory for Environmental Testing (NLET) organics lab.

Toxaphene, endosulfan isomers and endosulfan sulfate, PBDEs and hexabromocyclododecane (HBCDD) and bis(tribromophenoxyethane (BTBPE) were analysed by low resolution GC-negative ion mass spectrometry (GC-NIMS) by NLET. Toxaphene was determined as “total” toxaphene using a technical toxaphene standard and also by quantification of individual chlorobornanes (Muir et al. 2004).. Perfluorinated chemicals (PFCs) in char muscle were analysed in the Muir lab as described in Reiner et al. (2012).

Thirty-two 32 elements were determined in Arctic char muscle (skinless) by Inductively Coupled Plasma- Mass spectrometry (ICP-MS) (NLET 2002). In brief, muscle (1 g) was digested with nitric acid and hydrogen peroxide (8:1) in a high pressure microwave oven at 200C for 15 minutes and the digest was analysed by ICP-MS. Mercury was analyzed from the same digest by using cold vapor atomic absorption spectrometry.

Stable isotope analyses

Muscle from all fish analysed for mercury and POPs were analysed for stable isotopes of carbon (d13C) and nitrogen (d15N) 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 SRM 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 for all analysed generally had non-detectable concentrations or levels <5% of measured values. No blank correction was used. NLET organics and metals labs as well as ALS Global (Burlington) are participants in the NCP Quality Assurance Program and are accredited by the Standards Council of Canada through Canadian Environmental Analytical Laboratory program. There was no NCP comparison for perfluorinated compounds but the Muir laboratory participated in an interlab comparison of reference materials from the National Institute for Standards and Technology (NIST) which is now published .

Statistical analyses

Based on previous data analyses (Muir et al. 2011) results for all elements and POPs were log10 transformed in order to reduce coefficients of skewness and kurtosis to <2. 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.

Results

Mercury

The trends of mercury over time, updated with results from 2012 are shown in Figure 1. The 2 year running average suggests declining concentrations in all four lakes since approximately 2005. This decline is statistically significant in Amituk, Resolute, and Char lakes when analysed using the PIA software (Bignert 2007) (Table 1). Results for Resolute Lake, with 16 sampling years, have achieved the goal of detecting a 5% change (with a power of 80% at a=5 %). Thus any future change is likely to be quickly detected.

Legacy POPs: Trends for legacy POPs based on samples collected up 2011. Results for analysis of the 2012 samples are pending. ΣHCH is changing the most rapidly of all POPs in all four lakes with an annual decline of -9.7 to -20 %/yr (Table 2). β-HCH actually increased in char from Amituk and Hazen Lakes, however, it makes up only 5 to 7% of ΣHCH; the other components α- and γ- HCH isomers are declining. ΣDDT, toxaphene, ΣCHL, and ΣPCBs declined significantly in Char, Amituk and Hazen lakes but not in Resolute Lake. Toxaphene shows 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.

Table 1. PIA analysis of time series for mercury concentrations in landlocked char muscle (ns = not statistically significant)

Lake	All years			Trend 2005-2012		
	Interval	# years	Overall trend	Interval	# years	Overall trend
Amituk	1989 - 12	11	-0.61% (ns)	2005-12	7	-9.1%
Char	1993 - 12	11	-1.51% (ns)	2005-12	7	-19%
Hazen	1990 - 12	12	0.47% (ns)	2001-12	7	2.3% (ns)
Resolute	1993 - 12	16	-0.24% (ns)	2005-12	8	-8.5%

[1] Trends based on length adjusted geometric means analysed using PIA (Bignert 2007).

Table 2. Percent annual decline (negative) and increase in legacy POPs 1 in arctic char from the four study lakes (to 2011)

Species	Location	Years	ΣCBz	ΣHCH	ΣCHL	ΣDDT	ΣPCB	Toxaphene
Arctic char	Amituk	11	-6.7 ns	-17 (11-22)	-7.6 (3.6-12)	-7.8 (5.2-7.8)	-7.6 (3.2-12)	-9.5 (4.0-15)
Arctic char	Char	11	-3.9 ns	-20 (12-28)	-10.3 (0.7-20)	-11 (6.4-15)	-9.0 (4.9-13)	-6.5 (7.6-14)
Arctic char	Hazen	10	-3.2 ns	-9.7 (7.7-12)	-6.7 (3.2-10)	-12.3 (8.7-16)	-6.4 (3.3-9.4)	-7.6 (0.8-14)
Arctic char	Resolute	13	1.6 ns	-7.9 (4.8-11)	-1.7 ns	-2.7 ns	-3.5 ns	13 (1.8-25)

[1] ns = indicates no statistically significant log linear trend ($P > 0.05$). Significant trends include 95% confidence intervals in parentheses

New POPs

Trends for ΣPBDEs (sum of 14 BDEs; major congeners 47, 99, and 100) in landlocked char vary widely among lakes. ΣPBDE concentrations increased overall in all lakes compared to the 1990s but are now declining in Amituk, Hazen, and Resolute lakes (Table 3). No decline of ΣPBDEs has been observed in char from Char Lake.

HBCDD and BTBPE, which are both replacements for PBDE flame retardants have also been detected in char muscle. HBCDD concentrations have increased significantly in Amituk Lake char (+142%/yr) since 2003 reflecting a rapid change from near detection limit values in 2003-2005. Increases of HBCDD were also seen in Resolute and Char Lakes but they were not statistically significant (Table 3). BTBPE concentrations remain near detection limits except in Char Lake where concentrations reached 1 ng/g lipid wt in 2009; therefore statistical analysis was not carried out.

With new results from 2011, PFOS continues to remain higher in char from Char Lake, than in other lakes and is not declining significantly (Table 3). PFOS is declining (not statistically significant) in Amituk and Hazen. ΣPFCAs (sum of perfluoro alkyl acids with 9 to 12 carbons) has increased over the period 2007 to 2011 in Amituk Lake but is showing a declining trend in Hazen and Char Lakes.

Table 3. Percent annual decline (negative) or increase in PBDEs, PFOS and ΣPFCAs in arctic char from the four study lakes

Location	PBDEs		HBCDD		PFOS		ΣPFCAs	
	Period	% dec or inc /yr[1]	Period	% dec or inc /yr[1]	Period	% dec or inc /yr	Period	% dec or inc /yr
Amituk	2003-11	-17 ns	2003-11	+142 (33-252)	2007-11	-8.5 ns	2007-11	+30 ns
Char	1993-11	4.2 (0.3-8.0)	2003-11	+94 ns	1993-11	-1.6 ns	1993-11	-2.0 ns
Hazen	2001-08	66 (32-99)	ND[2]		2003-11	-6.0 ns	2003-11	-8.0 ns
	2008-11	-23 ns			-	-	-	-
Resolute	1997-05	21 (8.6-33)	2003-11	+105 ns	ND[3]	-	-	ND[3]
	2005-11	-8.7 ns			-	-	-	-

1 Percent annual change per year estimated using the PIA program. Ns = no significant log linear trend(P>0.05). Significant trends include 95% confidence intervals in parentheses

2 ND= Not determined. HBCDD < method detection limit

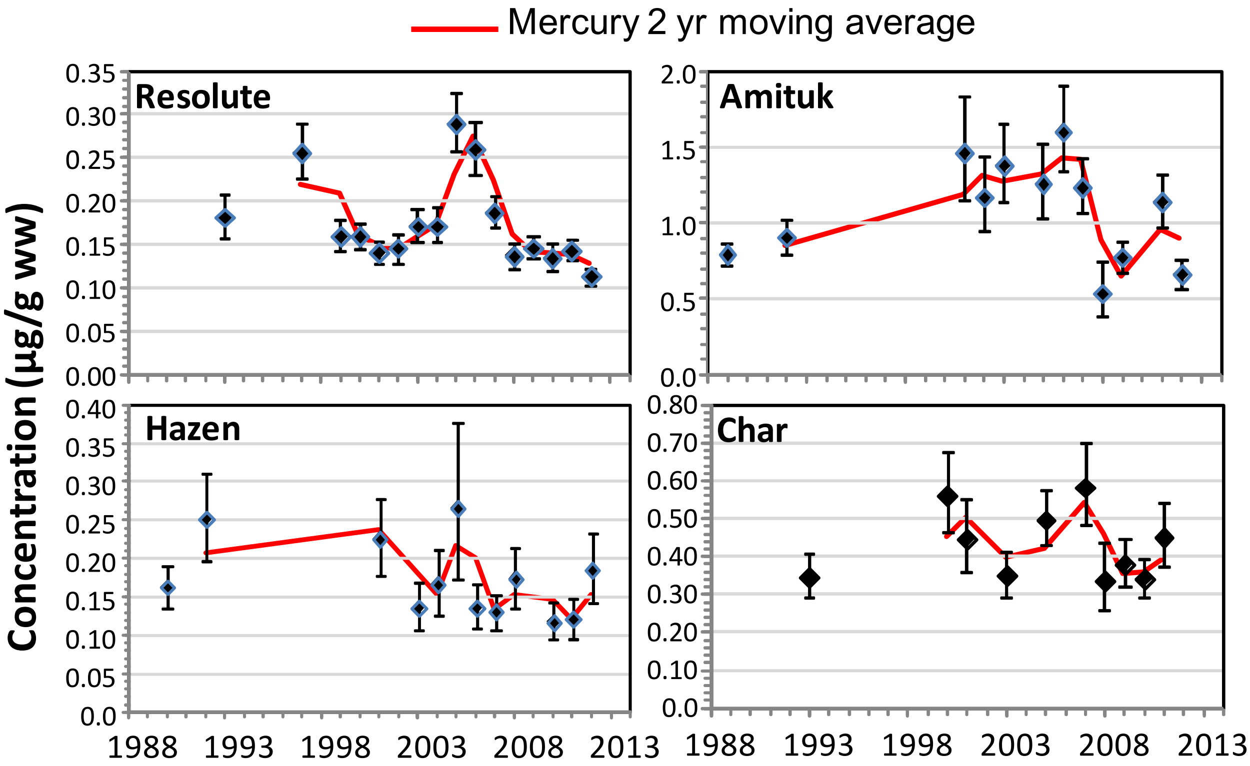
3 ND = Trends for PFCAs and PFOS in Resolute Lake not determined due to local source contamination

Discussion and Conclusions

Analysis of trends of mercury in landlocked char from the four lakes suggests declining concentrations in all four lakes since approximately 2005. The results contrast with lake trout and burbot from Great Slave Lake (Evans and Muir 2011; Evans and Muir 2012), and with burbot in the Mackenzie River, where increases in mercury may have leveled off but are showing no decline (Carrie et al. 2010; Stern et al. 2012a). 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. Why mercury concentrations are not showing the same increasing trend in a top predator in high arctic lakes is unclear but might be related to very low productivity of these systems, low rates of methyl mercury production and high rates of photodemethylation (Chetelat and Hintleman 2012), especially compared to more productive lakes south of the treeline.

The recent decline in PBDEs in char is in agreement with recent observations for seabirds in the Lancaster Sound area. Mean ΣPBDEs have declined significantly in thick-billed murres and northern fulmars since the mid-2000s (Braune et al. 2012). However, ΣPBDEs have not declined significantly in ringed seals in the same region. In fish, ΣPBDEs are showing declining trends in lake trout from Lake Laberge and Kusawa Lake (Stern et al. 2012b) and from Great Slave Lake (Evans and Muir 2012). These trends presumably reflect reduced emissions of "penta" and "octa" BDEs as a result of phase out and bans in North America, the major use area in the world for these flame retardants (Alcock et al. 2003). Similarly the declining trend for PFOS likely reflects with phaseout of volatile precursors of this chemical by the major manufacturer in 2002 (Paul et al. 2009). Thus, landlocked char in remote high Arctic lakes appear to reflect changes in chemical production and emissions relatively well. Therefore we can conclude that the increases in HBCD and BTBPE are indicative of increased production and emissions due to their use as replacements for PBDEs (Covaci et al. 2011).

Figure 1. Trends in mercury concentrations in landlocked char from Resolute, Amituk, Char, and Hazen lakes. Symbols represent geometric mean concentrations and vertical bars are standard errors of the mean.



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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 contaminants organiques persistants et des métaux chez le touladi et la lotte dans les Territoires du NordOuest

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Abstract

Our study is investigating temporal trends in mercury and persistent organochlorine contaminants in lake trout and burbot in Great Slave Lake. Two areas are being investigated which differ in their overall limnology, fisheries ecology, and contaminant sources. The West Basin is the more productive region, supports a commercial fishery and is under a strong Slave River influence. The East Arm is less productive, supports only a domestic and sports fishery, and direct atmospheric inputs may be the more important contaminant source. 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

Résumé

Notre étude examine les tendances temporelles du mercure et des contaminants organochlorés persistants chez le touladi et la lotte dans le Grand lac des Esclaves. L'étude porte sur deux zones qui diffèrent quant à la limnologie générale, l'écologie halieutique et les sources de contamination. Le bassin ouest, sur lequel la rivière des Esclaves influe fortement, fait partie d'une zone productive où l'on pratique la pêche commerciale. Le bras est, où les apports atmosphériques directs seraient la plus importante source de contamination, constitue une région moins productive où l'on pratique seulement une pêche locale et sportive. Des touladis ont été capturés à Hay River (bassin ouest) et à Lutsel K'e (bras est),

monitoring at Lutsel K'e and northern pike (mercury only) at Fort Resolution. With the formal NCP monitoring beginning in 1998 and supplemented with data collected from earlier studies, our data bases are becoming strong enough to detect statistical trends, particularly for mercury. Mercury concentrations are showing significant trends of increases for lake trout and burbot but not northern pike: average mercury concentrations for a given species, year and location are well below the 0.5 µg/g commercial sale guideline for fish. Among the legacy persistent organic contaminants, the strongest trends of decline have been observed for HCH followed by DDT; other trends are weaker and inconsistent with species and location. CBZ may be showing a trend of increase in lake trout.

et des lottes, à Fort Resolution (bassin ouest), grâce à des fonds provenant du Programme de lutte contre les contaminants dans le Nord (PLCN). D'autres fonds ont permis de poursuivre la surveillance de la lotte à Lutsel K'e et du grand brochet (pour le mercure seulement) à Fort Resolution. Les données issues des activités de surveillance officielles par le PLCN (lancées en 1998), à laquelle ont été ajoutées des données supplémentaires provenant d'études antérieures, alimentent nos bases de données. Cellesci sont en train de devenir suffisamment efficaces pour déceler les tendances statistiques, notamment dans le cas du mercure. Les concentrations de mercure montrent des tendances significatives à la hausse chez le touladi et la lotte, mais non chez le grand brochet. Les concentrations moyennes de mercure pour une espèce, une année et un emplacement donnés sont bien inférieures à la ligne directrice de 0,5 µg/g visant les poissons destinés à la vente commerciale. Parmi les contaminants organiques persistants légués du passé, les tendances les plus à la baisse ont été observées pour les concentrations de HCH et de DDT; d'autres tendances sont plus faibles et ne concordent pas avec les espèces et l'emplacement. Les concentrations de CBz pourraient montrer une tendance à la hausse chez le touladi.

Key Messages

- Mercury concentrations in lake trout (fillet) and burbot (fillet) collected from the West Basin and East Arm are showing a significant trend of increase. Average mercury concentrations remain below <0.5 µg/g with occasional exceedences associated with large fish.
- Northern pike, currently monitored in Resolution Bay as part of the Cumulative Impact Monitoring Program, have shown no trend of increase. Average mercury concentrations remain below <0.5 µg/g with occasional exceedences associated with large fish.

Messages clés

- Les concentrations de mercure des spécimens de touladi (filet) et de lotte (filet) capturés dans le bassin ouest et le bras est connaissent une tendance significative à la hausse. Les concentrations moyennes de mercure demeurent inférieures à 0,5 µg/g, à l'exception de dépassements occasionnels chez les poissons de grande taille.
- Chez le grand brochet, qui fait actuellement l'objet d'une surveillance à Resolution Bay dans le cadre du Programme de surveillance des effets cumulatifs, on n'observe pas de tendance à la hausse. Les concentrations moyennes de mercure demeurent inférieures à 0,5 µg/g, à l'exception de dépassements occasionnels chez les poissons de grande taille.

- Among the legacy persistent organic contaminants, HCH and DDT are showing the strongest trends of decline in lake trout (fillet) and burbot (liver) in fish caught from the West Basin and East Arm of Great Slave Lake.
- PCBs, chlordane, and dieldrin are showing a significant trend of decline in West Basin trout but not East Arm trout and, with the exception of dieldrin, East Arm burbot.
- CBz is showing a general decline in burbot and a general increase in lake trout although trends are significant only for West Basin lake trout and East Arm burbot

- Chez des spécimens de touladi (filet) et de lotte (foie) capturés dans le bassin ouest et le bras est du Grand lac des Esclaves, on constate que les concentrations de HCH et de DDT affichent les plus fortes tendances à la baisse parmi les concentrations de contaminants organiques persistants légués du passé.
- Les concentrations de PCB, de chlordane et de dieldrine connaissent une tendance significative à la baisse chez le touladi du bassin ouest, mais non chez le touladi du bras est. Dans le bras est, cependant, on n'observe pas de tendance à la baisse des concentrations de dieldrine chez la lotte.
- On observe un déclin général des concentrations de CBz chez la lotte et une hausse générale chez le touladi; cependant, les tendances ne sont significatives que pour le touladi du bassin ouest et la lotte du bras est.

Objectives

- 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.
- Investigate factors affecting temporal variability in contaminants in lake trout and burbot including length, age, trophic feeding, and lipid levels.
- Participate in and contribute information to AMAP and CACAR expert work groups for trend monitoring for POPs and mercury.
- Communicate results to the communities and the commercial fisheries in a timely manner, including through the Northwest Territories Regional Contaminants Committee.

Introduction

The Northern Contaminant Program (NCP) was established to assess contaminant concentrations and pathways in Canada's north with an initial focus on persistent legacy organic contaminants with mercury, other metals and newer organic compounds such as PBDEs gaining greater predominance in the late 1990s. The overall goal of the program is to assess trends. With reductions in the usage of legacy organic contaminants, it is anticipated that concentrations of chemicals such as HCH, DDT and PCBs will decline in the environment, including biota. Conversely, the future with respect to mercury is less certain. While North America and Europe have implemented improvements in industrial technologies which have resulted in a reduction in their Hg emissions, these improvements may counterbalanced by the rapidly accelerating growth in Asian sources: Asian mercury emissions are now a major atmospheric source to North America (Muir et al. 2009; Dietz et al. 2009; Durnford et al. 2010; Jaffe and Strode 2008; Kirk et al. 2011).

Global warming is occurring at a particularly rapid rate in northern Canada (ACIA 2005; Latifovic and Poluiot 2007). This warming may result in an increase in the concentration of contaminants such as PCBs as warming temperatures enhance the release of such compounds from the watershed; increased productivity may result in atmospherically-transported contaminants being more effectively retained in aquatic ecosystems through their capture in organic matter and retention in sediments (Outridge et al. 2007; Carrie et al. 2010). However, increased productivity could result in a decrease in organic contaminant concentrations through the dilution of these contaminants in the larger pool of organic matter (Larsson et al. 1998; Berglund et al. 2001; Houde et al. 2008). Similarly, increases in fish growth rates as a result of increased warming and productivity could result in contaminant biodilution; relatively high mercury concentrations in northern predatory fish have in part, been related to their age and slow growth rates (Evans et al. 2005b).

Great Slave Lake, located in the Northwest Territories, is part of the NCP's long-term biomonitoring program which includes lake trout and burbot. The first measurements of persistent organic contaminants in fish occurred in 1993 with lake trout and burbot (in addition to whitefish and lower components of the food web) investigated in two regions of the lake (Evans 1994, 1995). Great Slave Lake's inclusion in the NCP program in the early 1990s was based on several considerations including its size, the fact that the majority of the Northwest Territories population lives along its shores (including a number of sizable First Nation communities), a commercial fishery operates on the lake, and it is relatively accessible. It is divided into two basins – the West Basin which is relatively shallow, warm and productive, and the East Arm which is deeper, colder, and less productive (Rawson 1955; Fee et al.1985). These basic features will affect contaminant pathways in a number of ways, e.g., persistent organic contaminant concentrations could be higher in biota in the low productivity waters of the East Arm than the higher productivity waters of the West Basin unless contaminant inputs from the Slave River counteract this. Mercury levels could be higher in the West Basin than the East Arm because of temperature, watershed, and productivity effects (Bodaly et al. 1993; Evans et al 2005 a,b) although this may be counteracted by the greater age of East Arm fish in the absence of a commercial fishery.

The formal trend monitoring program began in 1998 with lake trout (a pelagic, cold-water stenotherm) monitored at Lutsel K'e in the East Arm and from the commercial fishery operating out of Hay River in the West Basin; a relatively large record exists of mercury concentrations in fish harvested from the commercial fisheries with the records beginning in the late 1970s (Lockhart et al. 2005). Burbot, which is a more sedentary and warmer-water fish, was monitored at Fort Resolution (near the Slave River inflow) and at Lutsel K'e. Burbot monitoring at Fort Resolution to some extent allowed for an assessment of Slave River influences on contaminant loading to the lake as it was assumed that contaminant body burdens in Lutsel K'e fish would be primarily from atmospheric sources. Burbot monitoring at Lutsel K'e was not supported by NCP after 2009 due to budget considerations. Northern pike were monitored briefly over 1999-2002 at Fort Resolution under NCP. Other funding sources have allowed for a continuation of the burbot monitoring at Lutsel K'e and pike (mercury only) at Fort Resolution. In the West Basin, pike monitoring is allowing us to compare mercury trends in three species with different ecological niches while at Lutsel K'e we can compare lake trout and burbot captured from the same region. Furthermore, the Lutsel K'e burbot study allows for comparisons with trends being observed at Fort Resolution with assessments of Slave River influences. The Slave River is formed by the confluence of the Peace and Athabasca Rives and hence is under the influence of downstream activities including pulp and paper mills and oil sands activities (Evans yet al. 1996).

Activities in 2012-2013

Great Slave Lake and related - collections and biological measurements

In 2012-2013, 20 lake trout were collected from the domestic fishery at Lutsel K'e area (East Basin) and from the commercial fishery operating out of Hay River (West Basin). In addition, 20 burbot were collected in the domestic fishery at Fort Resolution area (near the Slave River inflow, West Basin) and, with Cumulative Impact Monitoring Program (CIMP) funds, burbot from Lutsel K'e and northern pike from Fort Resolution. 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; pike from Fort Resolution were analyzed only for mercury. With the exception of persistent organic contaminants, all analyses of 2012 caught fish have been completed.

With George Low, Deh Cho AAROM Coordinator, Dehcho First Nations, and Mark Wasiuta Contaminants Officer, Department of Health and Social Services, we worked on the continued periodic assessment of mercury concentrations in Deh Cho Lakes. Some unanticipated delays were encountered in the receipt of samples and in setting up of our new mercury analyser which eventually were resolved with the manufacturer. 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.

Capacity Building and Traditional Knowledge

Because our studies are based on the simple collections of a relatively small number of fish from the domestic fishery, opportunities for capacity building are limited. Traditionally, such building has occurred through our interactions with the environmental committees with whom we deal. These interactions have been successful and have led to successful submissions to the Cumulative Impact Monitoring Program (CIMP) which, in turn, are providing for greater community training and involvement in monitoring. This NCP study is contributing to three of these CIMP projects.

At Fort Resolution, we helped initiate a water quality monitoring program in late summer 2012 at the domestic intake. The overall goal was to track seasonal and annual changes in water quality including temperature, turbidity, plants nutrients, and phytoplankton. Monitoring at water intakes has been successfully used for decades to track trends in water quality in the Great Lakes. In late August, we also ran a workshop in Fort Resolution which discussed limnological sampling in Great Slave Lake and was attended by representatives from Lutsel K'e, Smith's Landing, Fort Resolution and Yellowknife. It was organized by Diane Giroux, AAROM Coordinator, Fort Resolution. Lutsel K'e has its own CIMP monitoring program; we provided support and advice on the water quality sampling when asked. We also contributed also contributed to George Low's (Deh Cho AAROM Coordinator, Hay River), CIMP and NCP programs. Finally, we provided support to a student enrolled at Aurora Community College in Fort Smith who was conducting a project on mercury levels in fish from Tsu Lake. Initially we provided example data to use in a preliminary report and then mercury analyses of fish that she had collected from Tsu Lake.

Communications

As part of our collaborative studies of mercury concentrations and trends in fish in the Deh Cho lakes led by George Low, Marlene participated a very successful two-day workshop on "A Return to Country Food" over August 21 and 22 in Jean Marie River with training in lake sampling provided on the 23rd ; there she gave the presentation on "Mercury Studies in Fish in the Deh Cho" speaking on mercury in the environment and the specific findings for nine lakes utilized by Wrigley, Fort Simpson, Fort Providence, Jean Marie River, Trout Lake and Kakisa.

In Hay River, Marlene met with Chris Heron with the Hay River Métis to discuss the NCP Great Slave Lake monitoring program and possibilities for developing new proposals (submitted either to NCP or CIMP) to address community concerns and interests. A similar meeting was held with the Katlodeeche First Nation.

A presentation was given in Fort Resolution on the highlights of the Great Slave Lake NCP studies; the meeting was open to all community members. As already noted above, a workshop on limnological sampling was held during this visit. Marlene also met with the Akaitcho Aquatic Monitoring Program (AAMP) Technical Board and discussed possible future studies with Fort Resolution, Yellowknife, Lutsel K'e and Smith's Landing.

We continued to contribute to CACAR and CARA expert work groups (Douglas et al. 2012) including a CARA (DePew et al. 2012) and a chapter discussing temporal trends in mercury in biota through Canada, including the north.

Results and Discussion

Mercury trend monitoring

Mercury trend monitoring has continued with analytical results available to 2012. Earlier records exist from the commercial fisheries (Evans et al. 2005a,b: Lockhart et al. 2005); mercury concentrations also were measured in fish from Resolution Bay over 1992-1993 (Lafontaine 1997) with these data supplementing NCP-supported studies in this area (Evans et al. 1998 a, b). Some archived fish which were not previously analyzed for mercury were analyzed. Overall, lake trout harvested from the West Basin and East Arm are showing a long-term trend of increase (Fig. 1); with the exception of West Basin lake trout in 2007 and 2008, average mercury concentrations of provided fish were less than 0.2 µg/g with mercury rarely exceedingly 0.5 µg/g; such fish were large. Various statistical analyses of these data have been conducted; models which include fish length and year length are statistically significant for West Basin lake trout ($R2 = 0.60$, $p<0.0001$) and large (> 590 mm fork length; $R2 = 0.40$, $p<0.0001$) East Arm lake tout (Evans et al. unpublished manuscript).

Burbot for the West Basin and East Arm also are showing a trend of increase basin over the available record (West Basin $R2 = 0.30$, $p<0.0001$; East Arm $R2 = 0.24$, $p<0.0001$). However average mercury concentrations were generally below 0.2 µg/g; mercury concentrations rarely exceeded 0.5 µg/g. This is in contrast to burbot harvested from the Mackenzie River at Fort Good Hope where mercury concentrations in fillet have been averaging 0.35-0.45 µg/g in recent years (Stern 2012).

Highest mercury concentrations were observed in West Basin northern pike. Northern pike are generally a nearshore species with Rawson (1951) reporting that 90% of the Great Lakes population resides within 0.5 km of shore. Pike also inhabit rivers which flow into Great Slave Lake including the Little Buffalo River (Scott and Crossman; Evans et al. 1998a) which discharges into Resolution Bay. Higher mercury concentrations in pike than burbot and lake trout may be associated with their more nearshore habitat and proximity to sites of mercury methylation production and/or input. However, there was no trend of mercury increase when analyses where limited to fish captured from Resolution Bay (Evans et al., unpublished manuscript).

Persistent organic contaminants trend monitoring

Several legacy persistent organic contaminants continue to decline in concentration in lake trout fillet and burbot liver at the two study locations (Fig. 2). Statistical analyses to investigate time trends have been initiated on these data sets with year and length considered as independent variables. As these analyses are ongoing only highlights and preliminary results are reported here. The decline has been strongest for HCH which has decreased ca. 10-fold in concentration since 1993; this decline is statistically significant ($p< 0.001$) for both species and locations. DDT also has shown a steady and ca. 3-fold decrease in concentration in both species and the two regions of the lake years. While chlordane has shown a significant decline in burbot at both locations ($p<0.003$) and lake trout (<655 mm total length) in the West Basin, it has not declined in lake trout from the East Arm where there is some evidence of increasing concentrations in recent years. While the trends are weaker, PCBs have declined in burbot in the East Arm and West Basin ($p<0.001$). PCBs have not declined in East Arm lake trout but have in West Basin lake trout (1998-2011) when fish length also is considered ($p=0.03$).

CBz concentrations were low in burbot in the 1990s, high in the early 2000s and have generally declined in recent years (Fig. 3). However temporal trends were not significant for East Arm fish. While significant ($p=0.04$) for West Basin fish, year explained little (5%) of the overall variation in CBZ concentrations. CBZ has been showing a trend increase in lake trout from both locations since 2005: however, this trend was significant ($p= 0.006$) only for West Basin trout. Dieldrin concentrations are showing evidence of a decline in West Basin lake trout and burbot since higher concentrations in the 1990s ($p<0.001$) whereas no trend is evident in East Arm fish.

Conclusions

As reported in Evans and Muir (2012), mercury concentrations are showing significant trends of increase in lake trout and burbot in both regions of Great Slave Lake. However, concentrations remain low with only large fish periodically having concentrations which exceed 0.5 µg/g, the commercial sale guideline. Most legacy persistent organic contaminants are showing significant trends of decrease with the strongest decrease in HCH and DDT. PCBs, chlordane, and dieldrin declines are less apparent and consistent among species and locations. There is some evidence that CBz concentrations may be increasing in lake trout. With the data set now large enough to detect trends, continuing effort will focus on the drivers of these trends.

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 at the former community and lake trout and burbot at the later and Shawn Buckley for collecting lake trout at Hay River. Special appreciation also is extended to Diane Giroux, Akaitcho AAROM Coordinator, Fort Resolution and George Low, Deh Cho AAROM Coordinator, for organizing workshops to facilitate the exchange of information on this study and related mercury projects. The Cumulative Impact Monitoring Program (CIMP) provided support to this study for pike collections from Fort Resolution and burbot from Lutsel K'e and travel in August for training and various communications. Environment Canada supported mercury analyses of pike from Fort Resolution and mercury and organochlorine analyses of burbot from Lutsel K'e.

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Figure 1. 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) and Lafontaine (1998).

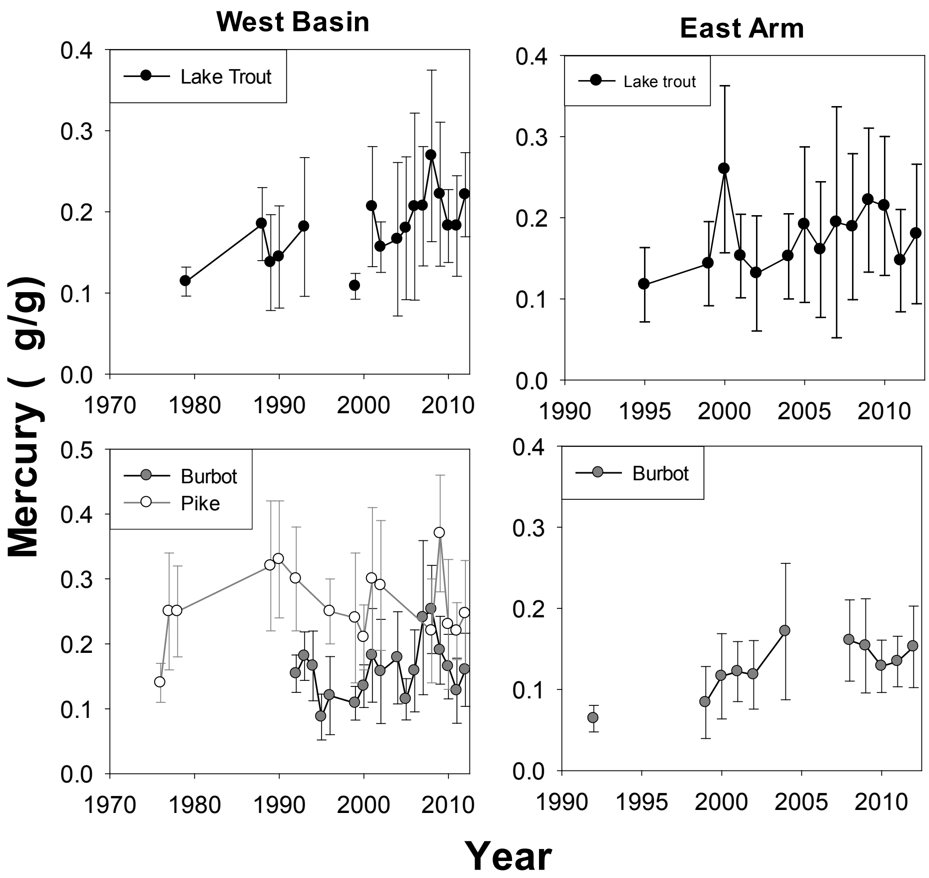


Figure 2. Time trends in HCH, chlordane, DDT, and PCBs concentrations (wet weight) in lake trout (fillet) and burbot (liver) collected from the West Basin (black circle, solid line) and East Arm (white circle, dotted line). Data are shown as means ± 1 standard deviation

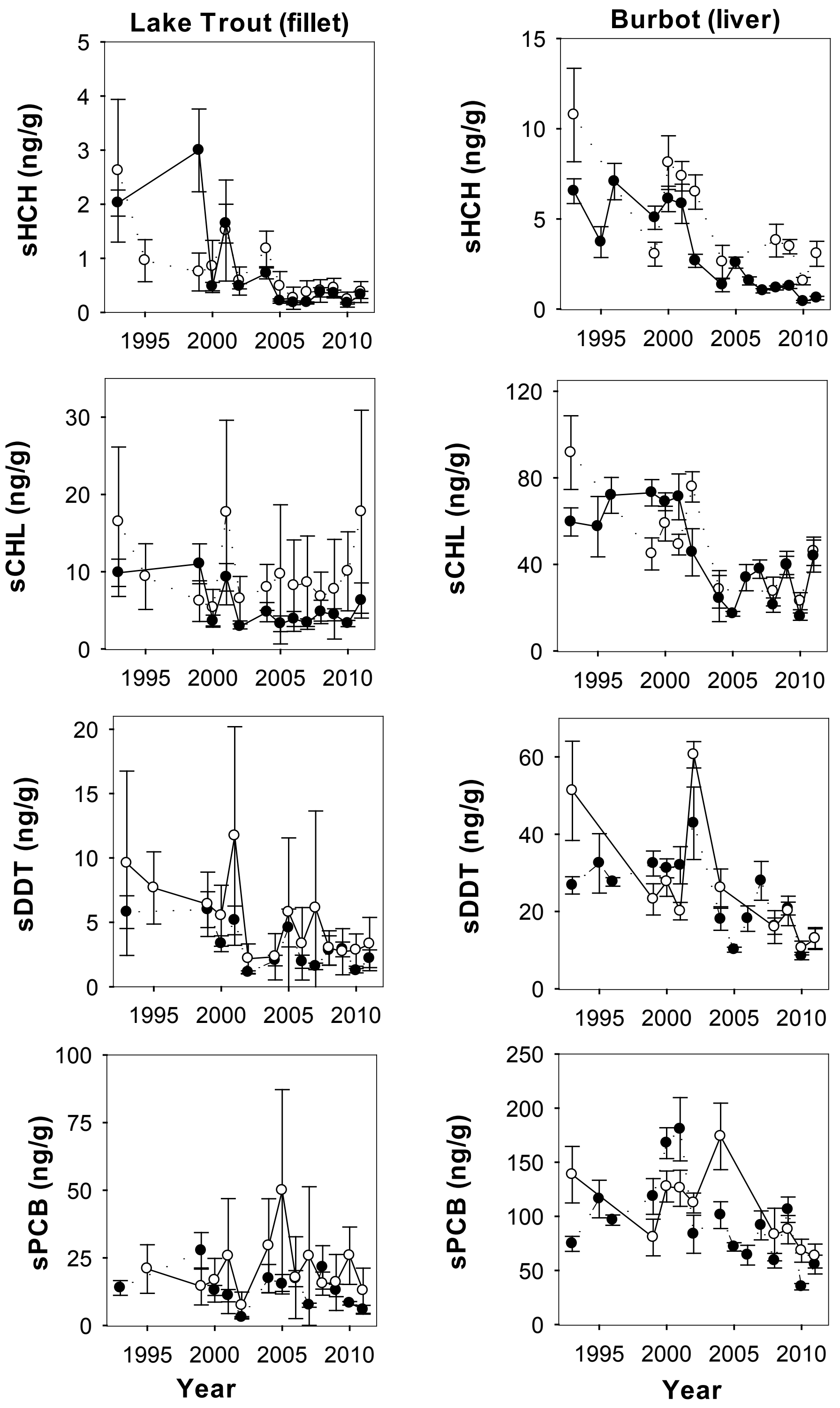
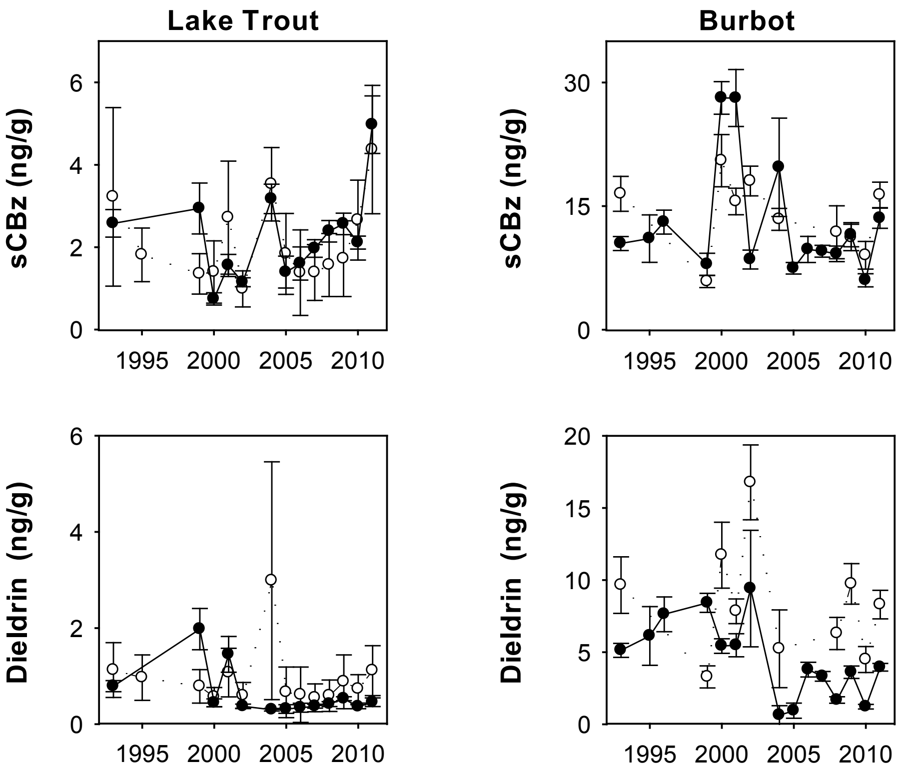


Figure 3. Time trends in CBz and dieldrin concentrations (wet weight) in lake trout (fillet) and burbot (liver) collected from the West Basin (black circle, solid line) and East Arm (white circle, dotted line). Data are shown as means ± 1 standard deviation



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 nouveaux et émergents, chez la lotte du fleuve Mackenzie à Fort Good Hope (T.N.-O.)

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Abstract

Tissues from burbot collected at Fort Good Hope (Rampart Rapids) in December 2012 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, 2011) and OC (1988, 1994, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011) together covering time spans of 27 and 24 years, respectively. No significant correlation between length and mercury concentration was observed with muscle or liver for either

Résumé

Des tissus de lottes capturées à Fort Good Hope (rapides Rampart) en décembre 2012 ont été analysés pour déterminer s'ils contenaient des contaminants organohalogénés (composés organochlorés, biphényles polychlorés [BPC], produits ignifuges bromés et composés organiques fluorés) et des métaux lourds (Hg/Se/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 2011) et les composés organochlorés (1988, 1994, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010 et 2011), couvrant des périodes respectives de 27 et de 24 ans. Aucune

sex. Mean Hg concentrations in muscle and liver over the entire data sets were 0.356 ± 0.138 (n = 545) and 0.092 ± 0.078 (n = 532) $\mu g\ g^{-1}$, respectively. Muscle mercury levels are below the recommended guideline level of 0.50 $\mu g\ g^{-1}$ 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.

corrélation significative entre la longueur des lottes et les concentrations de mercure n'a été observée dans les muscles et le foie chez les deux sexes. Les concentrations moyennes de Hg dans les muscles et le foie pour les ensembles complets de données étaient de 0,356 ± 0,138 µg g-1 (n = 545) et de 0,092 ± 0,078 µg g-1 (n = 532), respectivement. Les niveaux de mercure dans les muscles se situent sous le niveau recommandé dans les directives, qui est de 0,50 µg g-1 pour la vente commerciale. Les niveaux des congénères des principaux 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 ceux 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 niveaux de PFNA et de PFUA ont été à leur plus haut en 2003.

Key Messages

- Mean Hg concentrations in muscle and liver over the entire data sets were 0.356 ± 0.138 (n = 545) and 0.092 ± 0.078 (n = 532) mg g-1, respectively.
- Since the mid-1980s, 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 mg g-1 for commercial sale.
- Significant declines, 10- and 4-fold, occurred for both a- and g-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 SPBDE 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

Messages clés

- Les concentrations moyennes de Hg dans les muscles et le foie de la lotte pour les ensembles complets de données étaient de 0,356 ± 0,138 µg g-1 (n = 545) et de 0,092 ± 0,078 µg g-1 (n = 532), respectivement.
- Depuis le milieu des années 1980, une augmentation de deux à trois fois environ des concentrations de mercure a été mesurée dans les muscles et dans le foie, respectivement, de la lotte de Fort Good Hope.
- Les niveaux de mercure dans les muscles et dans le foie de la lotte se situent sous le niveau recommandé dans les directives, qui est de 0,50 µg g-1 pour la vente commerciale.
- Des baisses importantes, de 10 et de 4 fois, des α-HCH et γ-HCH sont survenues au cours de la période de 23 ans entre 1988 et 2011.
- Les concentrations de PBDE semblent avoir atteint un pic au milieu des années 2000 et sont maintenant en déclin.

consistent increase overtime. PFNA and PFUA levels peaked in 2003.

- Les niveaux actuels de ΣPBDE sont environ d'un ordre de grandeur moindre que ceux 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 niveaux de PFNA et de PFUA ont été à 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 2012/13

In December 2012, 40 burbot were collected from the Mackenzie River at Fort Good Hope (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 26 years and 17 time points (1985, 1988, 1993, 1995, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012). Mean Hg concentrations in muscle and liver over the entire data sets were 0.356 ± 0.138 (n = 545) and 0.092 ± 0.078 (n = 532) mg g^{-1}, respectively. Mercury levels in muscle are below the recommended guideline level of 0.50 mg g^{-1} for commercial sale.

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-1980s. 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 mg g^{-1}, occurred in a muscle sample from a female burbot collected in 1999.

Table 1. Mean (standard deviation) concentrations of mercury, selenium and arsenic in Fort Good Hope burbot muscle (mg g-1).

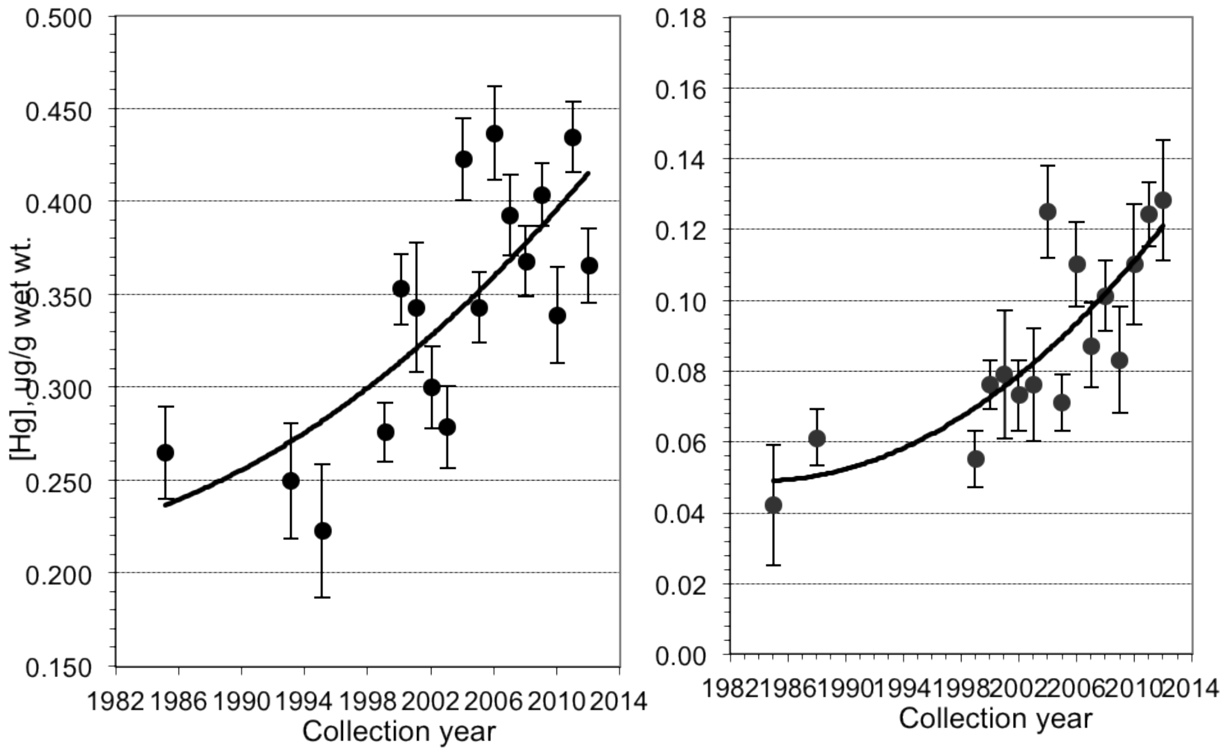
Collection	Sex	n	Length	Hg	Se	As
Apr851	M	10	633 (84)	0.222 (0.035)	0.358 (0.087)	-
Dec-93	M	7	677 (109)	0.231 (0.113)	0.534 (0.163)	2.291 (3.151)
Sept-95	M	2	-	0.265 (0.035)	-	-
Dec-99	M	21	676 (107)	0.286 (0.095)	0.395 (0.107)	0.637 (0.637)
Dec-00	M	21	699 (104)	0.345 (0.097)	0.478 (0.136)	1.333 (1.944)
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	701 (112)	0.418 (0.141)	0.481 (0.112)	0.681 (0.838)
Dec-12	M	8	713 (77)	0.313 (0.074)	0.408 (0.163)	1.854 (2.797)
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	725(108)	0.448 (0.106)	0.458 (0.146)	1.032 (1.355)
Dec-12	F	32	703 (119)	0.379 (0.137)	0.449 (0.148)	1.219 (2.147)

[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	701 (112)	0.119 (0.079)	2.333 (1.407)	-
Dec-12	M	8	713 (119)	0.063 (0.024)	1.946 (0.623)	0.456 (0.378)
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	725 (108)	0.128 (0.043)	1.664 (0.973)	-
Dec-12	F	32	703 (119)	0.144 (0.114)	2.730 (2.410)	0.409 (0.586)

Figure 1. Mean Hg concentrations in muscle (left) and liver (right) from Fort Good Hope burbot (males + females).



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.

Figure 2. Lipid normalized ΣHCH, α–, γ-HCH concentrations in FGH burbot liver (1988–2011)

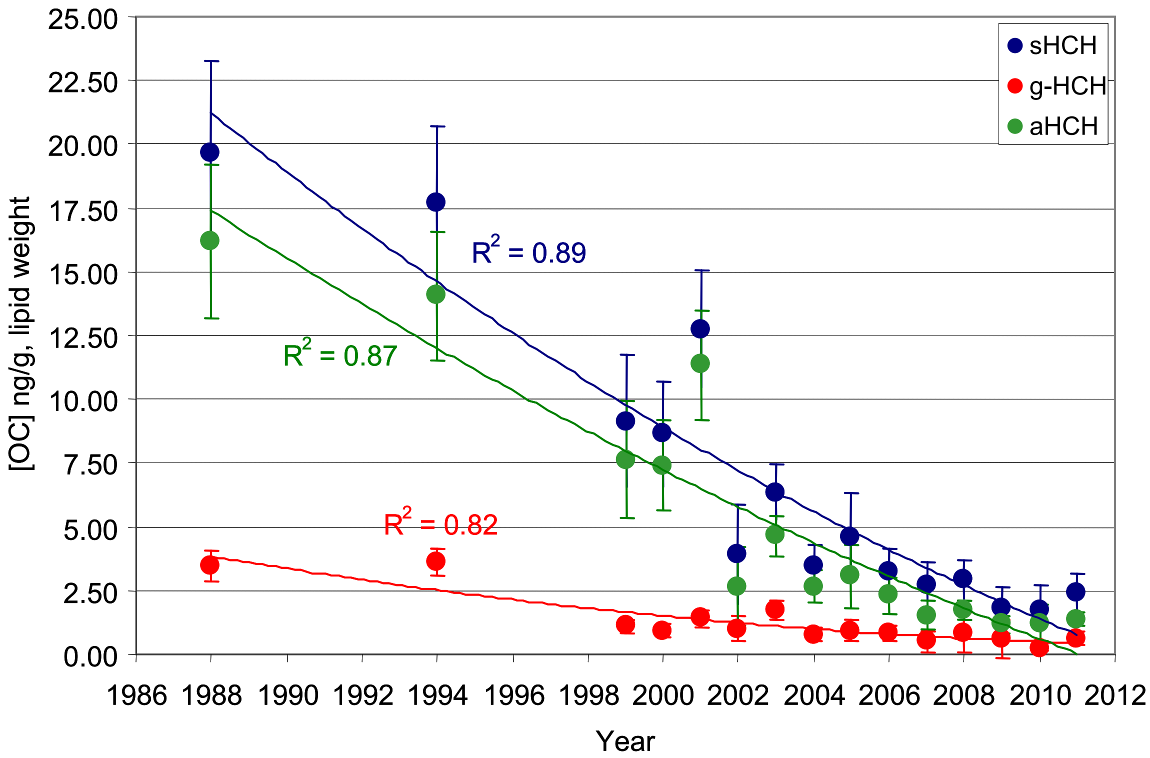


Table 3. OCs in Burbot liver from Fort Good Hope (mean and standard deviation, ng g-1, ww)

Year	sex	n	% Lipid	SCBz	SHCH	SCHL	SDDT	SPCB	SCHB	HCBz	Oxychlor
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	8	25.57 (13.71)	2.25 (1.89)	0.42 (0.22)	17.32 (18.06)	20.39 (14.77)	32.48 (19.12)	127.90 (116.51)	2.16 (1.85)	3.26 (3.28)
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	10	32.83 (10.10)	4.78 (2.93)	0.55 (0.38)	20.85 (24.11)	27.71 (17.08)	105.94 (54.79)	107.32 (138.18)	4.42 (2.72)	4.48 (4.36)
2008	M + F	9	35.35 (14.46)	8.42 (2.56)	1.13 (0.45)	14.79 (9.52)	37.62 (16.83)	99.48 (52.60)	274.87 (201.36)	5.96 (2.33)	3.28 (2.44)
2009	M + F	10	37.64 (12.16)	5.80 (2.20)	0.72 (0.29)	16.21 (12.45)	27.13 (18.18)	45.59 (25.64)	114.65 (92.19)	5.27 (2.04)	2.85 (2.64)
2010	M + F	9	44.44 (12.54)	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)	20.26 (24.86)	51.90 (40.81)	114.06 (96.09)	5.22 (3.49)	6.03 (4.64)
2012	M + F	9	32.44 (6.67)	5.45 (5.31)	1.04 (0.74)	17.85 (21.18)	21.40 (31.35)	48.55 (53.13)	159.62 (185.33)	5.20 (5.15)	4.25 (4.96)

Table 4. Lipid normalized OCs concentrations in Burbot liver from Fort Good Hope (mean and standard deviation, ng g^{-1})

Year	sex	n*	SCBz	SHCH	a-HCH	g-HCH	SCHL	SDDT	SPCB	SCHB	Oxychlor
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	8	8.37 (1.66)	1.69 (0.16)	1.32 (0.12)	0.38 (0.12)	66.92 (22.01)	84.11 (18.34)	128.73 (28.13)	441.62 (145.54)	12.69 (3.78)
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	10	13.77 (4.84)	1.53 (0.67)	0.85 (0.59)	0.36 (0.32)	58.65 (55.31)	85.34 (41.78)	327.05 (140.00)	291.59 (321.48)	12.73 (9.75)
2008	M + F	8	23.04 (5.10)	3.03 (0.75)	1.69 (0.38)	0.96 (0.78)	41.20 (27.52)	102.71 (52.23)	283.38 (200.07)	803.57 (648.64)	9.54 (8.29)
2009	M + F	9	15.69 (4.96)	2.00 (0.53)	1.37 (0.26)	0.54 (0.34)	45.98 (31.32)	80.36 (39.42)	138.68 (87.32)	321.38 (222.39)	8.17 (7.42)
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	12.42 (6.55)	2.40 (0.74)	1.39 (0.29)	0.63 (0.54)	49.36 (35.55)	60.01 (68.37)	136.85 (125.72)	276.71 (222.36)	14.41 (10.14)
2012	M+F	9	15.59 (11.06)	3.07 (1.46)	2.62 (1.46)	0.45 (0.21)	57.73 (79.68)	72.71 (124.51)	155.87 (196.88)	503.32 (671.88)	13.90 (19.19)

* only liver samples with lipid > 10 % included.

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
2012	M+F	10	7.62 (7.32)	4.52 (8.19)	4.31 (8.19)	6.83 (6.76)	0.93 (1.38)	24.21

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.

Expected Project Completion Date

Temporal trend studies are long-term propositions and thus annual sampling is projected into the foreseeable future

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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 organohalogénés de poissons de certains lacs 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 19 years, 16 and 14 time points, respectively. Mean Hg levels over the entire data sets for the Laberge and Kusawa samples were 0.49 ± 0.22 (n=154) and 0.39 ± 0.24 (n=133) mg g-1, respectively. In both lakes, levels are below the recommended guideline level of 0.50 mg g-1 for commercial sale. No significant trends have been observed in the Laberge lake trout Hg levels over the last 19 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

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 19 ans et est constituée de 16 dates d'échantillonnage pour le lac Laberge et de 14 dates pour le lac Kusawa. Pour l'ensemble des données, la concentration moyenne de Hg est de 0,49 ± 0,22 mg g-1 (n = 154) dans le lac Laberge et de 0,39 ± 0,24 mg g-1 (n = 133) dans le lac Kusawa. Dans les deux lacs, la concentration est inférieure à celle recommandée dans les directives, qui est de 0,50 mg g-1 pour la vente commerciale. Au cours des 19 dernières années, aucune tendance significative des concentrations de

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.

Hg dans les touladis du lac Laberge n'a été observée. Quant au lac 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, les concentrations d'organochlorés corrigées en fonction de la teneur en lipide ont recommencé à augmenter vers 2003-2004, après une baisse rapide. On a noté une variation significative dans les 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 19 years, 16 and 14 time points, respectively
- The mean Hg levels over the entire data sets for the Laberge and Kusawa samples were 0.49 ± 0.22 (n=154) and 0.39 ± 0.24 (n=133) mg g-1, respectively. In both lakes, levels are just below the recommended guideline level of 0.50 mg g-1 for commercial sale.
- No significant trends have been observed in the Laberge lake trout Hg levels over the last 19 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 again around 2003/04. Significant variability in the Laberge samples is observed and as a result no temporal trends are evident.

Messages clés

- La série chronologique des teneurs en métaux lourds du muscle des touladis s'étend sur 19 ans et est constituée de 16 dates d'échantillonnage pour le lac Laberge et de 14 pour le lac Kusawa.
- Pour l'ensemble des données, la concentration moyenne de Hg est de 0,49 ± 0,22 mg g-1 (n = 154) dans le lac Laberge et de 0,39 ± 0,24 mg g-1 (n = 133) dans le lac Kusawa. Dans les deux lacs, la concentration se situe immédiatement sous le niveau recommandé dans les directives, qui est de 0,50 mg g-1 pour la vente commerciale.
- Au cours des 19 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 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, les concentrations d'organochlorés corrigées en fonction de la teneur en lipide ont recommencé à augmenter vers 2003-2004, après une baisse rapide. On a noté une variation significative dans les 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 2012/13

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 2012, 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 19 years, 16 and 14 time points, respectively (Table 1). Mean Hg concentrations in the 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 0.49 ± 0.22 (n=154) and 0.39 ± 0.24 (n=133) mg g-1, respectively. In both lakes, levels are just below the recommended guideline level of 0.50 mg g-1 for commercial sale. A significant correlation between length and muscle mercury concentration was observed in the Laberge ([HgT] = m*length + b, m=0.0013, b=-0.2892, r2 = 0.59, p<0.001, n=143) and Kusawa ([Hg] = m*length + b, m=0.0018, b=-0.5046, r2 = 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.

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.

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.

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.

2012 (n=10); PFOS = 1.98 (1.89); PFNA = 5.61(12.17); PFDA = (non detect) 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.

2012 (n=10); PFOS = 0.31 (0.67); PFNA = 3.51(4.12); PFDA = 1.37 (4.23) 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 1. Mean (standard deviation) concentrations of mercury, selenium and arsenic in lake trout muscle from Laberge and Kusawa Lakes. All levels are in mg/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)
	2012	10	579 (47)	0.63 (0.24)	0.46 (0.06)	0.07 (0.02)
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)
	2012	10	433 (47)	0.53 (0.13)	0.54 (0.13)	0.04 (0.03)

Figure 1. Length adjusted Hg concentrations in trout muscle from Lake Laberge (1993-2012) and Kusawa (1993–2012). Only Kusawa trout less than 700 mm in length were used in the ANCOVA.

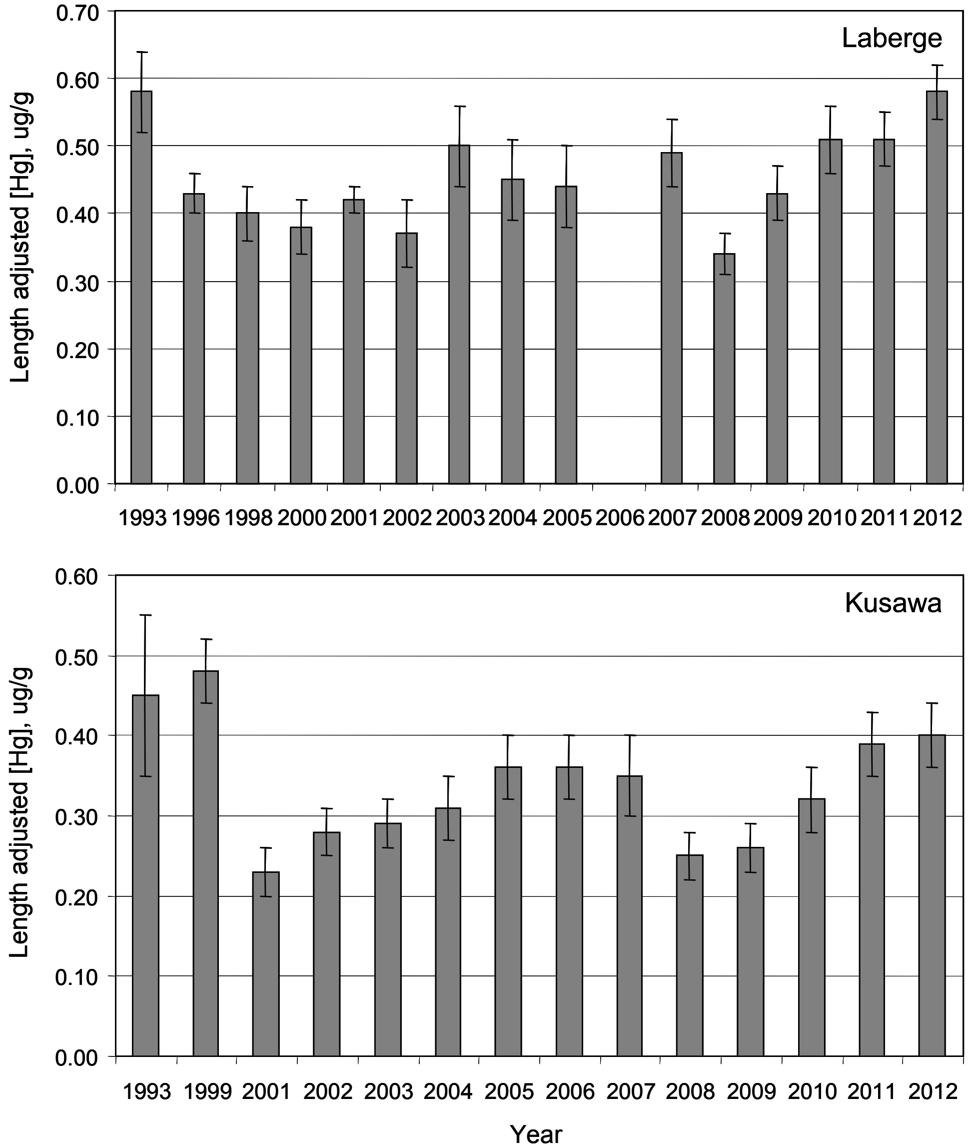


Table 2. Mean (S.D.) HOC levels (ng/g wet wt.) in lake trout muscle from Lake Laberge

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)
2012	10	11 (5)	2.0 (1.2)	31.80 (20.61)	20.24 (9.62)	2.14 (1.49)	0.13 (0.08)	11.57 (7.37)	0.65 (0.25)

Table 3. Mean (S.D.) OC levels (ng/g wet wt.) in lake trout muscle from Kusawa Lake

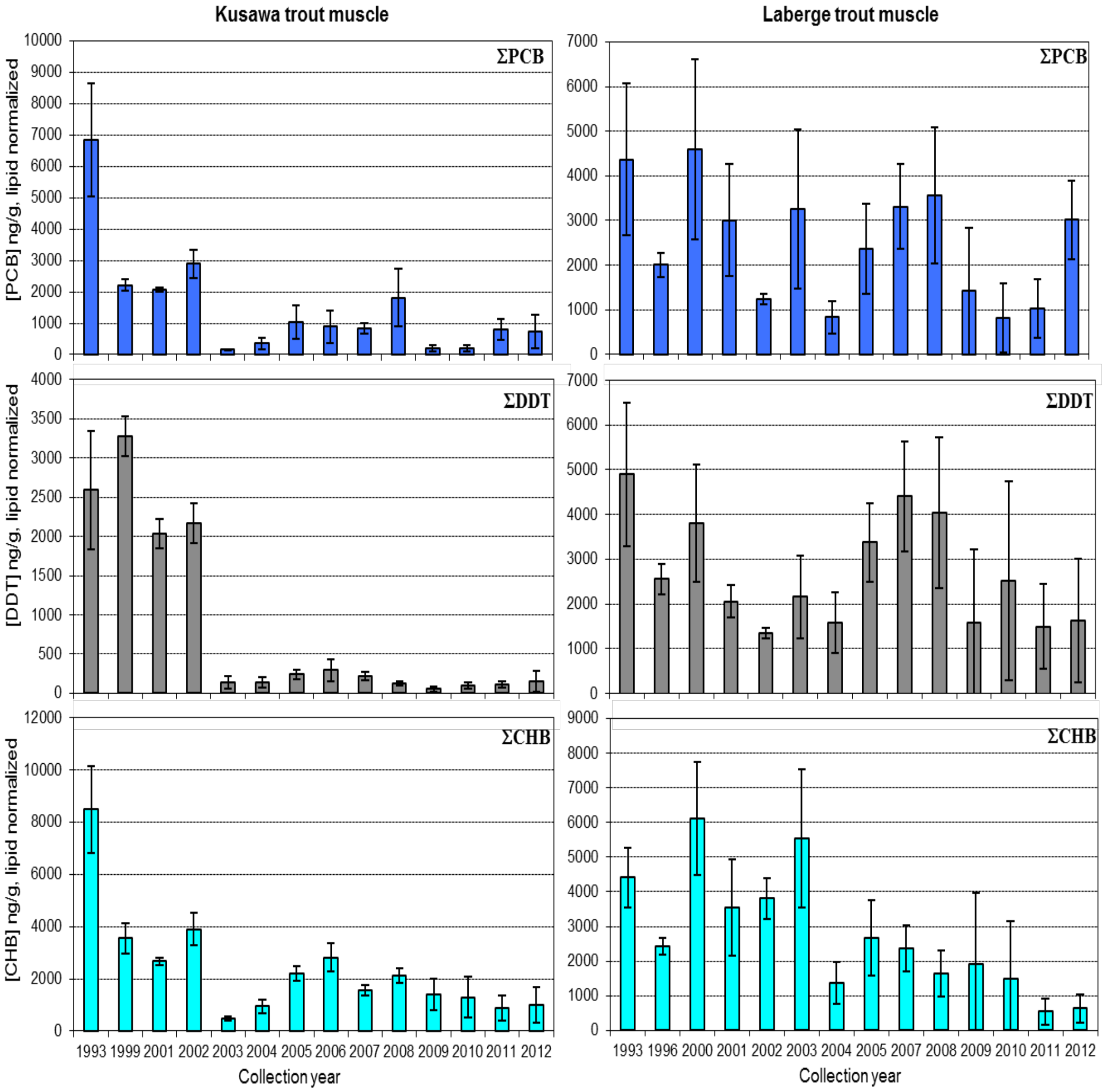
Kusawa	N	Age	% lipid	SPCB	SDDT	SCHL	SHCH	SCHB	SCBz
1993	10	19 (2)	1.8 (1.6)	85.62 (26.07)	44.16 (21.50)	17.33 (2.78)	1.21 (0.36)	120.80 (24.94)	1.15 (0.28)
1999	14	18 (1)	4.6 (3.0)	91.09 (11.85)	139.16 (19.72)	17.82 (2.74)	1.68 (0.23)	148.38 (29.29)	1.52 (0.20)
2001	9	12 (1)	2.4 (1.4)	48.55 (7.91)	56.58 (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)
2012	10	10 (4)	1.5 (1.1)	8.48 (4.47)	1.70 (0.90)	1.68 (0.83)	0.15 (0.11)	13.10 (9.96)	0.74 (0.33)

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)
	2000	6	0.5 (0.3)	4900 (1680)	2100 (240)	8590 (1170)	3380 (630)	5740 (1320)	4460 (1190)
	2003	8	0.4 (0.2)	3170 (1430)	1290 (750)	5890 (2860)	2450 (1200)	3920(4050)	3200 (2810)
	2005	10	2.0 (1.2)	2659 (1977)	165 (117)	4093 (2389)	1848 (1235)	740 (580)	986 (732)
	2006	1	1.0	24920	1630	35900	11370	4120	3240
	2007	9	1.2 (0.8)	5500 (901)	1100 (1130)	9680 (1627)	6700 (5850)	200 (560)	1900 (1450)
	2008	10	2.3 (1.1)	2389 (1207)	2175 (1476)	1721 (1222)	139 (99)	258 (152)	560 (211)
	2009	10	2.9 (1.1)	1590 (1815)	1546 (1476)	2799 (1165)	1421 (729)	347 (141)	250 (355)
	2010	10	2.3 (1.3)	2907 (3266)	2640 (2525)	3124 (3989)	1271 (1457)	365 (487)	566 (646)
	2011	10	2.2 (1.0)	525 (700)	320 (280)	629 (994)	229 (339)	82 (115)	131 (193)
Kusawa	1999	10	3.0 (2.2)	4377 (2490)	nd	3636 (2011)	2573 (1623)	894 (622)	1495 (895)
	2001	10	2.8 (1.6)	700 (990)	130 (160)	720 (1090)	250 (250)	260 (480)	230 (330)
	2003	5	0.2 (1.1)	960 (1220)	360 (47)	2630 (3510)	950 (1260)	1180 (1590)	870 (1150)
	2006	9	1.8 (1.5)	1103 (1231)	66 (99)	824 (911)	446 (514)	136 (140)	202 (236)
	2007	9	1.6 (1.4)	9900 (1216)	300 (700)	12300 (1271)	3900 (5990)	1100 (830)	600 (790)
	2008	10	1.2 (0.4)	4178 (1781	648 (240)*	1653 (1394)	294 (113)	58 (103)	1653 (609)
	2009	10	1.5 (1.1)	417 (135)	73 (88)	273 (106)	121 (53)	27 (10)	69 (38)
	2010	10	1.9 (1.6)	359 (640)	231 (471)	252 (510)	138 (283)	33 (64)	65 (124)
	2011	10	0.8 (0.5)	240 (110)	70 (130)	180 (100)	80 (40)	70 (50)	60 (50)
Quiet	1992	6	2.5 (0.7)	25 (20)	nd	18 (31)	3 (5)	6 (6)	11 (14)
	2001	5	0.9 (0.9)	28 (40)	nd	19 (32)	8 (10)	11 (7)	12 (14)
	2003	5	0.1 (0.1)	51 (106)	7 (4)	127 (273)	18 (41)	32 (71)	17 (35)

nd = non detect

Figure 2. Lipid adjusted OC group concentrations in trout muscle from Kusawa and Laberge (1992-2012).



Arctic caribou contaminant monitoring program

Programme de surveillance des contaminants

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Abstract

This project studies contaminant levels in caribou in the Canadian Arctic to determine if these populations remain healthy (in terms of contaminant loads), whether these important resources remain safe and healthy food choices for northerners and if contaminant levels are changing over time. In 2012/13 samples were collected from 20 Porcupine and 20 Qamanirjuaq caribou. The Qamanirjuaq samples were collected in the spring and had not been analyzed at the time this report was prepared. Arsenic and lead concentrations decreased significantly over time in Porcupine caribou kidneys, although the absolute declines were small, possibly reflecting an increased ability in laboratory detection of

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 (du point de vue des 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 20122013, on a prélevé des échantillons sur 20 caribous de la harde de Porcupine et sur 20 caribous de la harde de Qamanirjuaq. Les échantillons provenant de la harde de Qamanirjuaq ont été prélevés au printemps et n'avaient pas encore été analysés au moment de rédiger le présent rapport. La concentration d'arsenic et de plomb a diminué de manière

smaller amounts of these elements as well as an increase in precision and accuracy of measurement rather than actual declines in the caribou over time. Renal lead concentrations in these caribou may also be affected by the reduction of the use of unleaded gasoline after the prohibition of leaded gasoline in Canada in 1990. Although other elements of interest (cadmium, copper, mercury, selenium, zinc) did not show overall increasing or decreasing trends, inter-annual variation in element concentration was common and may be of particular interest in the case of mercury, where that variation may offer insight into potential drivers of these elements in caribou. The inter-annual variation seen in mercury levels in the Porcupine caribou herd seems to be at least somewhat cyclic and is likely affected by atmospheric patterns of deposition of Hg as well as local environmental conditions affecting Hg concentrations in winter forage in conjunction with forage availability and selection by the caribou. This includes timing of green-up in the spring and the subsequent switch to lower-mercury forages and could therefore potentially be impacted by a changing climate. Levels of most elements measured in Porcupine caribou 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.

significative au fil du temps dans les reins des caribous de la harde de Porcupine, bien que la diminution absolue soit légère, peut-être en raison de la capacité accrue des laboratoires de détecter de petites quantités de ces éléments, avec plus de précision et d'exactitude, plutôt qu'en raison d'une réelle diminution chez le caribou au fil du temps. Chez ces caribous, la concentration de plomb dans les reins peut aussi s'expliquer par la réduction de l'utilisation de l'essence sans plomb après l'interdiction de l'essence au plomb au Canada en 1990. Bien qu'on n'ait pas relevé de tendance générale à la hausse ou à la baisse en ce qui concerne d'autres éléments d'intérêt (cadmium, cuivre, mercure, sélénium, zinc), on a souvent relevé une variation interannuelle de concentration, ce qui est particulièrement intéressant dans le cas du mercure, puisque cette variation peut constituer un indice pour cerner les causes possibles de la présence de ces éléments dans les tissus du caribou. La variation interannuelle observée dans la concentration de mercure chez les caribous de la harde de Porcupine semble plutôt cyclique et dépend probablement des schémas de dépôt atmosphérique du Hg et des conditions environnementales locales qui se répercutent sur la concentration de Hg dans le fourrage d'hiver, facteurs qui se conjuguent à la disponibilité du fourrage et à sa sélection par les caribous. Le moment de la feuillaison printanière qui marque le passage à des fourrages contenant moins de mercure joue, et des changements climatiques pourraient donc avoir une incidence. La concentration de la majorité des éléments mesurés dans les échantillons prélevés chez des caribous de la harde de Porcupine ne soulève pas de préoccupations sur le plan toxicologique, 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. Santé Yukon conseille de réduire la consommation de rein et de foie de caribou du Yukon, la quantité maximale recommandée variant selon la harde (p. ex., 32 reins par an dans le cas de la harde de Porcupine). L'avis de santé publique confirme que les métaux lourds sont présents en très faibles quantités dans la viande (muscle) du caribou et que le caribou demeure un bon aliment pour la santé.

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 appears to undergo a cycle. More research is required to determine drivers of the cycle and mercury dynamics within the caribou food chain.

Messages clés

- Les concentrations de la plupart des éléments mesurés dans les tissus de caribou ne sont pas préoccupantes, bien que celles du mercure et du cadmium dans les reins puissent l'être 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 de 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 subissent 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.

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 2012/13

Samples were collected from 20 Porcupine caribou in the fall of 2012 by Environment Yukon staff as part of a Yukon Government initiative working with hunters in Old Crow to study body condition in the Porcupine caribou herd. Only three samples were collected from the Qamanirjuaq caribou herd in Arviat in the fall of 2012 due to poor weather conditions and changes in the herd's migration close to that community. However, samples from 50 Qamanirjuaq caribou from the spring of 2012 were acquired from a GNWT project studying body condition in that herd. Twenty samples from this collection were chosen to fulfill the 2012 requirement for these caribou.

As of April 2013, only the Porcupine caribou samples have been analyzed and are presented. Samples from the Qamanirjuaq herd are in the process of being 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). Incisors from the Qamanirjuaq caribou herd were aged by Matson's Laboratory (Milltown, Montana).

Although kidneys were analyzed for 34 elements, only results for 7 elements of concern were statistically analyzed in detail (arsenic, cadmium, copper, lead, mercury, selenium and zinc). Temporal trends were assessed for the Porcupine caribou using a general linear model. Only males were considered since all samples collected in the fall of 2012 were male. 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.

Capacity Building

This year provided few opportunities for capacity building and training, since the project was limited to collections from the two caribou herds by territorial agencies in cooperation with local hunters. However, results of past years of this project were presented to several venues in Whitehorse including Yukon College and an experiential high school in which the students were very engaged.

Communications

Results and conclusions from this ongoing program were presented in poster format at the NCP Science Event in Whitehorse, YT in October, 2012 and at the Biodiversity Forum presented by Yukon College in November, 2012. A presentation was also made to an experiential science high school class (Wood St. School, Whitehorse) in October, 2012 which was very well received. This program was discussed in several radio, newspaper and television interviews in October 2012.

Results of this project are communicated to the YCC and NAC by this report and will be presented at the NCP symposium scheduled for the fall of 2013. The project coordinator is available throughout the year to answer specific questions or address relevant issues from any of the participating groups or Regional Contaminants Committees as they arise. All data will be incorporated into the existing database for Canadian Arctic moose and caribou contaminants, currently maintained by INAC, Whitehorse. Plain language summaries, brochures and/or posters focussing on individual herds/populations will be prepared and circulated to stakeholder groups in cooperation with each Regional Contaminants Committee as requested. Special presentations may be made as the results dictate, or upon request, in cooperation with the Regional Contaminants Committees. Data collected through this program were included in the most recent updates of the CACAR and AMAP reports. Results of this (and other related NCP projects) will be presented at the 2013 International Mercury Conference in Edinburgh, Scotland in July, 2013.

Although participating Government of Nunavut biologist (Mitch Campbell) has, in the past, included project results in ongoing communications with local communities and HTOs, the NAC has requested more direct contact with this program. This will be developed over the coming year and will include the production of brochures on contaminants in the Qamanirjuaq and Dolphin and Union caribou which have been in development for some time.

Although the data gathered through this program is the technical property of NCP, the data is being made available to participating researchers and communities for public information purposes. Publication of the data in scientific journals is the responsibility of the project leader. All researchers participating in this program have agreed to abide by the Northern Contaminants Program Data and Sample Accessibility Agreement.

Plans for the upcoming year (2013/14) were discussed with the Yukon Contaminants Committee, the NAC, First Nation traditional users of the caribou and related Resource Councils and Management agencies.

Traditional Knowledge Integration

This program relies on the traditional knowledge of both Aboriginal and non-Aboriginal people when collecting samples from caribou for analysis. In all cases local hunters use traditional knowledge when hunting caribou and ultimately submitting samples as well as providing food for their families.

Results

Results for the seven elements of interest are presented in Table 1. Renal mercury concentrations were negatively correlated with age while cadmium, selenium and zinc concentrations were positively correlated with age in male Porcupine caribou (Figure 1). Arsenic and lead concentrations decreased significantly over time (Figure 2), while none of the other elements studied (cadmium, copper, mercury, selenium, zinc) showed an overall trend over time in Porcupine caribou kidneys.

Discussion and Conclusions

As in previous years, year of collection was negatively correlated with renal arsenic and lead in male, fall-collected Porcupine caribou (Figure 2). However, the absolute declines are small and may reflect an increased ability for the laboratory detection of smaller amounts of these elements as well as an increase in precision and accuracy of measurement rather than actual declines in the caribou over time. It is notable that both arsenic and lead concentrations measured prior to 2004 were more erratic and variable whereas from 2004 to the present measured renal concentrations have been more consistent and relatively low. Renal lead concentrations in these caribou may also be affected by the reduction of the use of unleaded gasoline after the prohibition of leaded gasoline in Canada in 1990.

Renal cadmium, copper, mercury, selenium and zinc neither increased nor decreased significantly over time in the Porcupine caribou herd. However, inter-annual variation in element concentration was common and may be of particular interest in the case of mercury (Figure 3), where that variation may offer insight into potential drivers of this element in caribou. The inter-annual variation seen in mercury levels in the Porcupine caribou herd seems to be at least somewhat cyclic and is likely affected by atmospheric patterns of deposition of Hg as well as local environmental conditions affecting Hg concentrations in winter forage in conjunction with forage availability and selection by the caribou. This includes timing of green-up in the spring and the subsequent switch to lower-mercury forages and could therefore potentially be impacted by a changing climate.

Levels of most elements measured in the Porcupine caribou herd 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.

Data collected from this program continues to provide baseline data for contaminants in the Porcupine caribou as well as a valuable tissue archive for legacy and emerging contaminants. This tissue archive has recently been accessed to assess whether these caribou were affected by fallout from the recent nuclear accident in Fukushima, Japan (NCP project: Monitoring of Radioactivity in Caribou and Beluga in response to the Fukushima accident). The ongoing nature of this program provides security and confidence for northerners using caribou as a food source and acts as an early warning system for wildlife managers. The length and consistency of this program also provides a valuable database for exploring the dynamics of particular contaminants of concern (eg. mercury) within the terrestrial ecosystem. This program will continue to collect and analyze kidney samples from the Porcupine and Qamanirjuaq caribou herds (20 animals from each) in the coming fiscal year.

Table 1. Element concentration s (mg g^{-1} dry weight) in kidneys from male fall-collected Porcupine 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
2012	20	6.2	0.11 ± 0.11	34.7 ± 21.9	22.8 ± 2.1	0.09 ± 0.03	1.84 ± 0.70	4.8 ± 0.5	107.8 ± 9.3

*statistically significant decline over time ($p<0.05$)

Figure 1. Renal element concentrations in male Porcupine caribou, collected fall, 1993-2012. Cadmium, zinc and selenium were positively correlated with age while mercury was negatively correlated with age (p<0.05).

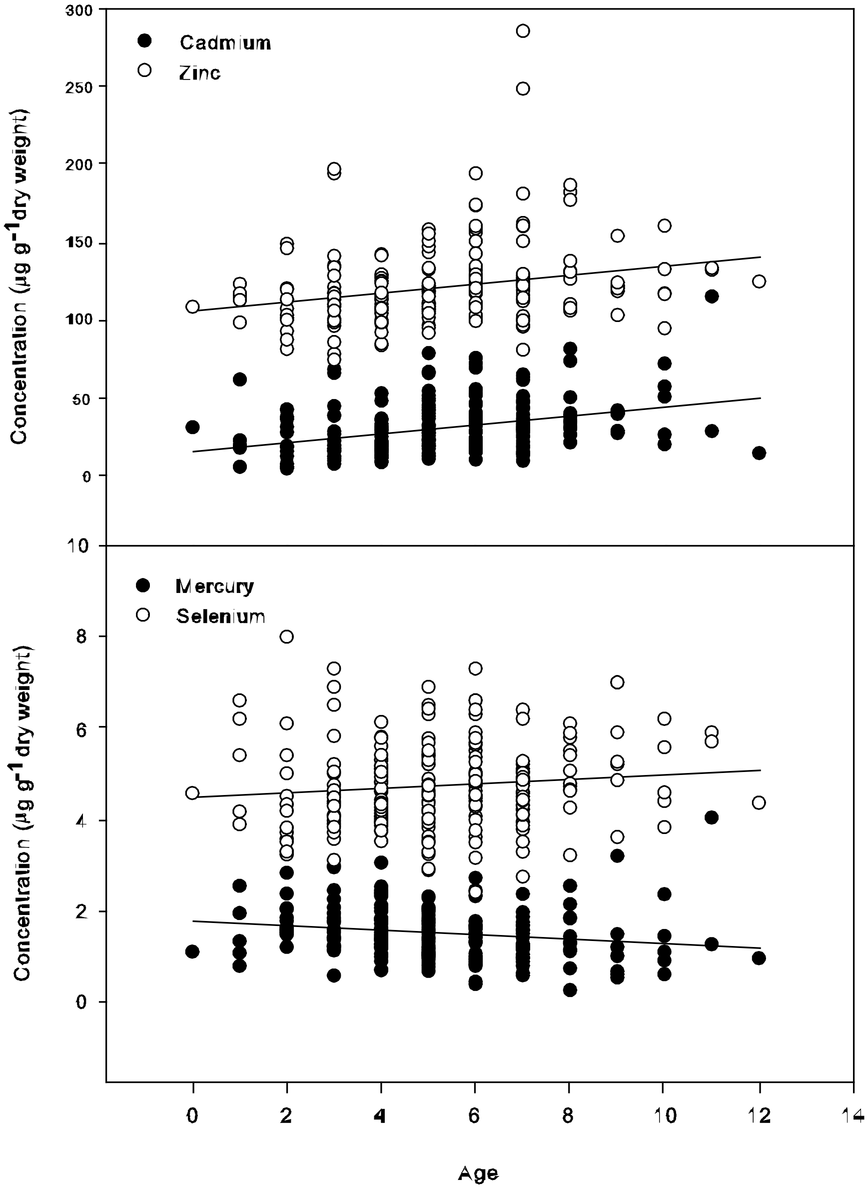


Figure 2. Renal lead (top panel) and arsenic (bottom panel) concentrations in male Porcupine caribou, collected fall, 1993-2012. Both lead and arsenic significantly declined over time ($p<0.05$).

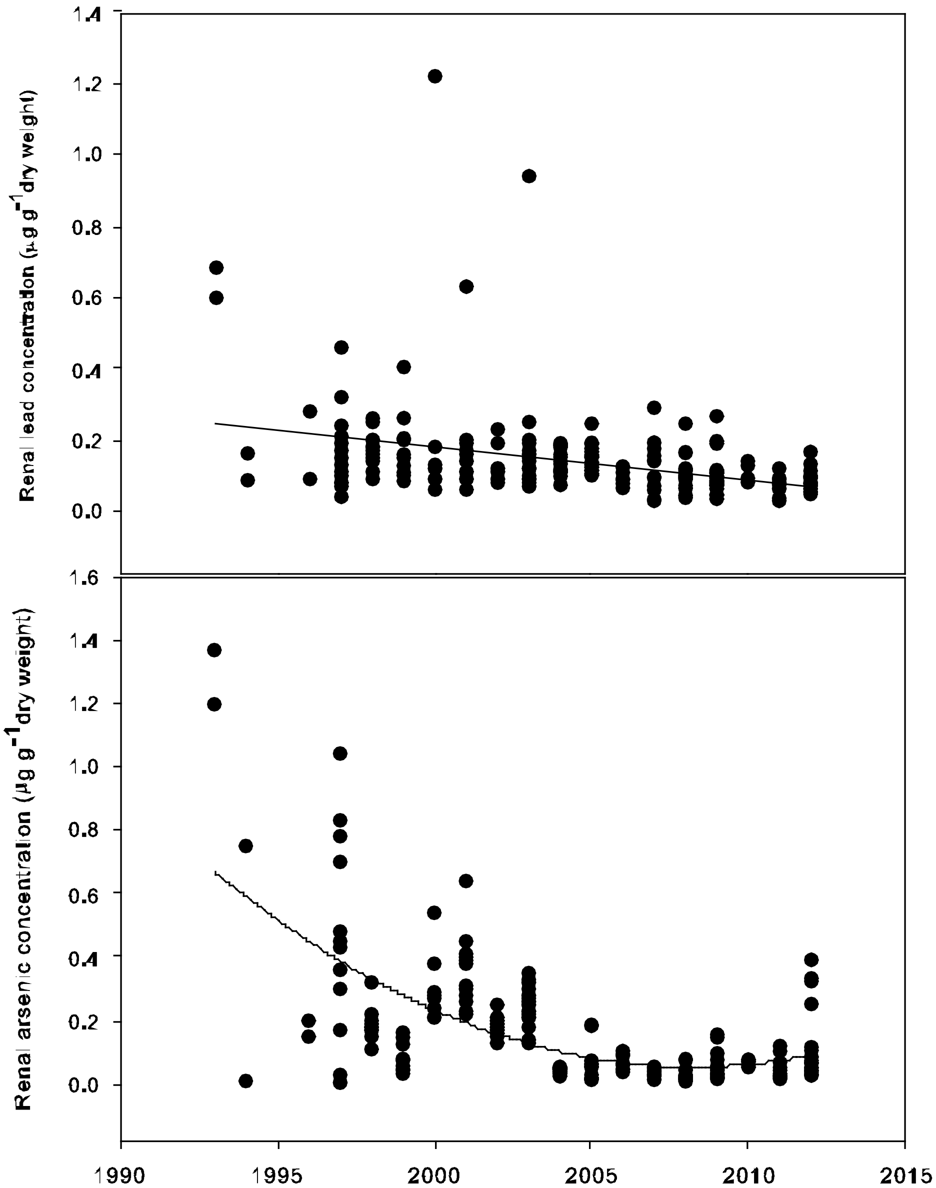
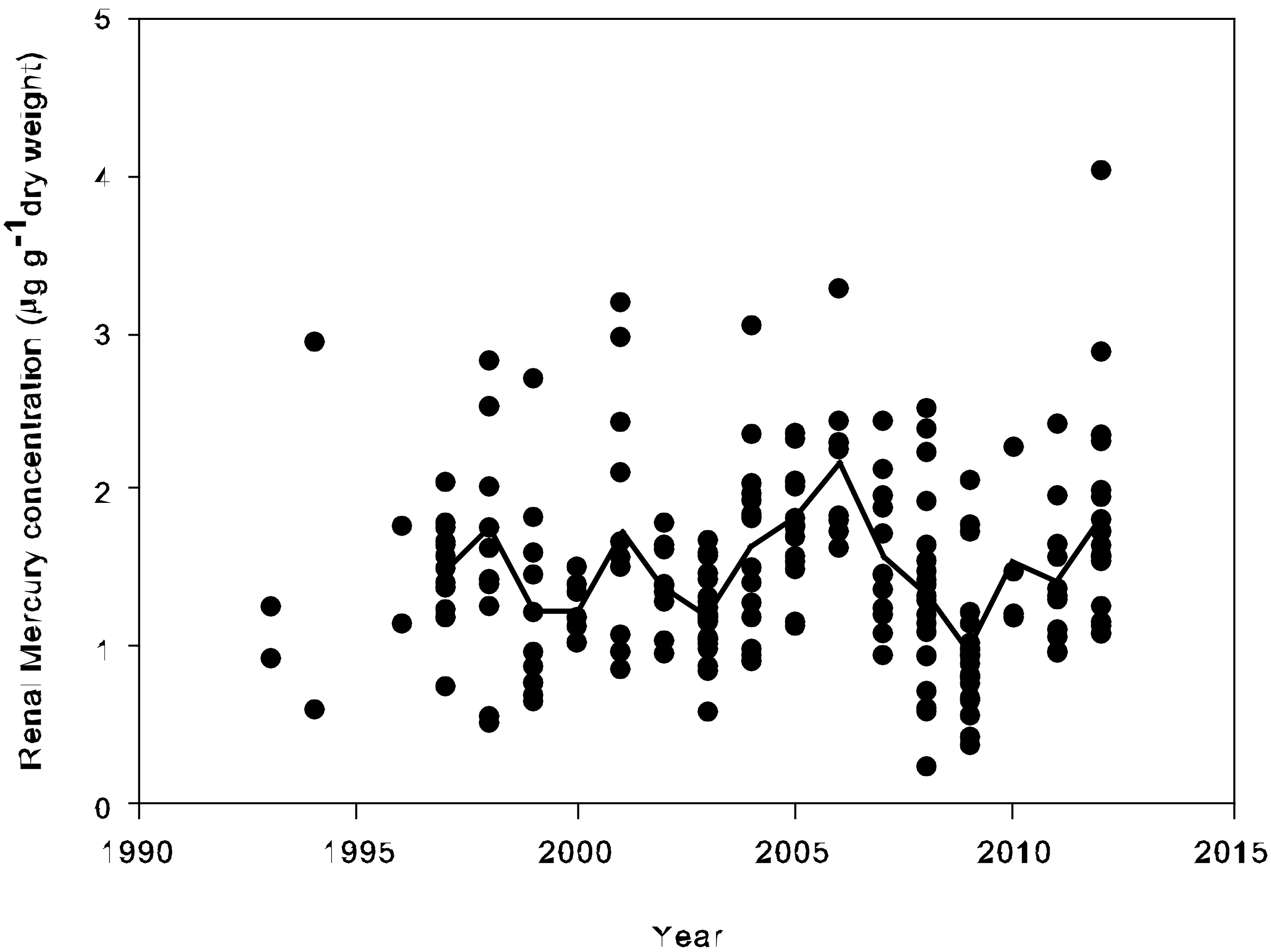


Figure 3. Renal mercury concentrations in male Porcupine caribou, collected fall, 1993-2012. Line indicates running average concentration.



Expected Project Completion Date:

This program is ongoing.

Acknowledgements

Many thanks to Yukon Environment staff: Martin Keinzler and Mike Suitor for providing samples from the Porcupine caribou herd, Mary Vanderkop, Jane Harms and Meghan Larivee for laboratory support and Angela Milani for aging the caribou teeth. Thanks also to Brett Elkin, GNWT for providing samples from the Qamanirjuaq caribou herd. I would also like to acknowledge the efforts of all hunters who have submitted samples to this program over the years – without them, this work would not be possible. This project was funded by the Northern Contaminants Program, Aboriginal Affairs and Northern Development Canada and administered by the Yukon Conservation Society.

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

Validation des constantes de vitesse expérimentales et modélisées pour la réduction et l'oxydation des espèces de mercure dans la neige de l'Arctique : évaluation de l'erreur de modélisation

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Abstract

Arctic snow is an important vector for mercury movement from the atmosphere to the surface environment. Photoreactions are critical to predicting the retention and release of mercury from snow. In this work we report controlled experiments quantifying the relationships between mercury photoreduction and oxidation kinetics in frozen and melted snow, and the effects of UV radiation intensity and snow chemistry. Both frozen (-10°C) and melted snow (4°C) were analysed for gross mercury photoreduction to determine rate

Résumé

La neige de l'Arctique est un important vecteur du transport du mercure de l'atmosphère à l'environnement de surface. Les photoréactions sont essentielles à la prévision du taux de rétention et de rejet de mercure par la neige. Dans ce projet, nous faisons état d'expériences contrôlées visant à quantifier la relation entre, d'une part, la cinétique de la photoréduction et de l'oxydation du mercure dans la neige gelée et la neige fondue et, d'autre part, les effets de l'intensité des rayons ultraviolets et de la chimie de la neige. Nous avons analysé la

constants and total photoreducible mercury with variation in UV (300-400 nm) radiation intensity spanning natural ranges (1.26 to 5.78 W m-2). Photooxidation rate constants and total photooxidized mercury amounts were also determined in melt water exposed to 5.78 W m-2 UV radiation. A parabolic relationship was found between mercury reduction rate constants in snow and snowmelt with increasing UV radiation intensity. Mercury oxidation rate constants were lower than reduction rate constants for melted snow from the three sites. Total photoreducible mercury in both frozen and melted snow was linearly related to UV radiation intensity. Mercury flux from undisturbed snowpacks was measured in Resolute Bay March of 2013 to examine trends in flux with changing irradiation and temperature. A dynamic Teflon flux chamber was used with continuous gaseous elemental mercury monitoring. This data will be used to validate the models developed. This report presents the reduction and oxidation results for snow and snowmelt collected for the 2012 field sampling campaign, as well as the preliminary data from the 2013 field campaign.

photoréduction brute du mercure dans la neige gelée (-10 °C) et la neige fondue (4 °C) pour déterminer les constantes de taux et la quantité totale de mercure photoréductible, avec un écart dans l'intensité du rayonnement ultraviolet (300-400 nm) couvrant les écarts naturels (de 1,26 à 5,78 W m-2). On a aussi mesuré les constantes de taux de photooxydation et la quantité totale de mercure photooxydé dans l'eau de fonte exposée à un rayonnement ultraviolet de 5,78 W m-2. On a relevé une relation parabolique entre les constantes de taux de réduction du mercure dans la neige et dans l'eau de fonte, en fonction de l'augmentation de l'intensité du rayonnement UV. Les constantes du taux d'oxydation du mercure étaient inférieures aux constantes du taux de réduction dans la neige fondue provenant des trois sites à l'étude. La quantité totale de mercure photoréductible dans la neige gelée et dans la neige fondue affiche une relation linéaire avec l'intensité du rayonnement UV. En mars 2013, on a mesuré le flux de mercure provenant du manteau neigeux intact à Resolute Bay afin d'examiner les tendances du flux en fonction de l'évolution du rayonnement et de la température. On a utilisé une chambre de flux dynamique en Teflon pour observer en continu le mercure élémentaire gazeux. Ces données serviront à valider les modèles mis au point. Le présent rapport présente les résultats relatifs à la réduction et à l'oxydation pour les échantillons de neige et d'eau de fonte prélevés pendant la campagne d'échantillonnage sur le terrain de 2012, de même que les données préliminaires de la campagne de 2013.

Key Messages

- Results suggest that mercury in snow is quickly converted to Hg(0) at both high and low UV intensities, and more slowly at mid-range intensities. Also that the total amount of Hg(0) created increases with increasing UV intensity.
- A field campaign during March 2013 was completed in Resolute Bay to measure natural mercury flux from Arctic snowpacks over several diurnal cycles using a dynamic

Messages clés

- D'après les résultats, le mercure contenu dans la neige serait rapidement converti en Hg(0) lorsque l'intensité du rayonnement UV est forte et lorsqu'elle est faible, et la conversion serait plus lente lorsque le rayonnement UV est d'intensité moyenne. Aussi, la quantité totale de Hg(0) créée augmenterait avec l'intensité du rayonnement UV.

mercury flux chamber. Data for mercury flux, meteorological data, and radiation data have been collected (see preliminary figure) and will be used to verify the models developed.

- Snow was collected to verify the effects of temperature changes on mercury release from surface snow using controlled experiments in summer 2013.

- En mars 2013, on a mené une campagne sur le terrain à Resolute Bay pour mesurer le flux naturel de mercure provenant du manteau neigeux en Arctique. On a utilisé une chambre de flux dynamique pour observer plusieurs cycles diurnes. On a recueilli des données sur le flux de mercure, des données météorologiques et des données sur le rayonnement (voir figure préliminaire), qui serviront à vérifier l'exactitude des modèles mis au point.

- Au cours de l'été 2013, on a prélevé de la neige pour vérifier l'effet des changements de température sur la libération de mercure par la neige de surface au moyen d'expériences contrôlées.

Objectives

The overall objectives of the present study are:

- To analyse the rate of mercury reduction in snow and both reduction and 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 a predictive models for mercury reduction rate constants using these properties.

- To collect data on natural mercury flux in response to changes in temperature and radiation in order to validate the models developed.

Introduction

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 (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 (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 snowmelt and to develop empirical relationships between reduction rate constants and snow physical/chemical properties. These models will then be validated using on-site data collected for mercury flux from undisturbed Arctic snowpacks. 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 2012-2013

Activities to date have been centred on the collection of snow and snowmelt samples near the Polar Continental Shelf Program base in Resolute Bay, NU, Canada. Controlled analyses have been performed to quantify photoreduction and photooxidation kinetics in these samples in relation to ultraviolet radiation and snow chemistry. We have also collected natural mercury flux field data to validate the models produced and to examine relationships with irradiation and temperature. Snow samples have also been collected to examine the relationship between temperature and mercury flux in more detail using controlled experiments.

Field Sampling: Surface snow (5-10 cm) was collected from 3 sites near the Polar Continental Shelf Program research base in Resolute Bay, NU , Canada between March 8- 12, 2012 in late morning. A second sampling campaign took place between March 18-31, 2013 near the Polar Continental Shelf Program research base in Resolute Bay, NU. Snow was stored in 2.2L Teflon bottles double Ziploc bagged and sealed dark coolers outdoors (-32 to -40 °C) until cold transport to the lab (~5 days). For the first campaign 7 bottles of snow and 6 bottles of melted snow (melted at room temperature in the dark then frozen) were sampled at each site. For the second campaign 16 bottles of surface snow were collected. A field blank was taken using an empty bottle for the same procedure and filling with Milli-Q water to assess sampling contamination.

Gross mercury photoreduction analysis: The rate of gross photochemical reduction of mercury in snow was determined in triplicate by irradiating a sample in a sealed vessel with UV radiation, while flushing the sample with mercury-free zero air and monitoring the concentration of Hg(0) evolved through time. A LuzChem photoreactor is placed in a freezer at -10 °C for frozen snow (4 °C for melted snow) and the number of UVA bulbs can be altered to vary UV intensity.

An acid-washed (20% HCl), pre-irradiated (UV) ("zeroed") quartz beaker (200 mL QSI Quartz Scientific) is used as the sample chamber. The quartz beaker is filled to 9 cm height with snow and capped with a silicon stopper and Hg(0) in the interstitial pore space of the snow is removed by passing mercury-free "zero air" through the sample (1 L/min) until no mercury peak is detectible in the headspace for 3 consecutive readings from the Tekran 2537A cold vapour atomic fluorescence spectrometer (CVAFS). The snow is then irradiated with continuous mercury analysis (5 min resolution) of the headspace and mercury-free air flowing into the sample. The pseudo-first order rate constant (k) is determined by fitting the integrated form of a pseudo first order reaction equation using SigmaPlot 12 software to the scatter plot of Hg(0) versus time .

Melted snow is stored as a frozen ice block in a 2.2L Teflon bottle. This ice is thawed in the dark and stored in the fridge until analysis. A 125 - 150 mL aliquot is weighed into the zeroed beaker and wrapped in foil. The melt water is blanked by bubbling mercury free zero air through the sample. The blanked sample is exposed to 2 to 10 UVA bulbs, with mercury free zero air bubbled through the sample at 1L/min for a 5 minute sampling time. For gross mercury reduction in melted snow, the procedure is the same as detailed by O'Driscoll et al (2005) and Qureshi et al. (2010) for freshwater and ocean water samples with the exception being that the Luzchem photoreactor is held in a refrigerator at 4 °C.Net mercury reduction and gross oxidation analysis

The rate constant for photooxidation of mercury in melted snow is determined by the difference between the net mercury photoreduction rate and gross mercury photoreduction rate. To determine net mercury reduction, 11 beakers (10 treatments and 1dark control) are filled without headspace and capped with silicone stoppers. Irradiation lengths of 0, 1, 2, 3, 5, 8, 12, 18 and 24 hours are then analysed for Hg(0) content. At 12 hours three beakers are removed for a triplicate analysis. To determine Hg(0) content, mercury-free air is bubbled through the irradiated samples and analysed with the Tekran model 2537 until removal. The net reduction curve is subtracted from the gross reduction curve for each irradiation intensity, and the result is the mercury oxidation curve and rate constants can be derived as previously outlined.

Chemical characterisation of frozen and melted snow: Melted snow from all 3 sites was analysed for total Hg, easily reducible Hg, pH, cations and anions, fluorescence and DOC. The pH was determined using an Accumet basic model AB15 pH meter, and fluorescence was measured using a Turner model TD 700 fluorometer. Easily reducible Hg, cations and anions, and DOC analyses were analyzed both pre and post irradiation. Easily reducible mercury (ERM) analyses were performed following the general procedure outlined but the US EPA method 1631 for total mercury in natural waters on a Brooks-Rand Model III system, without the use of bromine monochloride as a mercury oxidizing agent.

Dissolved organic carbon (DOC) was analyzed using a Shimadzu TOC-V CPH total organic carbon analyser. Samples were filtered through a 0.45 micron nylon syringe filter and frozen prior to analysis. For quality assurance, check standards of 5 ppm organic carbon and 5 ppm inorganic carbon were loaded with samples. Resultant total organic carbon (TOC; assumed to be DOC since samples were filtered to remove particulates), were plotted against UV intensity.

Samples were analyzed for cations after acidification to 1% HNO3 using inductively coupled plasma mass spectrometry (Perkin Elmer Elan DRC) and anions using ion chromatography. Samples were filtered through a 0.2 micron syringe filtration devices prior to anion analysis, while both 0.45 micron filtered and unfiltered samples were analyzed for cations analysis.

Capacity Building

Linkages made with the Polar Continental Shelf program greatly facilitated the research logistics. In addition our meeting with the Resolute Hunters' and Trappers' Association developed our communications with locals.

Communications

Research resulting from this work has been presented at several international conferences, local groups, and invited academic talks by Dr. O'Driscoll and his team including the following:

1. Mallory, M., O'Driscoll, N.J., Kidd, K., Mann, E. Update on Arctic Research. Meeting with the Hunters' and Trappers' Association. Resolute Bay, NU March 21, 2013. ORAL.

2. O'Driscoll, N.J. Mercury Rising. Acadia Chemistry Department Invited Seminar. Acadia University, Wolfville, NS. January 17, 2013. ORAL.

3. Mann, E., O'Driscoll, N.J., Mallory, M., Ziegler, S., Qureshi, A., Avery, T., Dalziel, J., Tordon, R. Determining rate constants for photochemical reduction of mercury in Arctic snow. Science Atlantic Conference. March 15-18, 2013. Wolfville, NS. ORAL

4. Mann, E., Mallory, M., Ziegler, S., Qureshi, A., Tordon, R., Dalziel, J., O'Driscoll, N.J. Determining rate constants for photochemical reduction of mercury in Arctic snow - Method development and testing (for poster) Society of Environmental Toxicology and Chemistry (SETAC) North America International Conference. Long Beach California, USA. November 11-15, 2012.POSTER

5. Mann, E., Mallory, M., Ziegler, S., Qureshi, A., Tordon, R., Dalziel, J., O'Driscoll, N.J. Determining rate constants for photochemical reduction of mercury in Arctic snow - Effects of site specific factors and irradiation intensity. Society of Environmental Toxicology and Chemistry (SETAC) North America International Conference. Long Beach California, USA. November 11-15, 2012. ORAL

6. O'Driscoll, N.J. Why do Some Ecosystems Accumulate Mercury? Earth System Science Research Group, University of Reading, Reading England. February 16, 2012. ORAL.

A brief summary of the work is also included in the annual *Coastlines* pamphlet put out as part of the Mallory Arctic Research Program communications plan.

Traditional Knowledge Integration

While traditional knowledge was not expressly incorporated in the research we did consult with a local organization on the work and its implications (meeting with the Hunters' and Trappers' association took place on March 21, 2013 in Resolute Bay, NU). Some useful insights were gained from these meetings.

Results

Gross mercury reduction in frozen snow:

- Rate constants for mercury reduction in frozen snow were determined in triplicate for each of the three sites. The gross reduction rate constant (k) showed an inverse parabolic relationship with UV irradiation intensity while the amount of reducible mercury (Hg(II)red) was linear with irradiation intensity.

- The pseudo-first order reduction rate constants (k) in melted snow showed very different relationships with increasing intensities of UV radiation as compared to frozen snow. In site 2 melted snow, there is a linear relationship between the pseudo-first order reduction rate constant and UV intensity, while in frozen snow from all sites and melted snow from sites 1 and 3, k vs. UV intensity follows a parabolic trend. In addition the levels of reducible mercury are substantially higher in site 2 meltwater. It was determined that mercury reduction rate constants in site 3 snow were lower than those in site 1 or 2 snow at the same intensity of UV radiation, while amounts of photoreduced mercury were the highest in site 3 snow.

- It was found that site 2 meltwater showed significantly different results compared with sites 1 and 3 melted snow. Site 2 was characterised by very low rate constants with a linear relationship to UV radiation, as well as very high cumulative photoreduced mercury amounts.

- A portion of the preliminary in-situ mercury flux data (March 24-26, 2013) can be seen in Figure 1. Diurnal trends in mercury flux (flux values ranging from 0 to >15 ng m-2h-1) from surface snow were measured in-situ at Resolute Bay, NU. Mercury flux data is observed to correlate well with incoming UV radiation measured at the top of the snowpack. More analysis is required to assess the effects of other meteorological variables such as air and snow temperature and wind speed. A wide range of temperatures were observed during the experiment (ranging -7 to -32 °C). This data analysis work will be completed over the next few months.

Discussion & Conclusions

In frozen snow it was found that the relationship of the pseudo-first order mercury reduction rate constant with UV (280 - 400 nm) intensity is inverse parabolic in nature, that is, we found higher reduction rate constants at both low and high UV intensities. We propose that this shape arises from the presence of two "pools" of photo-reducible mercury present in snow (an easily photoreducible mercury and a recalcitrant photoreducible mercury).

The trends observed in melted snow are proposed to be a result of variance in the chemical composition of the snow. In particular, snow from site 3 has the lowest concentrations of iron and chloride. Higher concentrations of chloride ion may favour photochemical oxidation over reduction in snow, while iron has been found to enhance mercury reduction in natural waters (Vost et al., 2012), although the role of iron in snow photochemistry is unexplored.

This site 2 data may result from differences in mercury binding to organic matter and particles in the melted snow due to the chemical composition in site 2 melted snow. Site 2 melted snow had significantly lower pH (sites 1 and 3 had more neutral pH values), while chloride concentrations were between those of the other two sites. It has been reported that in the presence of chloride ion and acidic pH mercury tends to sorb less to soil particles. It is possible that more Hg was present in the dissolved phase at Site 2, thereby resulting in higher Hg(II)red values. As such, it is proposed that differences found in the kinetics of frozen and melted snow reduction and oxidation at site 2 may be attributed to variation in snowpack chemical properties, however, further work is needed. Recommendations for future work would include controlled spiking experiments (chloride, iron, and pH) of the melted snow to examine the relationships with UV radiation induced mercury reduction kinetics. Such experiments would provide predictive linkages between mercury photoreduction and/or photooxidation rates and snow chemical properties. This ultimately will help to improving the predictive power of mercury fate models.

Expected Project Completion Date

At present, the Arctic frozen and melted snow samples have been collected and analysis is complete. In addition a field campaign has been completed to analyze mercury flux from the Arctic snowpack using dynamic mercury flux chamber methods. The expected completion date for analysis of this field data is August 2013. While not a part of the funded research, a series of experiments to quantify the release of mercury from snow with temperature changes will be performed during 2013 with an expected completion of March 2014. A third year of sampling will take place in 2014, with frozen and melted snow samples collected from a location in NS, Canada. This continuing research will be funded through other sources.

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

Étude horizontale de la sensibilité écosystémique à la bioaccumulation de méthylmercure dans les eaux douces de l'Arctique

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Abstract

Mercury is a priority contaminant of the Northern Contaminants Program (NCP) due to its prevalence in the Arctic and high levels found in some traditional food species. The main objective of this project is to investigate how climate affects methylmercury (MeHg) bioaccumulation in Arctic lakes. The study design involves a comparison of MeHg bioaccumulation in three study areas along a latitudinal gradient in climate-controlled ecosystem types in the Canadian Arctic, specifically sub-Arctic taiga (Kuujjuaraapik), Arctic tundra (Iqaluit) and polar desert (Resolute Bay). During the first year of the project, we partnered

Résumé

Le mercure est un contaminant d'intérêt prioritaire du Programme de lutte contre les contaminants dans le Nord en raison de sa prévalence dans l'Arctique et de sa teneur élevée dans certaines espèces constituant des aliments traditionnels. Le principal objectif du projet est d'étudier la façon dont le climat joue sur la bioaccumulation de méthylmercure (MeHg) dans les lacs de l'Arctique. Le plan d'étude prévoit une comparaison de la bioaccumulation de MeHg dans trois zones situées le long d'un gradient latitudinal dans des types d'écosystème à climat défini de l'Arctique canadien, plus précisément la taïga subarctique (Kuujjuaraapik), la toundra arctique (Iqaluit)

with the Sakkuq Landholding Corporation to conduct a field program at Kuujjuaraapik (Nunavik). We investigated key aspects of MeHg bioaccumulation—MeHg bioavailability to benthic food webs and organism growth rates—as well as how watershed characteristics affect the transport of Hg and organic carbon to lakes. Our preliminary results show that watershed processes, MeHg supply to food webs, trophic transfer, invertebrate taxonomy, and growth rates contribute to MeHg bioaccumulation in the sub-Arctic lakes. The detailed characterization of mercury cycling in these systems will be compared to higher latitude sites over the next two years to identify climate influences on MeHg bioaccumulation in aquatic food webs of the eastern Arctic.

et le désert polaire (Resolute Bay). Durant la première année du projet, nous avons travaillé en partenariat avec la Sakkuq Landholding Corporation pour réaliser un programme sur le terrain à Kuujjuaraapik (Nunavik). Nous avons étudié des aspects clés de la bioaccumulation de MeHg, soit la biodisponibilité du MeHg dans les réseaux trophiques du milieu benthique et le taux de croissance des organismes, de même que la façon dont les caractéristiques du bassin versant influent sur le transport du mercure et du carbone organique vers les lacs. Nos résultats préliminaires montrent que les processus à l'œuvre dans le bassin versant, l'apport en MeHg dans les réseaux trophiques, le transfert trophique, la taxonomie des invertébrés et le taux de croissance contribuent à la bioaccumulation de MeHg dans les lacs subarctiques. Au cours des deux prochaines années, nous comparerons la caractérisation détaillée du cycle du mercure dans ces systèmes avec celle de sites situés sous plus haute latitude afin de cerner l'influence du climat sur la bioaccumulation de MeHg dans les réseaux alimentaires aquatiques de l'Arctique de l'Est.

Key Messages

- Within this sub-Arctic landscape, watershed morphometry is a strong predictor of water chemistry and the accumulation of MeHg in lake water and biota.
- Bioavailable MeHg concentrations in sediment (measured using specialized samplers) suggest that the study sites differ in their capacity to methylate mercury.
- Some aquatic invertebrates, such as filter-feeding *Daphnia* (commonly called water fleas), can bioaccumulate higher concentrations of MeHg.
- Total Hg concentrations in brook trout muscle were related to fish trophic position and MeHg supply to the food web. The concentrations were less than Health Canada's consumption guideline of 0.5 $\mu g\ g^{-1}$ wet wt.

Messages clés

- Dans ce paysage subarctique, la morphométrie du bassin versant est un solide prédicteur de la chimie de l'eau et de l'accumulation de MeHg dans l'eau des lacs et dans le biote.
- La concentration de MeHg biodisponible dans les sédiments (mesurée au moyen d'échantillons spécialisés) suggère que les sites à l'étude n'ont pas tous la même capacité à transformer le mercure en méthylmercure.
- Certains invertébrés aquatiques, comme la Daphnia (communément appelée puce d'eau douce), qui se nourrissent par filtration, peuvent bioaccumuler de fortes concentrations de MeHg.

- The RNA content of brook trout muscle declined with fish size, reflecting slower growth rates in larger fish. RNA content will be used to compare fish growth rates among Arctic study regions in future project years.

- La concentration totale de mercure dans les tissus musculaires de l'omble de fontaine dépend de la position trophique du poisson et de l'apport de MeHg vers le réseau trophique. Les concentrations relevées étaient inférieures à la valeur recommandée par Santé Canada pour la consommation humaine, qui se situe à 0,5 µg g-1 poids humide.

- La teneur en ARN des tissus musculaires de l'omble de fontaine diminue avec la taille du poisson, ce qui indique un taux de croissance plus lent chez les gros poissons. La teneur en ARN servira à comparer le taux de croissance des poissons des régions arctiques à l'étude dans les prochaines années du projet.

Objectives

The main purpose of this project is to investigate how climate affects MeHg bioaccumulation in Arctic freshwater food webs. Recent evidence indicates that inorganic mercury (Hg) loadings to Arctic lakes decline with latitude (Muir et al. 2009); however, MeHg concentrations in benthic invertebrates and fish do not similarly decline along this gradient in Hg loading (Gantner et al. 2010, van der Velden et al. 2013). These observations suggest that regional environmental factors may play an important role in ecosystem sensitivity to Hg bioaccumulation in the Canadian Arctic.

During this three-year project (2012 to 2015), we will investigate three study areas that cover a latitudinal gradient in climate-related environmental factors in the Canadian Arctic. This research will include non-focal sites at Kuujjuaraapik (sub-Arctic taiga) in 2012 and Iqaluit (tundra) in 2013, as well as NCP-monitored sites at Resolute Bay (polar desert) in 2014.

Using a cross-ecosystem comparison to test hypotheses of how climate controls MeHg bioavailability and bioaccumulation, we will conduct the following in lakes and ponds from each study area:

- Characterize the watersheds of study sites (geomorphology and physiography) through satellite image classification and digital terrain analysis in order to examine watershed influences on measured lake physico-chemistry, particularly levels of organic carbon and Hg in sediment and water;

- Estimate bioavailable MeHg in sediment pore water using a novel technique (Diffusive Gradient in Thin films, or DGT);

- Measure MeHg concentrations in benthic food webs (algae, invertebrates and fish); and

- Estimate short-term growth rates in invertebrates and fish using a novel approach based on measurements of tissue nucleic acid content.

Introduction

High Arctic lakes may be more vulnerable to Hg inputs because MeHg concentrations in lake-dwelling Arctic char are at similar levels to more southern latitudes (Gantner et al. 2010, van der Velden et al. 2013) despite lower Hg loadings at higher latitudes. Several environmental factors could affect the sensitivity of Arctic freshwater ecosystems to Hg bioaccumulation, defined here as "the ability of an ecosystem to transform inorganic Hg load to MeHg in biota" (from Munthe et al. 2007). These factors could be related to Hg transport from watersheds to lakes, net methylation of inorganic Hg in either terrestrial or aquatic environments, or uptake of MeHg in the food web (Munthe et al. 2007). A fundamental environmental gradient in the Arctic that is associated with climate is a decline in terrestrial and aquatic productivity with latitude (Vincent and Laybourn-Parry 2008). A more severe climate at higher latitudes results in lower transport of terrestrial organic matter from watersheds to lakes and lower primary production in the lakes themselves (Vincent and Laybourn-Parry 2008).

How climate may mediate MeHg bioavailability and bioaccumulation—Two key climate variables, temperature and precipitation, decline with latitude. These first-order variables fundamentally control terrestrial and aquatic ecosystems in the Arctic, resulting in distinct ecotypes (sub-Arctic taiga, tundra and polar desert) that decline in productivity with latitude. Thus, on a broad scale, temperature and precipitation control the productivity (organic matter production) of aquatic ecosystems and their watersheds. We hypothesize that this climate-related variation in organic matter production affects mercury bioaccumulation in Arctic fresh waters through its control on mercury bioavailability and organism growth rates. Temperature also likely directly controls the growth rates of organisms.

We hypothesize that climate-related variation in organic matter production could affect Hg bioaccumulation in Arctic fresh waters through two processes. Organic matter strongly binds Hg and reduces its availability for transfer across bacterial or algal membranes, referred to as bioavailability (Barkay et al. 1997, Gorski et al. 2008). Less amounts of particulate or dissolved organic carbon in sediment may increase MeHg bioavailability to benthic food webs through: 1) a greater portion of the inorganic Hg pool being bioavailable for microbial methylation, or 2) a greater portion of pore water MeHg being bioavailable for uptake in algae and bacteria. A second hypothesis is that growth rates of consumer organisms in High Arctic lakes are slower because of low primary production (less available food) and colder water temperatures. Slower growth rates result in higher MeHg concentrations in consumers because less biomass is produced per unit of MeHg consumed (Karimi et al. 2007, Ward et al. 2010, Chen et al. 2011).

Activities in 2012-2013

A field program was conducted at Kuujjuaraapik in July 2012 based at the field station of the Centre d'études nordiques (Université Laval). A total of eight water bodies were characterized for a variety of physical, chemical and biological variables (Fig. 1, Table 1).

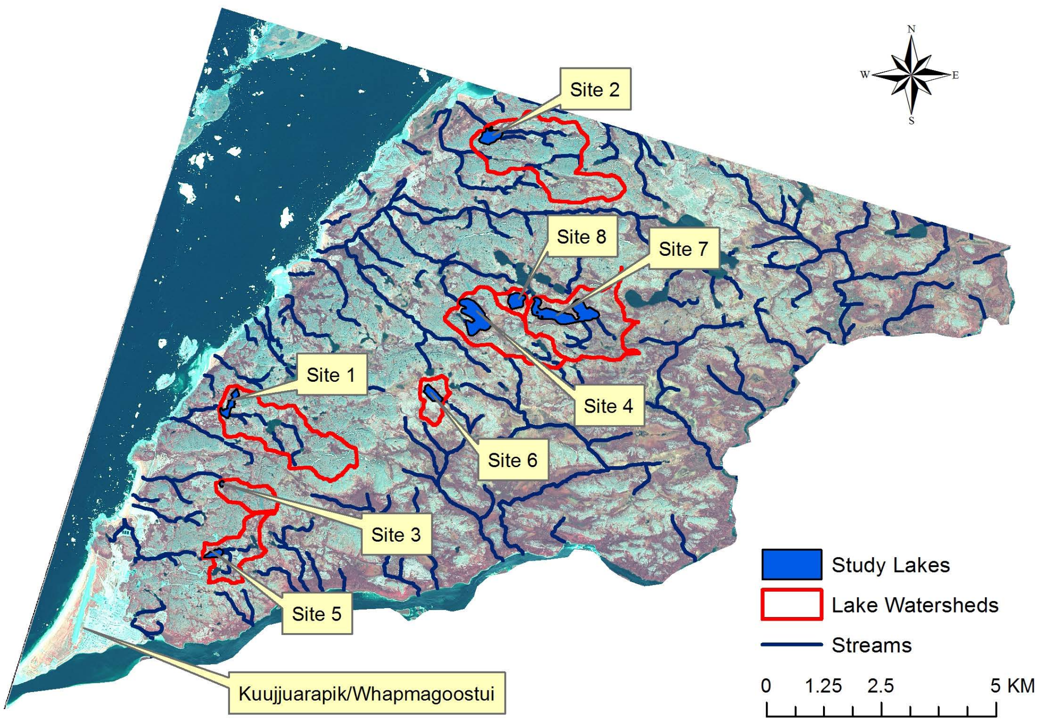
Lake morphometry and watershed characterization were conducted using GIS-based terrain analysis methods and satellite image classification. The bathymetry of each water body was measured in a boat using a GPS-linked echosounder. Lake areas were obtained from 1:50,000 scale CANVEC National Vector hydrography dataset and the watershed area for each water body was extracted from a hydrologically pre-processed, 1:50,000 Canadian Digital Elevation Data (CDED) Digital Elevation Model using well-established methods within the System for Automated Geoscientific Analysis (SAGA) GIS software (Conrad 2013). Additional watershed morphometric variables were also calculated, including average flowpath gradient and average topographic wetness index (a terrain variable that captures topographically driven spatial variability in local soil moisture conditions). A preliminary landcover map was produced from a 10 m resolution pan-sharpened, 4-band (Red, Green, Blue, Near-Infrared) Spot 5 image from late spring 2008

Table 1. Location, morphometry and fish presence for the eight lakes sampled at Kuujjuuaraapik in July 2012.

Water body	Latitude (°N)	Longitude (°W)	Lake Area (km²)	Catchment area (km²)	WA:LA Ratio	Mean Depth (m)	~Residence Time (days)	Fish present?
Site 1	55°19′11″	77°42′41″	0.08	2.70	32	0.8	~30	no
Site 2 (Christmas Lake)	55°22′10″	77°37′04″	0.11	3.35	30	1.3	~50	yes
Site 3	55°18′16″	77°42′56″	0.01	0.62	72	0.5	~10	yes
Site 4 (Kachishayoot Lake)	55°20′03″	77°37′31″	0.29	1.78	6	2.6	~500	yes
Site 5	55°17′26″	77°43′08″	0.05	1.00	20	1.4	~90	no
Site 6	55°19′12″	77°38′32″	0.08	0.39	5	0.7	~170	no
Site 7	55°20′01″	77°35′48″	0.39	2.31	6	1.2	~250	yes
Site 8	55°20′14″	77°36′42″	0.10	0.19	2	1.0	~620	yes

WA:LA = watershed area to lake area

Figure 1: SPOT 5, pan-sharpened, false-colour composite satellite imagery showing study lakes and lake basins. In the satellite imagery, the red channel is assigned to the near-infrared image band such that vegetation is seen as red.



using an unsupervised cluster analysis with manual interpretation of clusters. The resulting landcover classification discriminates between water, vegetated areas and un-vegetated areas, but will be further refined to include wetland areas, barren tundra and vegetated tundra. The percent vegetated landcover area in each lake watershed was calculated from this preliminary landcover map. Correlation and regression analyses were used to identify relationships between watershed characteristics, water chemistry variables and biotic MeHg concentrations for the eight study lakes.

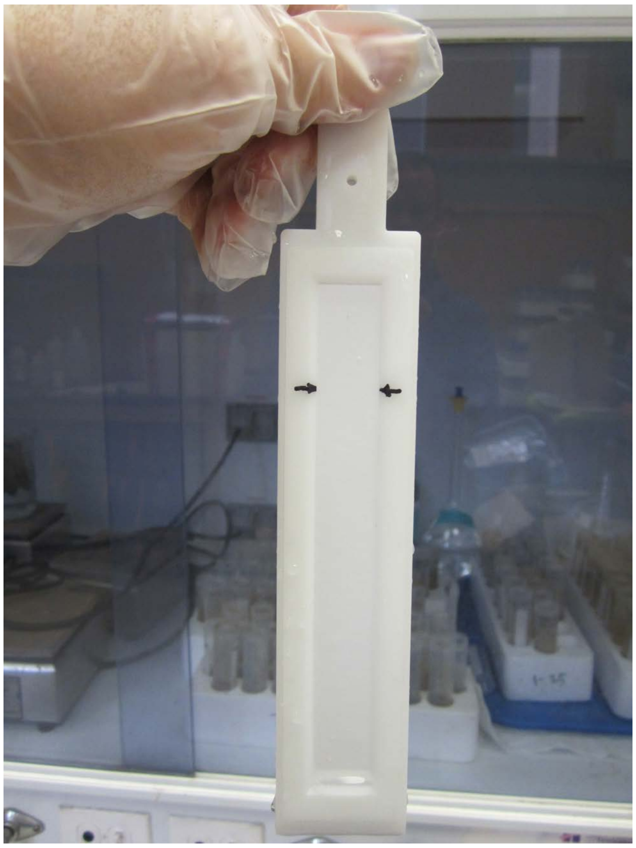
In situ measurements of specific conductance (SpC), temperature, pH and dissolved oxygen were taken with a YSI sonde. Water was collected as grab samples for analysis of THg and MeHg (filtered and unfiltered), dissolved organic carbon (DOC), UV-absorbance, nutrients, chlorophyll, anions and cations. Offshore surficial sediment was collected using an Ekman grab, and the top 1 cm of sediment was sampled for analysis of THg, percent organic matter and algal chlorophyll.

To measure bioavailable MeHg in sediment porewater, we deployed DGT (Diffusive Gradient in Thin film) samplers in sediments (Fig. 2). Offshore sediment cores were collected with a gravity corer, and the DGTs were inserted in the intact cores for an incubation period of 1-2 days. The incubations were conducted *in situ* to maintain environmental temperatures by sealing the cores and submersing them in shallow nearshore areas. More detail on the DGT method can be found in Clarisse et al. (2009).

Food web components (benthic algae, aquatic invertebrates, fish) were collected for Hg and stable isotope analysis. Benthic algae were collected for MeHg analysis by scraping biofilms off rocks with a nylon brush. Benthic invertebrates were collected for MeHg analysis using a kick net near shore (<1.5 m depth) or an Ekman grab for deeper waters. Zooplankton were collected in the pelagic zone using horizontal hauls with a net (mesh size 200 µm). Brook trout (*Salvelinus fontinalis*) were captured with a gill net from five water bodies and, following euthanization, dissected to examine gut contents (diet characterization) and remove muscle and liver tissue (THg) as well as otoliths (for ageing). Brook trout were the only large-bodied fish species captured in the water bodies, although ninespine stickleback (*Pungitius pungitius*) were also observed at some sites.

Benthic invertebrates and fish muscle samples were collected for analysis of their nucleic acid content to estimate short-term growth rates. The growth rates of aquatic organisms, including invertebrates and fish, are strongly correlated with the amount of RNA or the ratio of DNA to RNA contents in their tissues because growth involves protein synthesis, which is facilitated by cellular RNA (Vrede et al. 2004, Chicharo and Chicharo 2008). Tissue samples were preserved with RNAlater (a nucleic acid stabilization reagent) prior to analysis.

Figure 2: Diffusive gradient in thin film (DGT) samplers were used to estimate the concentration of bioavailable MeHg in lake sediments and the overlying water.



Capacity Building, Communications and Traditional Knowledge Integration

We partnered with Mr. Alec Tuckatuck and the Sakkuk Landholding Corporation in Kuujjuaraapik to conduct the 2012 field program. Mr. Tuckatuck organized a guide for us (Jimmy Angatookalook), who we hired to access sites that were up to a two hour ATV drive from Kuujjuaraapik. They provided critical information on the locations of water bodies that contained fish, and Mr. Tuckatuck identified sites of interest that he wished to have mercury information on because of their use for fish consumption. Their traditional knowledge and participation were critical to the success of the field program. Upon their request, a final report that contains the measured levels of Hg in local lakes will be provided later in 2013. The Nunavik Regional Contaminants Committee will be consulted prior to release of the report. In addition, metadata on this NCP project were submitted to the Polar Data Catalogue in November 2012.

Results and Discussion

a. Lake chemistry and watershed characteristics

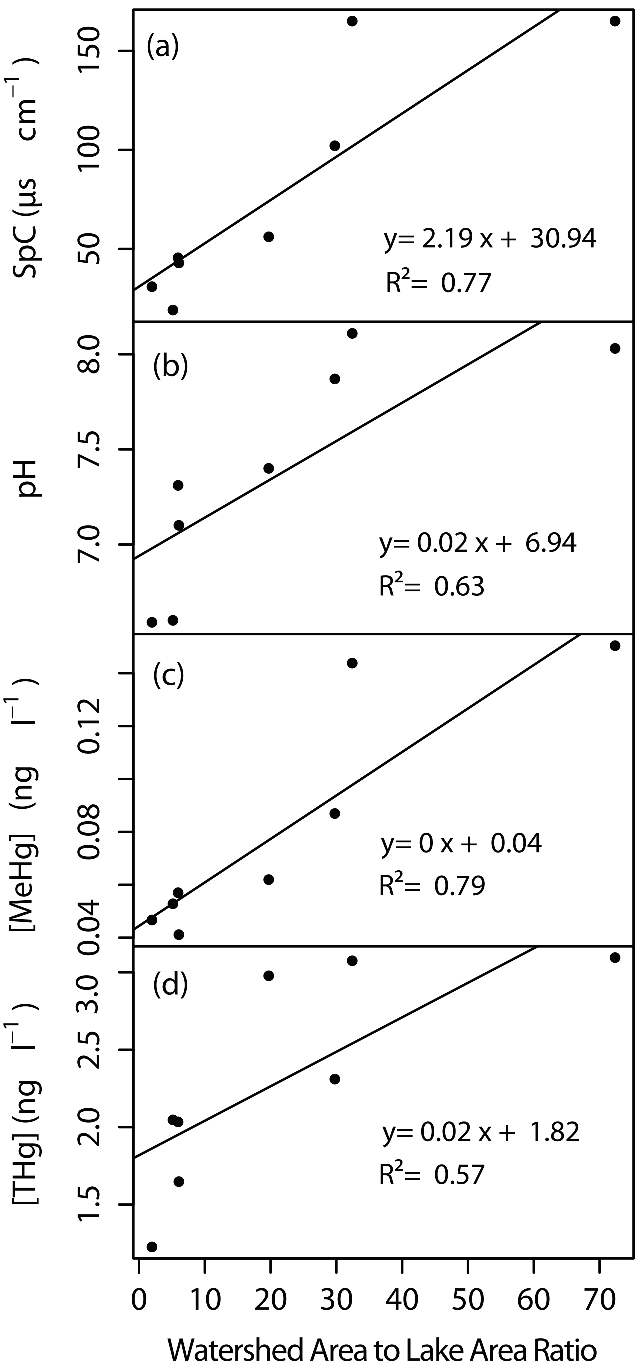
The eight water bodies sampled are shallow, first- or second-order lakes with short residence times ranging from approximately ten days to two years (Table 1). Watershed to lake area ratios range from 2 to 72 (Table 1), implying substantial differences in terrestrial-aquatic influences across the eight study sites. This is corroborated by the strong, positive relationships between several key water quality parameters (including SpC, pH, THg and MeHg) and watershed area to lake area ratios (Fig. 3a-3d). In contrast to these findings, organic matter characteristics within the lakes (including DOC concentration, UV absorbance and Specific UV absorbance) were unrelated to watershed to lake area ratio. Moreover, none of the water quality variables tested were associated with landcover proportions extracted from Spot 5 satellite imagery.

Additional analyses will be required to understand the sources and implications of the relationships shown in Figure 3. However, the strong statistical relationship between MeHg concentrations in lakes and watershed to lake area ratios implies that watershed processes may either enhance the supply of MeHg to the study lakes, or indirectly enhance net-MeHg production within them. There is a particularly strong relationship between MeHg concentrations and SpC within the lakes (Fig. 4). This relationship might reflect the influence of watershed runoff or groundwater inputs and associated supply of electron donors such as sulphate, on MeHg production in lake sediments or the water column (Krabbenhoft et al. 1998, Stoor et al. 2006). Regardless of the source of MeHg to the study lakes, our preliminary results imply a potential link between MeHg concentration in water and biotic uptake of MeHg (Fig. 5a and 5b). Specifically, there was a strong, positive association with MeHg concentration in benthic algae at all eight lakes (Fig. 5a). At the five lakes supporting fish populations (Table 1), there was a similarly strong, positive relationship between MeHg concentrations in water and resident brook trout (Fig. 5b). Together, Figures 3-5 imply that within this sub-Arctic landscape, watershed morphometry is a strong predictor of aquatic physico-chemistry and the accumulation of MeHg in lake water and biota. We will expand the analysis conducted here using additional landscape variables, and through additional statistical analysis of streamwater chemistry samples collected during our 2012 field campaign at Kuujjuaraapik.

b. Estimates of sediment MeHg bioavailability using DGTs

DGT samplers measure the fraction of MeHg in sediment porewater or overlying water that is dissolved and labile (i.e. not bound to large molecules), and therefore is considered most likely bioavailable. DGT measurements of bioavailable MeHg were taken at the sediment-water interface and at depths of 0-6 cm and 6-12 cm in the sediment. Considerable variation in

Figure 3: Bivariate scatterplots showing strong positive associations between watershed to lake area ratio and (a) specific conductance; (b) pH; (c) MeHg concentrations (dissolved phase only); and (d) total Hg (dissolved + particulate phase).



bioavailable MeHg was observed among sites with the highest concentrations at sites 2 and 3, and lowest concentrations at sites 1, 4, 5 and 7 (Fig. 6A). Sites with higher bioavailable MeHg concentrations reflect sediment with greater potential to produce MeHg, which subsequently diffuses upwards into the overlying water. Sediment-dwelling chironomids had MeHg concentrations that were positively correlated with DGT MeHg concentrations measured at the sediment-water interface ($r^2 = 0.71$, $p = 0.005$, $n = 8$) and in 0-6 cm of sediment (Fig. 6B). Site-averaged THg concentrations in brook trout (corrected for trophic position) were also positively correlated with bioavailable MeHg concentrations in sediment of 5 lakes ($r^2 = 0.83$, $p = 0.021$, $n = 5$). These findings suggest that the DGT samplers are a useful tool to predict MeHg exposure for aquatic biota in sub-Arctic lakes.

c. Food web bioaccumulation of MeHg

Concentrations of MeHg in aquatic biota ranged three orders of magnitude from 0.4–2,642 ng g-1 dry wt and increased as a function of trophic position, as estimated by their adjusted δ15N ratio (r2 = 0.78, p < 0.001, n = 122). Benthic algae had the lowest MeHg concentrations, with site means ranging from 1–5 ng g-1 dry wt. Benthic invertebrate taxa had intermediate MeHg concentrations, with site means ranging from 17–482 ng g-1 dry wt. Brook trout had the highest MeHg concentrations (estimated by THg measurements), which ranged from 181–2,642 ng g-1 dry wt in their muscle. The THg concentrations in brook trout muscle were converted to wet wt concentrations (assuming 80% moisture) for comparison with Health Canada's consumption guideline for mercury of 0.5 µg g-1 wet wt. With one exception, all fish had wet wt concentrations of THg that were below this guideline (Fig. 7).

Zooplankton were sampled from the eight lakes and an additional eight ponds near Kuujjuaraapik (Fig. 8). Preliminary results show relatively elevated average concentrations of MeHg, ranging from 56–415 ng g-1 dry wt in bulk zooplankton samples, from 93–675 ng g-1 dry wt in sorted *Daphnia*, and

Figure 4: Bivariate scatterplot showing a strong positive relationship between MeHg concentrations (dissolved phase only) and specific conductance in lake water.

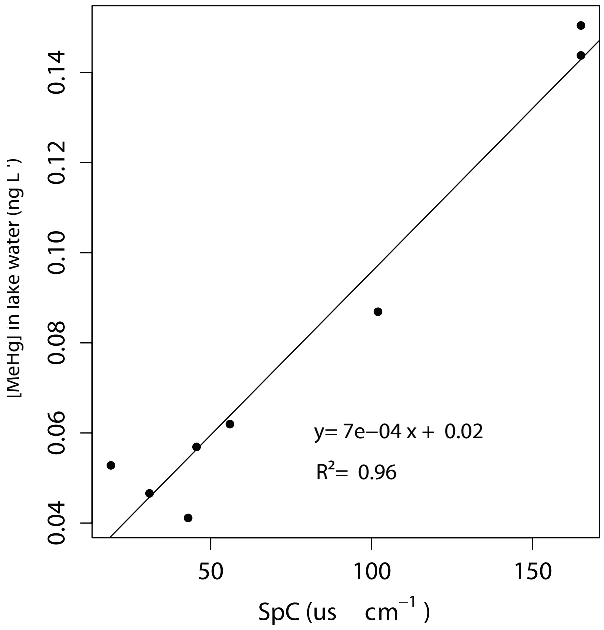


Figure 5: Bivariate scatterplots showing a strong positive relationship between MeHg concentrations (dissolved phase only) in lake water and MeHg concentrations in (a) benthic algae; and (b) brook trout muscle tissue (lake averages).

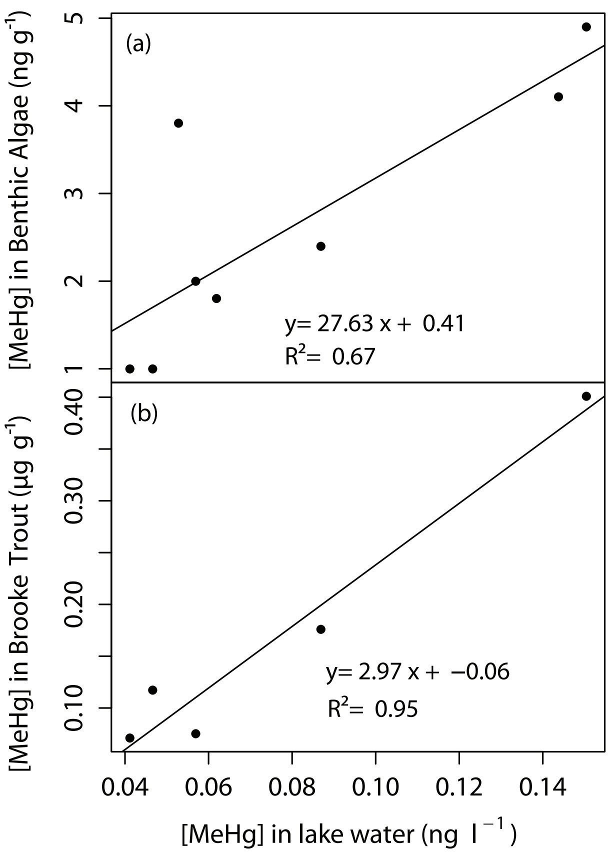


Figure 6: (A) DGT measurements of bioavailable MeHg concentrations in sediment and overlying water. (B) Relationship between MeHg concentrations in sediment-dwelling chironomids and bioavailable MeHg concentrations in sediment at the 8 study sites.

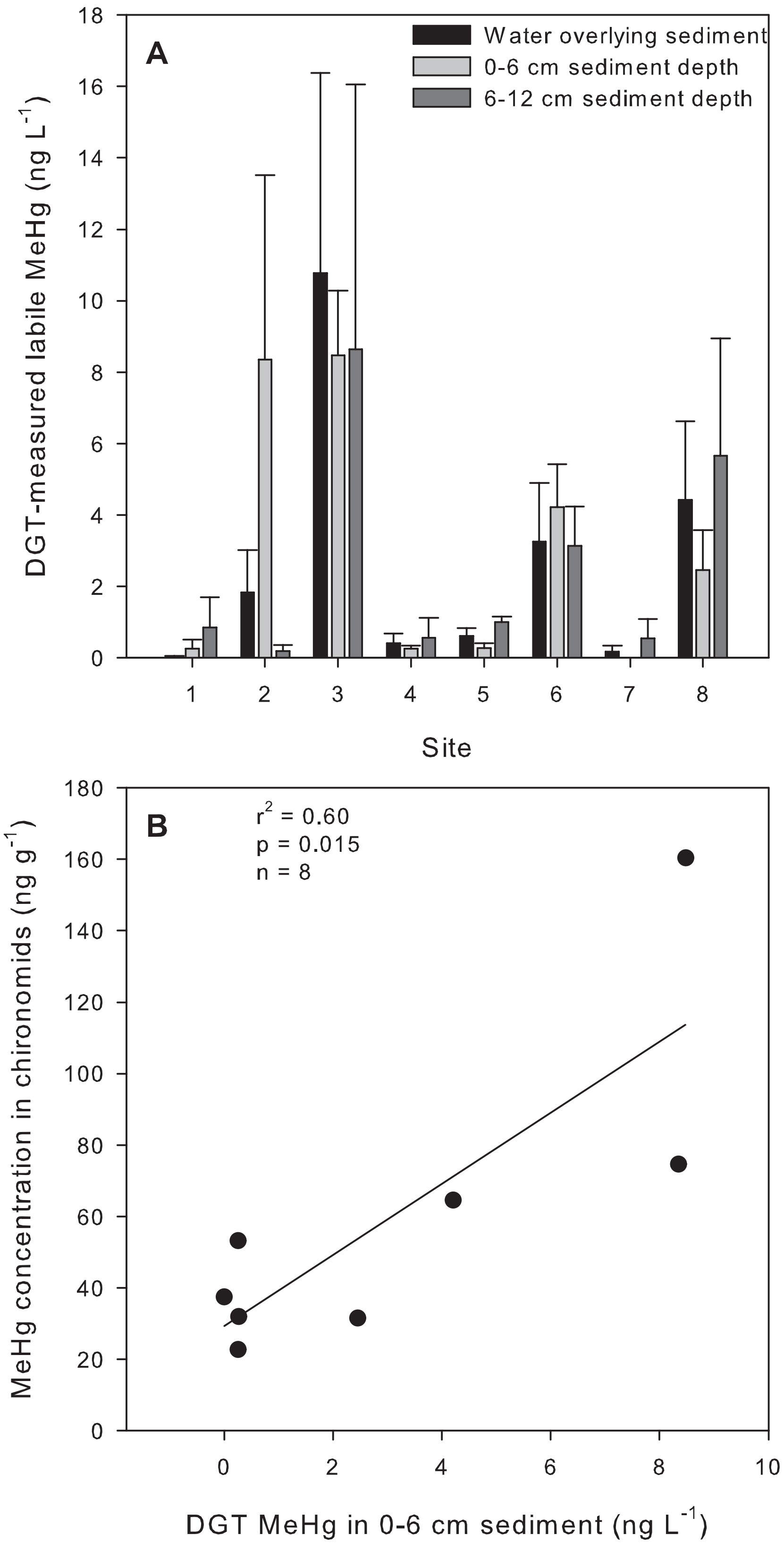


Figure 7: Boxplots of THg concentrations in muscle of 61 brook trout from 5 water bodies near Kuujjuaraapik. The boundary of boxes represent the 25th and 75th percentiles, the line in the box is the median, error bars represent the 10th and 90th percentiles, and closed circles are outliers.

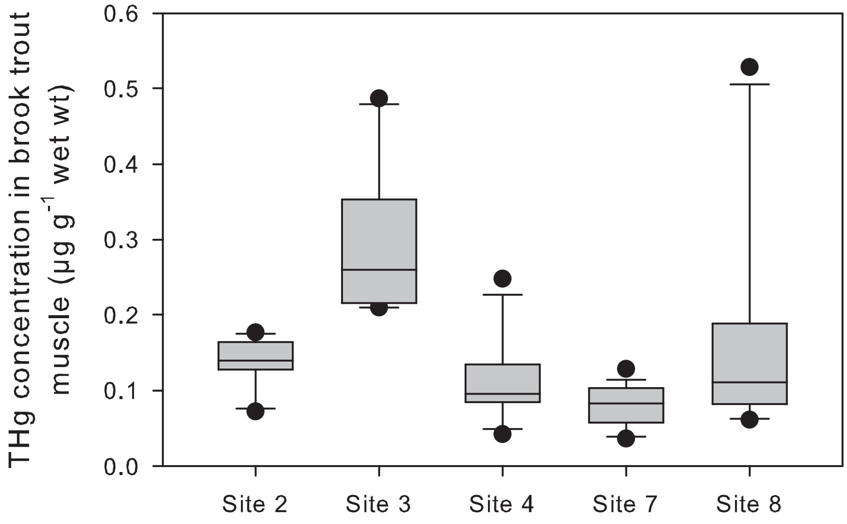


Figure 8: MeHg concentrations in zooplankton from 8 lakes and 8 ponds in Kuujjuaraapik; results shown are for bulk sample (dark green) and sorted samples of *Daphnia* (pale green), * shows lakes with less than 5% *Daphnia*, Φ shows ponds with more than 85% *Daphnia* (% for relative species abundance).

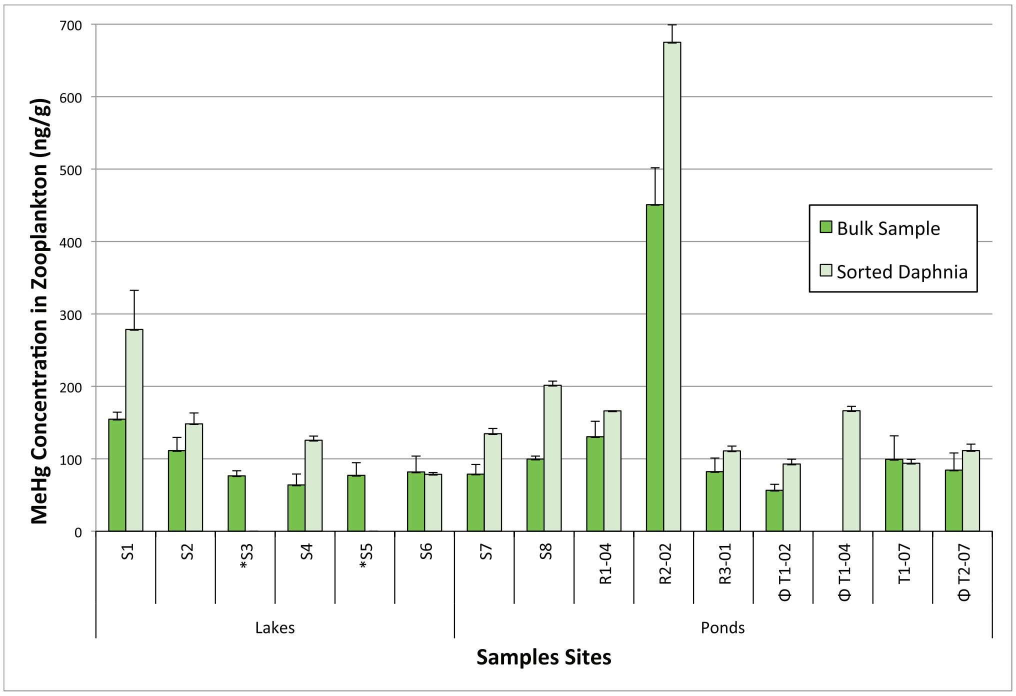


Figure 9: Relationship between THg concentrations in brook trout muscle and their trophic position in 5 water bodies near Kuujjuaraapik.

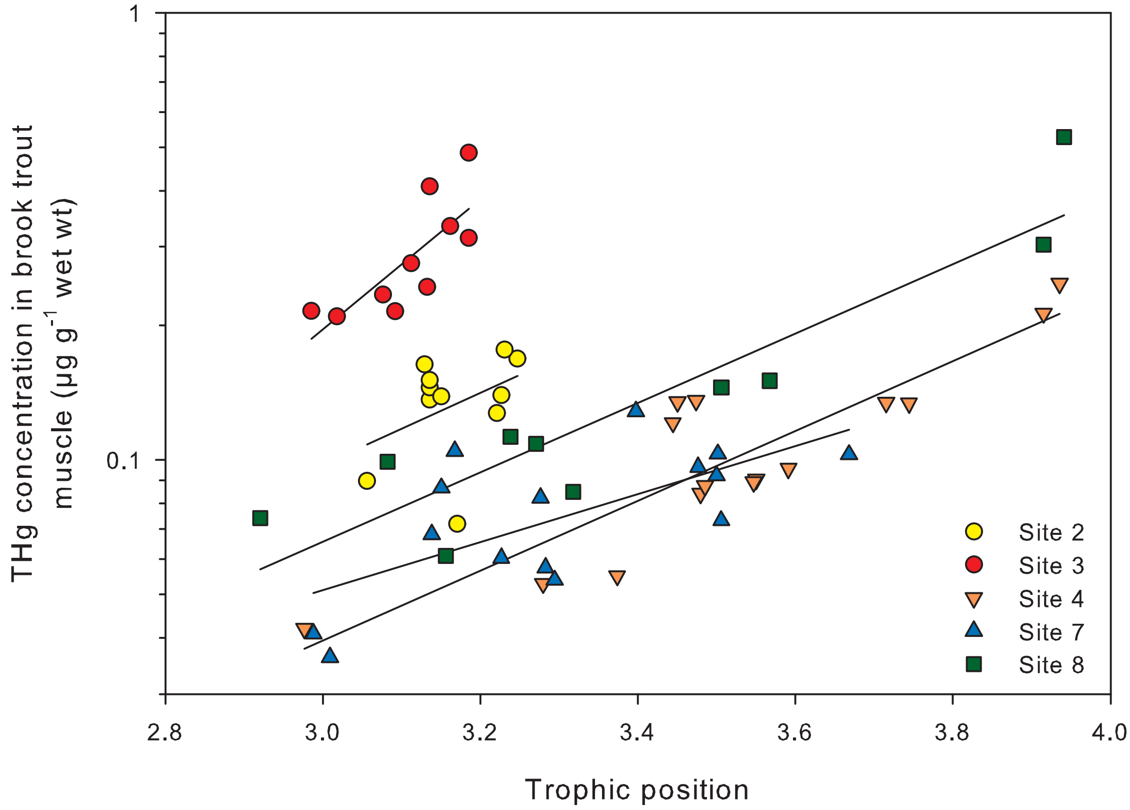
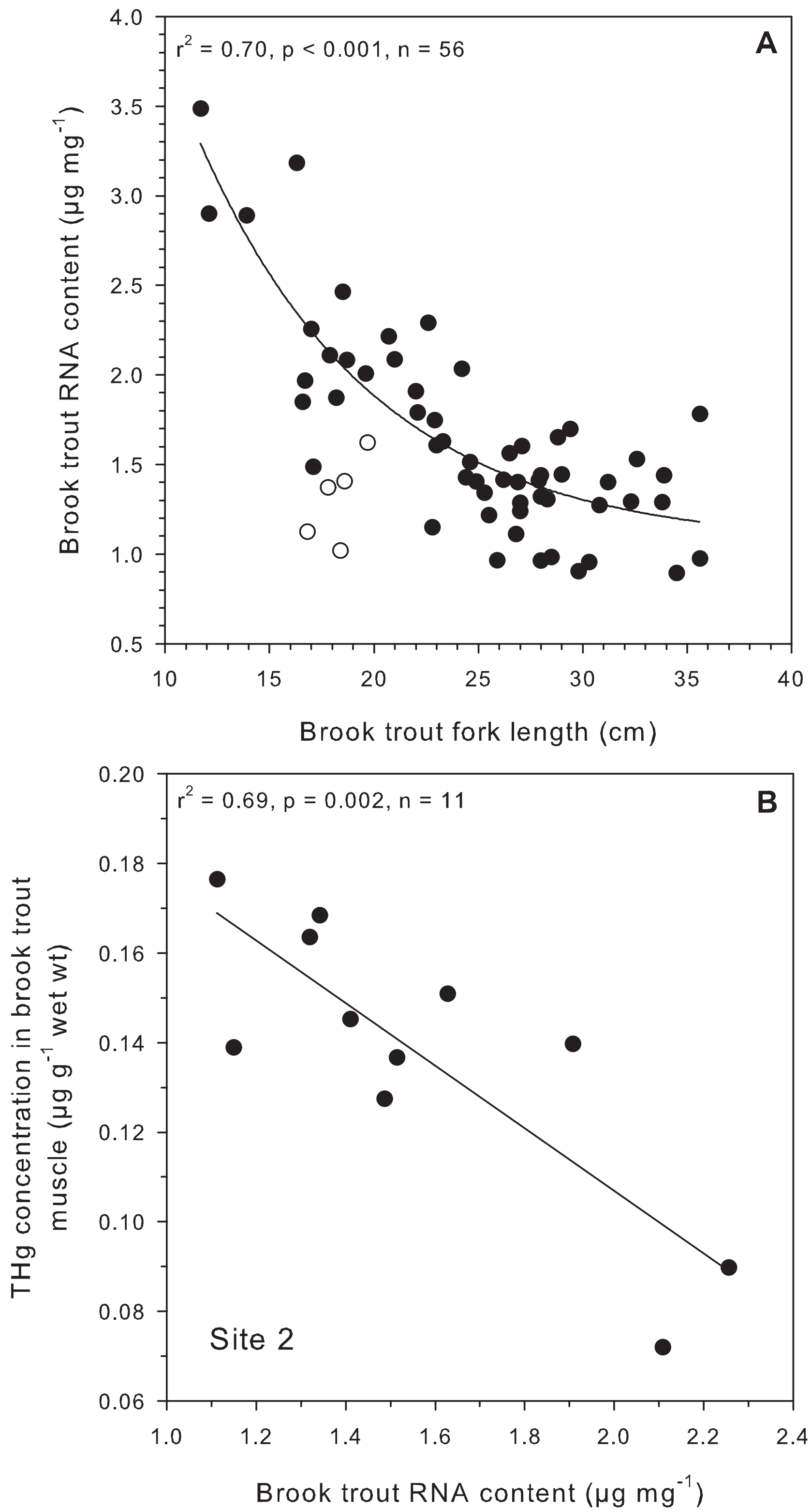


Figure 10: (A) Relationship between the RNA content of brook trout muscle and fish length. RNA content provides a proxy measurement for growth rate, which is expected to decline in larger and older fish. Five fish from site 3 (open circles) were outliers (excluded from regression) because they had stunted growth (<20 cm length at age 5 or 6) and lower RNA content than other fish of the same size. (B) Relationship between brook trout THg concentration and RNA content in muscle at site 2.



from 68–281 ng g-1 dry wt in sorted *Chaoborus*. Most samples fell within the range of 57–279 ng g-1 dry wt, with the exception of one highly contaminated rock pond (415 ng g-1 dry wt for bulk zooplankton, 675 ng g-1 dry wt for *Daphnia*). A review of the recent literature shows that, in freshwater zooplankton from the Canadian Arctic, average MeHg concentrations range from 3–269 ng g-1 dry wt for bulk samples, and from 127–302 ng g-1 dry wt for sorted *Daphnia* (NCP 2013). The concentration of MeHg in the zooplankton was not correlated to the concentrations of inorganic or organic Hg in the water column at each site. Other physicochemical and biological variables, such as nutrient stoichiometry and trophic interactions, are likely responsible for variation between sites. Our preliminary results show that samples of sorted *Daphnia* have consistently higher concentrations of MeHg than bulk zooplankton at each site, confirming that *Daphnia* play an important role in the bioaccumulation of MeHg. *Daphnia* have been previously identified as key vectors for MeHg transfer within food chains (Chételat and Amyot 2009).

The THg concentrations in brook trout varied both within each site and among sites (Fig. 7). In general, the THg concentration of individual fish at each site increased with trophic position (Fig. 9), age and total length. After correcting for differences in trophic position, significant differences in average THg concentrations of brook trout were found among sites (ANCOVA, Site $p < 0.001$, $n = 61$). Brook trout at site 3 had the highest mean concentration (adjusted for trophic position), intermediate concentrations were found at sites 2 and 8, and the lowest concentrations were found at sites 4 and 7 (Fig. 9). Higher concentrations of water MeHg and bioavailable MeHg were measured at sites 2 and 3 where higher brook trout THg concentrations were also observed, indicating site differences were related to MeHg supply to the food web (Fig. 5&6).

The nucleic acid content of benthic invertebrates and fish muscle were measured to estimate the growth rates of these organisms. RNA content was higher in chironomids (8.6 ± 0.4 µg mg-1, n = 8) and caddisflies (7.3 ± 0.7 µg mg-1, n = 2) than in small-sized amphipods (2.8 ± 0.1 µg mg-1, n = 8) and large-sized amphipods (2.1 ± 0.3 µg mg-1, n = 8). The RNA content of brook trout muscle decreased with the length of the fish (Fig. 10A), consistent with slower growth rates in larger, older individuals. Site 3 had a very small surface area and water depth, and some of the brook trout living there had stunted growth with lengths <20 cm at age 5 or 6 (open circles in Fig. 10A). Those fish had lower RNA content for their length than fish from other sites, showing that the RNA content reflected their stunted growth. This result highlights the utility of RNA content to compare growth rates and will be used in future project years to compare fish growth rates among study regions at different latitudes. Likewise, invertebrate growth rates estimated with RNA content will also be compared among regions. Growth rate may affect MeHg bioaccumulation, where faster growth rates result in a lower MeHg concentration through biomass dilution. As an example, brook trout at site 2 varied two-fold in THg concentration but all the fish had a similar trophic position (range = 3.1–3.2). Within this population, muscle THg concentration was negatively correlated with RNA content, suggesting that higher mercury levels were related to slower growth in some individuals (Fig. 10B).

Conclusions

We conducted a detailed characterization of mercury cycling in sub-Arctic lakes near Kuujjuaraapik. Our preliminary results show that watershed processes, MeHg bioavailability to food webs, invertebrate taxonomy, trophic transfer and organism growth rates contribute to MeHg bioaccumulation in the sub-Arctic lakes. Further, our preliminary results confirm the utility of novel approaches applied in this study including watershed characterization using satellite imagery, DGT measurements of bioavailable MeHg, and growth rate estimates using nucleic acid content. The information on mercury cycling in these systems will be compared to higher latitude sites over the next two years to identify climate influences on MeHg bioaccumulation in aquatic food webs of the eastern Arctic.

Expected Project Completion Date

The anticipated completion date for project activities (i.e. sample collection, laboratory analyses and data compilation) is March 31, 2015. Completion of data analysis and manuscript preparation will follow.

Acknowledgements

We thank the NCP for funding to conduct this project. Assistance for field logistics was provided by the Centre d'études nordiques (Université Laval). We thank the Sakkuq Landholding Corporation for permission to conduct this research in local lakes and their participation in the study. The guiding and field support provided by Jimmy Angatookalook was greatly appreciated.

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

Variations spatiales et temporelles des ratios d'isotope de mercure dans des noyaux de glace de l'Arctique canadien

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Abstract

The Arctic is vulnerable to global mercury (Hg) pollution, and Hg levels in top marine predators (e.g., beluga, polar bears) are reported to have increased ~10-fold in the past 150 years, raising serious concerns about the safety of traditional foods in northern populations. While Hg emissions in North America and Europe have declined in recent years, emissions from Asia have been rising. However, the exact sources and pathways of Hg to the Arctic have yet to be determined. This information is needed to inform national and international policy development, for example for the recently adopted Minamata Convention on Mercury.

Résumé

L'Arctique est vulnérable à la pollution globale par le mercure (Hg), et on rapporte que les niveaux de Hg chez les principaux prédateurs marins (p. ex., le béluga et l'ours polaire) sont environ dix fois plus élevés qu'il y a 150 ans, ce qui soulève des préoccupations sérieuses quant à la salubrité des aliments traditionnels pour les populations nordiques. Bien que les émissions de Hg aient décliné en Amérique du Nord et en Europe au cours des dernières années, celles provenant de l'Asie sont en hausse. Toutefois, les sources et les voies de transport exactes du Hg présent dans l'Arctique restent à préciser. Ces données sont nécessaires pour appuyer l'élaboration de politiques à l'échelle nationale

This study aims to provide clues about factors such as a changing climate and human-caused releases on Hg deposition in the Arctic by using Hg isotope measurements. Ice-cores spanning a north-south gradient in the Eastern Canadian Arctic are being examined for spatial differences of Hg isotope signals. Pre-industrial times with extremes in ice cover, and present (industrial) times will also be compared.

Ice core samples from Penny Ice Cap, Devon Ice Cap, Prince of Wales Icefield and Agassiz Ice Cap, as well as one time period from Mt Logan, were retrieved from the ice-core archive of the Geological Survey, Natural Resources Canada in Ottawa. The ice-core samples were cleaned at the Geological Survey and the University of Ottawa, respectively. Samples are currently being analyzed at Trent University for mercury isotopes, and at the University of Ottawa for total and methyl mercury.

First results show different Hg isotope signals in pre-industrial versus present time ice-core samples from Penny ice-cap. The results may reflect post-depositional processes, climate change effects, as well as changing mercury deposition that occurred over time, and it may be possible to differentiate source-specific signals.

et internationale, notamment pour la récente Convention de Minamata sur le mercure.

La présente étude a pour but de fournir, à l'aide de mesures isotopiques de Hg, des indications sur des facteurs comme le changement climatique et les émissions anthropiques sur les dépôts de HG dans l'Arctique. On a entrepris d'examiner des noyaux de glace selon un gradient nord-sud dans l'Est de l'Arctique canadien afin de déterminer les différences spatiales dans les signaux isotopiques de Hg. On comparera aussi les données de l'époque préindustrielle (niveaux extrêmes de couverture de glace) avec celles de l'actuelle ère industrielle.

Des échantillons de glace provenant de la calotte glaciaire Penny, de la calotte glaciaire de Devon, du champ de glace Prince-de-Galles et de la calotte glaciaire Agassiz, ainsi que du mont Logan (une période), ont été tirés des archives de la Commission géologique de Ressources naturelles Canada, à Ottawa. Les échantillons ont été nettoyés à la Commission géologique et à l'Université d'Ottawa respectivement. Des analyses sont en cours à l'Université Trent (isotopes de mercure) et à l'Université d'Ottawa (mercure total et méthylmercure).

D'après les premiers résultats, les échantillons de l'ère préindustrielle ne présentent pas les mêmes signaux isotopiques que ceux d'aujourd'hui en ce qui concerne la calotte glaciaire Penny. Ces résultats pourraient s'expliquer par des processus ayant suivi la sédimentation, les effets du changement climatique et l'évolution des dépôts de mercure au fil du temps, et il pourrait être possible de différencier les signaux propres à diverses sources.

Key Messages

- Hg values in ice cores are very low, and very large volumes of ice are needed for reliable Hg isotope measurements.
- Hg isotope values are in a similar range as those reported in the literature for recent precipitation, and can be compared with values measured in other media, such as lichens and sediments.
- Differences in Hg isotope values are evident for different time periods that may reflect climate effects and other pre- and/or post-depositional processes.
- It may be possible to differentiate source-specific signals for Hg isotopes in ice-cores.

Messages clés

- Les valeurs de Hg dans les noyaux de glace sont très basses, et de très grandes quantités de glace sont nécessaires pour obtenir des mesures isotopiques de Hg fiables.
- Les valeurs isotopiques de Hg sont semblables à celles signalées dans la documentation en ce qui concerne les précipitations récentes, et elles se comparent aux valeurs mesurées dans d'autres matières, par exemple les lichens et les sédiments.
- Les différences dans les valeurs isotopiques de Hg sont évidentes d'une période à l'autre, ce qui peut s'expliquer par les effets climatiques et d'autres processus précédant ou suivant la sédimentation.
- Il pourrait être possible de différencier les signaux d'isotopes de HG propres à diverses sources dans les noyaux de glace.

Objectives

Short term:

- Determine how mercury isotopic signatures in ice-cores vary at different temporal and spatial scales across the East Canadian Arctic.
- Contrast Hg isotopic composition in ice-core samples from periods with low/high extremes in temperature and sea ice cover to discriminate between climatic changes and changes caused by anthropogenic Hg releases.

Long-term:

- Identify Hg sources to the Arctic, how they have changed through time, and how climate variations affect the Hg cycle in the Eastern Canadian Arctic.

Introduction

The Arctic is particularly affected by global Hg emissions: Studies report that Hg deposition to remote environments has increased by a factor of three since pre-industrial times, and that there has been a ten-fold increase in Hg levels in top predator marine animals over the past 150 years (Point et al. 2011, AMAP 2011).

The longest series of atmospheric Hg measurements in Alert, Canada (starting in 1995), have revealed a slight decline in airborne Hg levels, while emissions from North America and Europe are reported to have decreased in recent decades (Cole and Steffen 2010, Pacyna *et al.* 2006). However, increasing energy consumption and associated fossil fuel burning in Asia is responsible for increasing global Hg emissions, and models show that this Hg is readily and rapidly transported to the Arctic (Pacyna et al. 2006, Durnford et al. 2010). Current research seeks to determine how atmospheric Hg is deposited in the Arctic, and how it subsequently makes its way into the Arctic food-web. Since Hg is a naturally occurring element with very unique properties, it is difficult to distinguish between natural and anthropogenic contributions to the Arctic's Hg budget. This is a prerequisite to regulation by international agreements, and is needed for the successful negotiation of a global treaty on Hg.

In the past decade, several studies have shown that stable isotope ratios of Hg can be used to trace and differentiate between sources of atmospheric Hg deposition in terrestrial or aquatic ecosystems. For example, Biswas et al. (2008) were able to determine diagnostic Hg isotopic fingerprints for coal deposits of the United States, China, and Russia-Kazakhstan, which are among the World's greatest coal-producing regions. Carignan et al. (2009) measured the Hg isotopic composition in lichens, which are thought to reflect the composition of atmospheric Hg. The authors found negative isotopic anomalies, contrasting positive isotopic anomalies of Hg found by Bergquist and Blum (2007) in aquatic environments. Carignan et al. (2009) conclude that Hg isotopic composition may be used to trace globally relevant sources and pathways of Hg. A similar conclusion is drawn by Gratz et al. (2010), who measured Hg isotope composition in precipitation and ambient air of the Great Lakes regions. They also suggest the potential use of Hg isotopes to identify Hg sources and important atmospheric processes.

A study on Hg in food webs of Arctic lakes found different Hg signatures in fish for the different regions observed and observed a latitudinal trend (Gantner et al. 2009). The authors hypothesized that this trend could be due to atmospheric transport processes, different atmospheric or terrestrial Hg sources, or a combination of the three (Gantner et al. 2009). Point et al. (2011) also found a latitudinal trend in Hg isotopic signatures in Arctic seabird eggs, and postulate that this gradient is related to sea-ice cover. However, the authors assume that latitudinal variations in coal-related deposition in northern environments would be too small in magnitude to explain the large gradient they found in seabird eggs. Nevertheless, the biotic environment is influenced by other factors compared to the physical environment, and source-specific signals may be distorted or altered by biotic processes or animal movement.

Other recent studies suggest that Hg isotope ratios in Arctic snow, fresh- or seawater and in biota may vary as a function of environmental parameters such as ambient temperature - through phase changes - and sunlight (Bergquist and Blum 2009; Sherman et al. 2010). Of particular interest is the recent discovery by Point et al. (2011) that mass-independent fractionation (MIF) of Hg isotopes in marine monomethyl mercury (MeHg) at subarctic or Arctic latitudes may be partly controlled by sea-ice cover extent, as mentioned above. Based on their findings, the authors suggest that the anticipated disappearance of Arctic sea ice in the 21st century might lead to a net decrease in the bioavailable marine MeHg pool. They expect this effect due to enhanced photodegradation in the absence of sea-ice. However there are still many unknowns concerning the role of biotic processes in controlling Hg isotope fractionation in Hg and MeHg (Berquist and Blum, 2009).

This study is using a powerful approach to help differentiate between the various factors that control Hg isotopic signatures in Arctic aquatic (or terrestrial) ecosystems. It will compare isotope ratios measured in modern and pre-industrial (up to 10,000 yrs before present) Arctic precipitation, as preserved in ice-cores, across a number of geographically distant sites from the Canadian Arctic.

Activities in 2012/13

Ice-core samples representing a north-south gradient across the Eastern Canadian Arctic were selected by Christian Zdanowicz and Eva Kruemmel for Hg isotope ratios determination (Table 1) and/or total/methyl mercury analyses. These include samples from Penny Ice Cap (Baffin Island), the Prince of Wales Icefield (central Ellesmere Island), and Agassiz Ice Cap (northern Ellesmere Island). We were additionally able to obtain some ice from Mt Logan (Yukon Territory) ice core from mid-Holocene for the Hg isotope analysis.

The selected time intervals for the ice cores are:

- Modern precipitation (the last ~50-100 years),
- Late Holocene precipitation (interval between ~150 and 3000 years ago),
- Mid-Holocene precipitation (interval between ~3000 and 6000 years ago),
- Early Holocene precipitation (interval between ~6000 and 11,500 years ago).

The approximate age estimates are based on depth-age models which are described in the following publications: Penny Ice Cap: Fisher et al. 1998; Devon Ice Cap: Kinnard et al. 2006; Prince of Wales Icefield: Kinnard et al. 2008; Agassiz Ice Cap: Fisher et al., 1995.

Cleaning process

Prior to analysis, the ice cores were cleaned by Eva Kruemmel to remove the outer layer of the ice cores that could have been contaminated with Hg during drilling or previous manipulations.

The cleaning process depended on whether ice core samples consisted of solid ice (which was the case for pre-industrial ice-core samples) or firn (most modern time/industrial era samples). The status of the ice core processing is given in Table 2. It should be noted that because of the very low mercury concentrations in the ice cores, a large volume of ice is needed for one reliable Hg isotope measurement. For example, for Penny 96.1, a total of 69 core segments were cleaned. The core segments were on average 85 cm in length, but frequently the cores were used for other analyses before, and cut in half or quartered lengthwise, meaning that often not the full cores were available for the Hg isotope analysis. Therefore usually many segments had to be combined for one Hg isotope measurement (typically around 10 L of meltwater needed to be pre-concentrated for one measurement). Therefore, as can be seen in the results, only a total of four Hg isotope measurements could be obtained from those 69 ice core segments.

For (solid) ice-core samples, the ice-cores were transported to the University of Ottawa frozen and processed at the Centre for Advanced Research in Environmental Genomics (CAREG) at the University of Ottawa. The core segments (bagged in polyethylene) were taken into a Class 100 clean room, where they were partially thawed at normal room temperature (20°C) inside their bags, until ~5 mm of ice had melted from the outer layers. Previous experience with trace metals analyses in ice cores showed that this is sufficient to remove outer contamination (Zheng et al. 2006). Once the ice was partially thawed, the bags containing the cores were cut open, the meltwater was decanted, and the remaining ice pieces were rinsed with distilled and double deionized water. They were then placed inside Hg-free, sealable Teflon bags. The decontaminated ice samples were immediately frozen again, and transported to the Water Quality Center at Trent University, Ontario, to be analyzed for total Hg (THg) and for Hg isotope ratio determination.

For firn cores (Prince of Wales and Agassiz industrial-era samples), samples were processed by cutting 5 – 10 mm of the outer layer with a bench saw at the cold room facilities (-5 to -10 degrees C) of the Geological Survey at Natural Resources Canada (NRCan) in Ottawa. The frozen, cut cores were then immediately placed inside Hg-free, sealable Teflon bags and stored at -20 degrees C at the Geological Survey until transport to Trent University for Hg isotope analysis.

Methods

Analytical work is conducted at the University of Ottawa for THg and MeHg analyses by Emmanuel Yumvihoze, and at Trent University for Hg isotope ratio determinations by Marko Strok.

Measurements of total mercury (THg) and monomethyl-mercury (MeHg) in meltwater are performed at the Mercury Laboratory, in the Centre for Advanced Research in Environmental Genomics of the University of Ottawa. The laboratory is proficient for inorganic and total mercury analyses in soil/sediment and in water, with a CALA accreditation (Canadian

Association for Laboratory Accreditation Inc.) and regularly participates in international inter-calibration exercises to evaluate its performance with MeHg analyses. Total mercury is determined by CV-AFS after a reduction step with $SnCl_2$, following EPA method 1631E (US-EPA, 2002). Analyses are performed on a Tekran 2600 system control module equipped with a liquid handling module and autosampler. The established method detection limit is 0.2 ng/L. The typical precision (reproducibility) of THg measurements, estimated from replicate analyses is between 10 and 20 % for Arctic snow and field samples and within 5% for homogeneous natural water samples.

For MeHg analyses, the melted ice samples are pre-concentrated by passing the acidified water through sulfhydryl cotton solid-phase extraction columns using a multi-channel peristaltic pump, as described by Cai et al. (1996). The MeHg adsorbed on the sulfhydryl cotton is then eluted into glass vials with added acidic $KBr/CuSO_4$ before analysis by capillary gas chromatography coupled with atomic fluorescence spectrometry (GC-AFS) using a PS Analytical mercury system model PSA 10.723. The established detection limit is 0.02 ng/L, and the typical analytical precision ranges between 10 and 30 %.

The determination of Hg isotope ratios is taking place at Dr. Hintelmann's laboratory in the Water Quality Center of Trent University. The Hintelmann lab pioneered the use of natural Hg isotope variation in environmental applications. For this study, we follow the protocols established by previous method development. Hg isotope ratios are determined on a Thermo Fisher MC-ICP/MS (Foucher and Hintelmann 2006). Hg is introduced in elemental form by continuous-flow cold-vapor generation after $SnCl_2$ reduction. Instrumental mass bias is corrected using a Tl internal standard, and external standard-sample bracketing with NIST SRM 3133 Hg solution. Hg vapors are mixed in the CV generation system with the dry Tl aerosol generated using a desolvation unit. ^{198}Hg, ^{199}Hg, ^{200}Hg, ^{201}Hg, ^{202}Hg, ^{203}Tl and ^{205}Tl isotopes are acquired. An exponential fractionation law is applied for internal mass bias correction assuming a reference value of 2.3871 for the ratio $^{205}Tl/^{203}Tl$. To ensure optimum results of instrumental mass bias correction, the concentration of the bracketing solution is systematically adjusted to within 10% of the Hg concentration in the sample digest (typically between 1 to 5 µg Hg L^{-1}).

Analytical uncertainty has been measured by analyzing the UM-Almadén (in 1% BrCl) as a secondary standard in addition to the bracketing standard NIST 3133. The overall average and uncertainty of $\delta^{202}Hg$ was -0.58 ± 0.10‰ (2 SD, n = 18), of $\Delta^{201}Hg$ was -0.03 ± 0.08‰ (2 SD, n = 18) and of $\Delta^{199}Hg$ was -0.01 ± 0.09‰ (2 SD, n = 18) for all UM-Almadén measurements, which agrees well with data reported in Blum and Bergquist (2007). The 2 SD of UM-Almadén also represents the typical external uncertainty of our sample measurement (Zheng and Hintelmann 2009).

Quality Assurance/Quality Control

To determine the efficacy of the ice core decontamination protocol, meltwater or scrapings from the outer core layers are being measured for THg, and (if enough material is available) are pooled for Hg isotope ratio determinations. For THg and MeHg measurements of melted samples take place at the University of Ottawa, the QC/QA protocols follow those recommended in EPA method 1631E. Each batch of samples is analyzed jointly with water blanks, calibration blanks, and internal and external standards for initial and ongoing precision recovery (IPR/OPR) estimates. NIST solutions are also used for checking calibration.

For Hg isotope ratio determinations, blanks are prepared for every batch of samples, and replicates of a certified reference material are used to evaluate the external precision of the measurement. A minimum of one procedural blank is analyzed at the beginning and the end of each experimental day and one certified reference material is run for every 4-5 samples. As well, a Hg solution, for which a consensus value has been reached (Almadén UM-1) will be measured before and after each batch of samples.

Progress of sample analysis

Table 2 summarizes the progress of the sample analysis to date. For the Hg isotope analysis, first total Hg is measured in the samples at Trent University. This data will be used and compared to the total Hg data measured at the University of Ottawa.

Some problems were encountered during the Hg isotope analysis, for example when Prince of Wales (modern time) samples were analyzed by Marko Strok at Trent University for total mercury and mercury isotopes: Higher mercury recoveries than expected were being observed in the first batch of five samples, and it was determined that this was due to mercury residues on the resin used in the pre-concentration process. A new cleaning method for the resin has been developed, and mercury recoveries improved. The results for the samples with the high mercury recoveries will be removed from the data analysis.

A delay is currently experienced with the remaining samples from Agassiz and Devon (Late – Early Holocene): Although we were able to accumulate large volumes of > 10 L for each of the time periods, total mercury values for composite samples of the different time periods are often under the required 5 ng/L for robust Hg isotope measurements, which make the analysis particularly difficult. The MC-ICP-MS at Trent University is also presently undergoing scheduled maintenance, and the samples will be measured when the instrument is ready for the analysis.

Capacity Building

Since the ice core samples were taken from archives of the Geological Survey, our ability to build capacity so far has been limited. One summer student at the University of Ottawa assisted Eva Kruemmel with some of the ice core cleaning of the Penny 96.1 samples, learned the cleaning method and learned why the study was being conducted.

Communications

So far, one presentation was held at the IPY Conference in Montreal (April 2012), titled "Mercury in ice and water from Penny Ice Cap in Auyuittuq National Park, Baffin Island, Nunavut" which summarized findings from the earlier study let by C. Zdanowicz (see below), and included some preliminary results from this study. Since not all samples have been analyzed yet, we are not in the stage of communicating the final results of this study. Communication of the results will rely on ICC Canada's usual communication pathways, which will include briefing notes to ICC Canada leadership and the regional board members, reporting in ICC Canada and NCP reports, as well as contributions in newsletters and other information items, as applicable. We are also planning one or more publications in peer reviewed journals.

The preceding NCP Project M-18 *(Atmospheric deposition and release of methylmercury in glacially-fed catchments of Auyuittuq National Park, Baffin Island)* lasted two years (2008-09, 2009-10). It was led by C. Zdanowicz and D. Lean, and aimed at characterizing the net atmospheric input, and the net release by melt and runoff of total mercury (THg) and monomethyl mercury (MeHg) in an eastern Arctic catchment on southern Baffin Island. Data from this study was included in several publications:

- Zdanowicz, C., Krümmel, E. M., Lean, D., Poulain, A. J., Yumvihoze, E., Chen, J., and Hintelmann, H. 2013. Accumulation, storage and release of atmospheric mercury in a glaciated catchment, Baffin Island, Canada. Geochim.Cosmochim. Acta. 107:316-335.
- Douglas, T.A. and 26 others, including Zdanowicz, C. 2012. The fate of mercury in Arctic terrestrial and aquatic ecosystems, a review. Environmental Chemistry 9: 321–355
- Douglas, T.A. and 10 others, including Zdanowicz, C. How does climate change influence Arctic mercury? Science of the Total Environment 414: 22-42.

- Third Canadian Arctic Contaminants Assessment Report on Mercury. Edited by J. Chetelat and B. Braune. Aboriginal Affairs and Northern Development Canada, Ottawa, 2011. (In press) [Contribution author to Chapter 4, under preparation as a review article]
- Arctic Pollution 2011: Mercury. Edited by P. Outridge and S. Wilson. Arctic Monitoring and Assessment Program, Oslo, 2011. [Contributing author to Chapter 3]

Traditional Knowledge Integration

Because not all data is available for the data analysis yet, we did not have the opportunity to look at the extent of which traditional and/or local knowledge may be used in this study. In the previous study (let by C. Zdanowicz) about mercury in ice and water from Penny Ice Cap in Auyuittuq National Park, Baffin Island, Nunavut, we were informed by Inuit from Pangnirtung about an extreme melting event on the ice cap that caused flooding in the community shortly before samples were taken. This information was then used in the interpretation of the results. Similar information may be used in this study, if applicable. Unfortunately much of the needed information would be from times from which there will be no traditional knowledge available. For example, in one segment of the Devon ice core belonging to the Early Holocene (8,000 – 11,000 yrs before present), small black particles were found in the core that could originate from a volcano eruption or wild fires. Information about an event during this time would be helpful in the data analysis; however, since the event took place approximately 10,000 years ago, we will have to rely on analysis of the particles for clues of their origin.

Results

Since not all samples have been analyzed yet, only some preliminary results for Penny Ice Cap (southern Baffin Island) are presented here.

While two composite samples for the mid- and early Holocene for the Penny 1995.4 core still await Hg isotope analysis, Hg isotope data for the Penny 1996.2 core has been analyzed and is summarized in Figure 1 and 2. Mass-dependent fractionation (MDF) is reported as per mil (‰) deviations relative to a reference standard for δ199Hg, δ200Hg, δ201Hg, and δ202Hg. Mass-independent fractionation (MIF) is reported as capital delta (Δ199Hg, Δ200Hg, Δ201Hg), which is the difference of the measured δxxxHg and the theoretically predicted value, in units of per mil (‰). The precision of the method is 0.08‰ for MIF and approx. 0.2‰ for MDF determination.

As can be seen on Figure 1, MDF is observed in composite ice-core representing three time periods: Modern (industrial time) of 16 - 90 years ago, and three pre-industrial times (Late-Mid Holocene: 1,000 – 1,500 B.P., and 1,500 to 3,000 B.P, as well as Mid-Early Holocene: 3,800 – 10,600 B.P.). All samples show negative δ values, and there is an apparent time trend for all four Hg isotopes. δ202Hg and δ201Hg values display a significant enrichment over time (δ values are more positive in the composite samples from the present time compared to pre-industrial times). A slight enrichment over time is observed for δ200Hg. δ199Hg, on the other hand, does not show a clear trend, with slightly more negative values in the modern time, which become more positive in the Late-Mid Holocene, and then slightly depleted again in the Mid-Early Holocene.

It is notable that all Holocene samples show a more pronounced depletion of δ202Hg and δ201Hg relative to δ199Hg and δ200Hg, but this pattern is particularly distinct for the oldest time period (3800 – 10600 B.P.).

Differences are also evident for Hg isotopes undergoing MIF, as shown in Figure 2. While the composite sample of the present time shows quite significant negative MIF of the odd-mass isotopes Δ^{199Hg} and Δ^{201Hg}, there is much less MIF visible in the composite samples of the two earlier pre-industrial time periods (Late to Mid- Holocene), with both odd-mass isotopes having values that are slightly positive and/or close to zero in those samples. The oldest time period (Mid-Early Holocene, 3800 – 10600 yrs B.P.) however displays a Δ^{199Hg} MIF closer to the other two pre-industrial times and is even more positive, while its Δ^{201Hg} value is negative and closer to the modern time period.

Discussion and Conclusions

Several studies reported significantly depleted δ202Hg values, for example Sherman et al. (2012) in precipitation (mean -2.56‰, and as low as -4.37‰) and Carignan et al. (2009) in lichens (between -2 to +1.5‰), and attributed this to source signals from local sources (coal combustion and mining, respectively). While the very negative value (-2.3‰) we measured for δ202Hg in the oldest ice-core sample of Penny Ice Cap is in a comparable range to some of the values for δ202Hg reported by the Sherman and Carignan studies, local sources of Hg cannot be the reason for the depleted δ202Hg values in our study due to the remote location of the Penny Ice Cap. However, there is a possibility of long-range transport events, for example from wildfires or volcano eruptions. This option could be supported by findings from Zambardi et al. (2009), who measured very negative δ202Hg0 values (-1.74‰) in the plumes of volcanic fumaroles. We found small black (maybe ash or dust) particles in Devon ice-core samples from the Early Holocene, but so far we are unclear about their nature and origin.

Additionally, a study on historical variation in Hg isotopes from Arctic lake sediments showed a gradual increase of δ202Hg values from 1899 (close to -3‰) to 1997 (around -1‰) (as reported in Yin et al. 2010). The possible reasons are not clear, but it was found that the δ202Hg trend in that study is positively correlated with total Hg concentration, and the authors thought that sediment cores may reflect sources of Hg (Yin et al. 2010).

Also striking is the observed MIF in Penny Ice Cap samples from our study. As explained above, we found slightly positive MIF of Δ199Hg for the oldest time period of Early-Mid Holocene (0.18‰ and around 0.04‰, respectively), and a slightly negative value for the present time (-0.26‰). For Δ201Hg, values were more negative for both the modern and oldest time periods (close to -0.2‰) compared to the Mid-Holocene samples (close to 0‰).

Several studies have described the effect of Hg photoreduction in aquatic systems on MIF, and it was concluded that "photoreduction of aquatic Hg should produce volatile Hg0 with negative Δ199Hg and Δ201Hg that will escape into the atmosphere" (Carignan et al. 2009). Point et al. (2011) found distinct Δ201Hg MIF signatures in seabird eggs, which decreased with increasing latitude. The authors postulated that the signatures are related to the different ecosystems in which the birds forage during breeding season, and particularly the different extend of ice-cover in those systems. They suggested that Hg MIF can be used "as a tracer for both ice cover and surface ocean photochemistry, and this tracer can be used on both recent and geological timescales" (Point et al. 2011). Indeed, historical climate reconstruction from Penny Ice Cap suggests minimal sea-ice cover during the early Holocene (11,500 – 9,000 years b.p.), with temperatures in Baffin Bay reaching those close to modern times or even higher, and a cooling around 3,000 years b.p. (Kaufman et al. 2004). In our results, we see a separation of Δ201Hg MIF that may be related to the extent of ice-cover: in both modern and early-mid Holocene ice Δ201Hg values are more negative and likely originate from a warm climate with very similar (low or minimal) sea-ice cover, whereas late-mid Holocene ice (likely from a colder climate with likely maximum sea-ice cover) display Δ201Hg MIF close to zero. It is therefore possible that the open ocean surface water during the early-mid Holocene and in the modern time allowed for increased photoreduction of aquatic Hg, which produces volatile Hg0 with negative MIF. Those negative MIF are then retained and reflected in precipitation on Penny Ice Cap.

However, while the MIF of Δ199Hg is also negative in modern time samples from Penny Ice Cap, it is positive for the oldest time period of the Early-Mid Holocene, and therefore does not follow the same pattern of increased depletion from photoreduction during those two warm time periods. The question is if another source signal (possibly not climate related, but maybe related to the anthropogenic influence of modern Hg emissions) could be reflected in the different MIF of Δ199Hg from Penny Ice Cap precipitation.

A more in-depth analysis with the pending results of our additional samples will be needed to attempt to answer this question and to better interpret our preliminary Penny Ice Cap data.

Expected Project Completion Date

We expect to have all data available later this spring and conduct data analysis, writing of publications and other communication material during the summer of this year (2013).

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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 dulçaquicole des 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 and 2012, we collected landlocked char from "NCP focal ecosystem" lakes on Cornwallis Island to determine whether wild populations are indeed experiencing

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 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) dulçaquicole. L'analyse des données sur l'omble chevalier dulçaquicole du Nord du Canada et du Groenland révèle que les seuils de toxicité pour le mercure sont dépassés chez 30 % des populations étudiées. En 2011 et en

Hg toxicity. Collections were conducted in cooperation with the char "core" monitoring project led by D. Muir (Environment Canada). The lakes sampled (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 from fish collected in 2011 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. Analyses of fish collected in 2012 are currently underway. 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."

2012, nous avons prélevé des ombles chevaliers dans des lacs d'un écosystème d'intérêt pour le PLCN, à l'île Cornwallis, afin de déterminer si 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, d'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 en présentant une forte concentration. Les paramètres sont la reproduction, l'anatomie/la physiologie du foie et l'état de santé général. Les données sur les poissons prélevés en 2011 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 la mort généralisée des cellules et l'inflammation des tissus en résultent. Les analyses des poissons prélevés en 2012 se poursuivent. Ces recherches devraient produire des résultats clairs sur la toxicité du mercure, et les données obtenues permettront d'estimer un seuil de toxicité propre à l'omble chevalier dulçaquicole. 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

- 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.
- Mercury concentrations in char from all of the lakes, except Small Lake, exceed values known from laboratory studies to cause effects on fish.
- Preliminary results indicate mercury may be affecting char via effects on reproduction and liver function.
- Analyses of fish collected in 2012 are ongoing.

Messages clés

- Nous avons effectué l'échantillonnage d'ombles chevaliers dulçaquicoles dans des lacs (Small, Nine Mile, North, Char, Amituk) près de Resolute Bay, au Nunavut, afin de déterminer les effets du mercure sur cette espèce.
- 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.
- 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.
- Les analyses des poissons prélevés en 2012 se poursuivent.

Objectives

- Study the toxic effects of Hg in landlocked char in "NCP focal ecosystem" High Arctic lakes on Cornwallis Island
- Estimate a threshold concentration of Hg associated with toxic effects in landlocked char
- 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).

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."

Activities in 2012-2013

To investigate the effects of Hg on landlocked char, we collected char in 2010, 2011, and 2012 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 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 and 2012, 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 and 2012 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 and 2012, 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 char projects conducted collaboratively in the lakes of Cornwallis Island (i.e., "core" monitoring led by Muir, the food web project led by Kidd and Muir, and this project).

Preliminary results from this project have also been presented at scientific conferences: the 2011 NCP results workshop (Victoria BC) (poster), the 2012 International Polar Year conference (Montreal QC) (poster), the 2012 SETAC Europe Annual Meeting (Berlin, Germany) (poster), the 2012 and 2013 Gananoque Environmental Science and Engineering Conferences (Gananoque ON) (platform), the 2013 Arctic Workshop (Amherst, MA, USA) (poster), and the 2013 GSA Northeastern Section Meeting (Bretton Woods, NH, USA) (platform).

The Hg data from this project have also been used to validate a new method for Hg speciation in fish tissue. The method is published in a recent issue of ET&C (Barst et al. 2013).

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.

Table 1. Summary data for fork length, mass, condition factor (CF), and concentrations of total mercury (HgT) 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				Hg_T (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
	2012	15	33.4	275	0.740	0.098	0.035	0.040-0.169		0.215	0.093	0.099-0.447
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
	2012	15	34.3	371	0.842	0.143	0.067	0.058-0.275		0.316	0.203	0.084-0.788
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
	2012	14	36.1	470	0.894	0.217	0.183	0.092-0.804		0.484	0.490	0.162-2.09
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												
	2009[c]	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
	2012	14	35.9	415	0.765	0.805	0.438	0.139-1.58		1.54	1.02	0.258-3.79

a Condition factor = 100 x mass / fork length3

b Only four char were caught in Char Lake in 2011 and seven in 2012. 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.

Table 2. Progress and preliminary results for hypotheses designed to detect changes due to Hg in key biological systems of landlocked char.

Hypothesis	Analysis…	Preliminary result
Reproduction (suite of endpoints in relation to HgT 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 (2011)	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 (2011 and 2012)	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 (2011 and 2012)	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 (2011 and 2012)	MeHg comprises, on avg., 78% of Hg_T in livers.
H7: Both MeHg and inorganic Hg are primarily bound to cytosolic metal-binding proteins.	in progress	
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.	in progress	
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 (2011 and 2012)	LSI is <u>positively</u> 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 (2011 and 2012)	Condition factor is not related to Hg concentration.

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) for fish collected in 2011. 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 = 61) and males (n = 37) we collected in July/August 2011 and 2012, GSI was a function of (1) whether gonads were developed and (2) body size. 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 2011 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 in fish collected in 2011. We have complete data from determinations of (H5) total Hg (HgT) and (H6) MeHg. Concentrations of HgT 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 78% of HgT 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 (LSI = liver weight / body weight x 100). LSI is positively related to HgT concentration. Adams et al. (1990) similarly found elevated LSI in sunfish (Lepomis auritus) with high HgT 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 HgT concentration. With two additional years' data (2011 and 2012), however, there is no relation between condition factor and HgT. Condition factor can be "insensitive to changes in body condition", though (Adams et al. 1990).

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. Upon completion of analyses of char collected in 2012, the research will yield unambiguous results about Hg toxicity, and the data will be used to estimate a toxicity threshold specific to landlocked char.

Expected Project Completion Date

We expect to complete the project by September 2013.

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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.

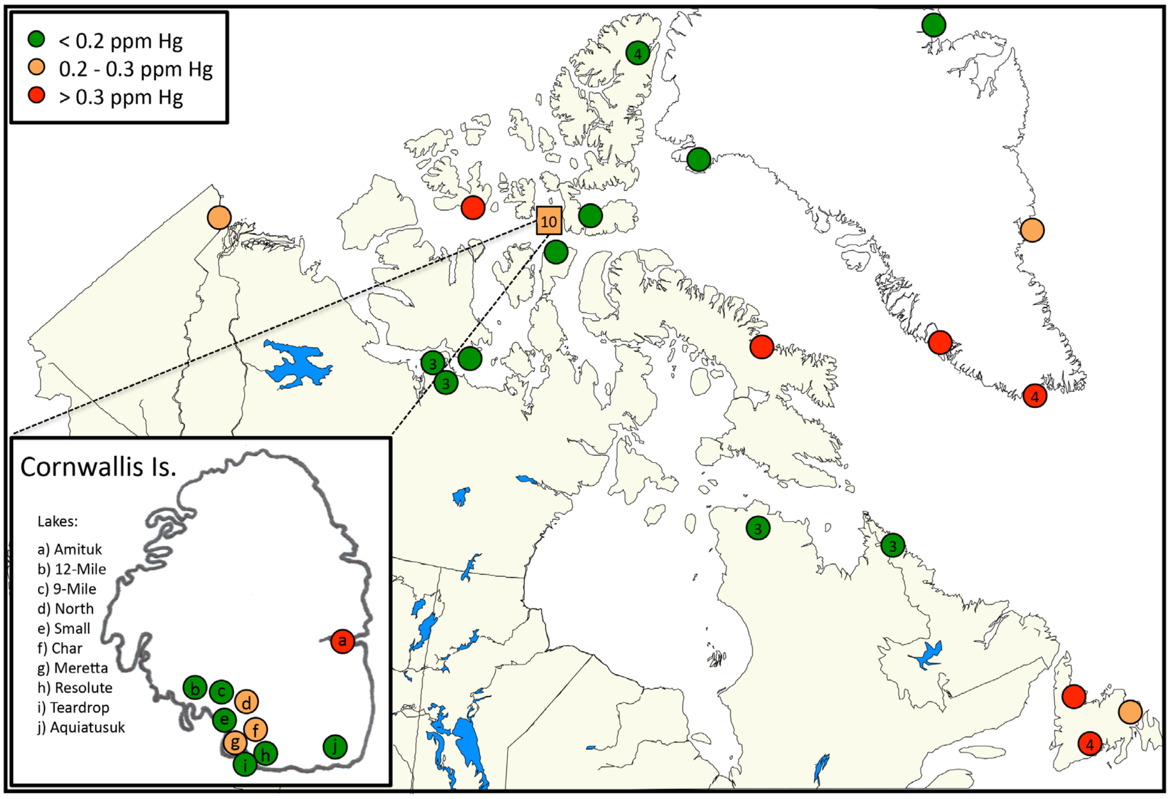
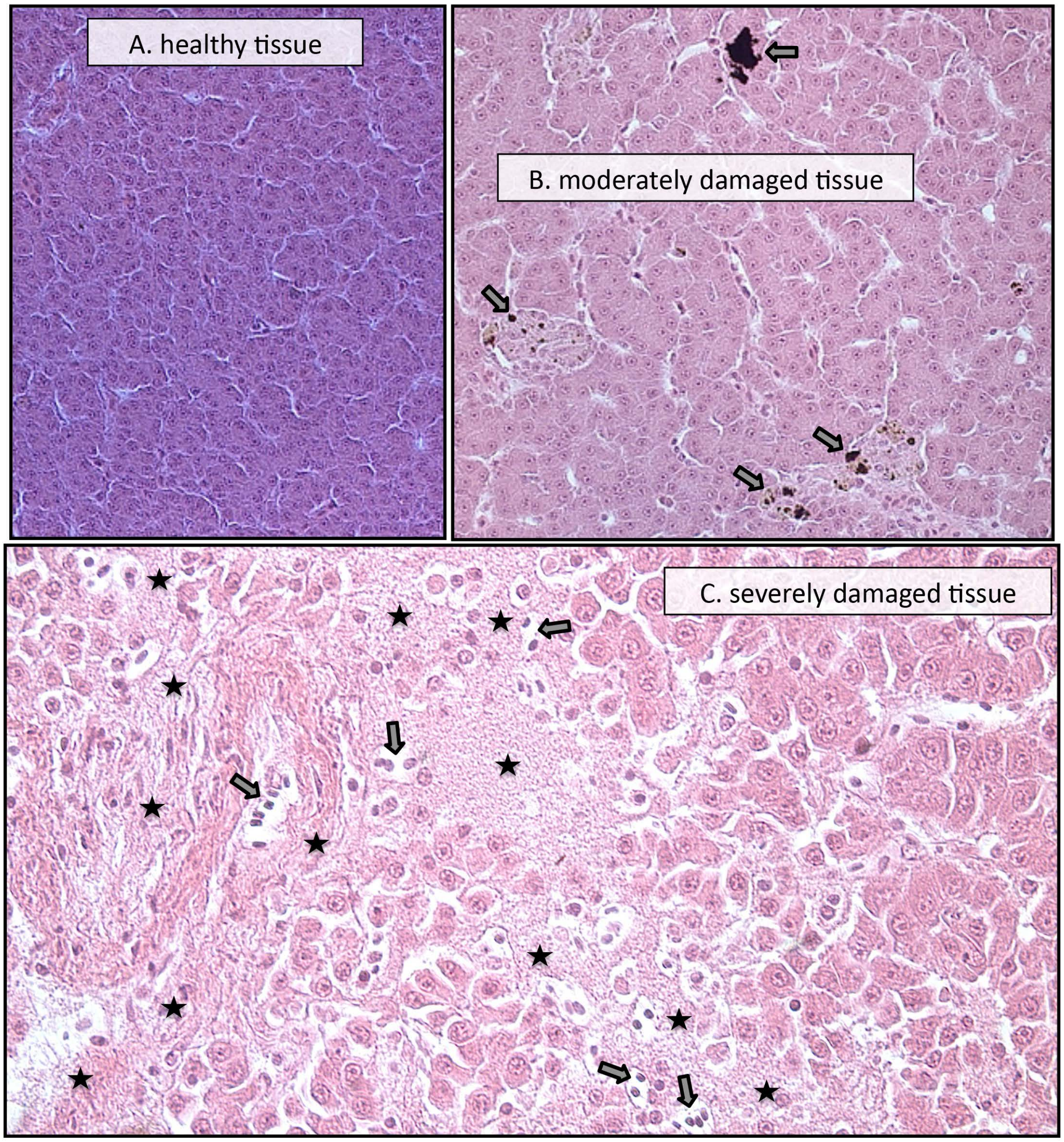


Figure 2. H&E stained livers under light microscopy. (A) With low Hg exposure, tissues appear healthy (char from Small Lake, 0.223 ppm Hg wet wt; 200x magnification). (B) With moderate Hg exposure, melanomacrophage centres (groups of immune cells that repair damage) are evident (arrows), as well as associated 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).



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

Quantification des charges de contaminants, de la qualité de l’eau et des incidences des changements climatiques dans le plus grand lac au monde au nord du 74° de latitude (lac Hazen, Parc national Quttinirpaaq, nord de l’île Ellesmere, Nunavut)

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Abstract

Human activities have elevated atmospheric concentrations of greenhouse gases to levels that have resulted in an unequivocal warming of the Earth’s climate. This is especially true in the high Arctic, where in the past century average annual temperatures have increased at almost twice the global rate. Such warming is anticipated to result in numerous ecological impacts, including permafrost thaw and glacial melt, increased surface runoff, and enhanced productivity on landscapes. Human activities

Résumé

Les activités humaines ont entraîné l’élévation des concentrations atmosphériques de gaz à effet de serre à des niveaux qui ont causé le réchauffement sans équivoque du climat de la Terre. Cela est particulièrement le cas dans l’Extrême-Arctique où les températures annuelles moyennes ont augmenté près de deux fois plus vite que la moyenne mondiale au cours du dernier siècle. Un tel réchauffement est susceptible d’entraîner de nombreuses incidences écologiques, notamment le dégel

have also resulted in unprecedented releases of contaminants to the atmosphere, many of which make their way to the high Arctic. Unfortunately in many regions of the high Arctic, it is largely unknown how much change has already occurred since the beginning of industrialization and what the current state of Arctic ecosystem health is in general. We are monitoring contaminant loadings, water quality and climate change impacts (e.g., levels of productivity) in the world's largest lake north of 74° latitude (Lake Hazen, Quttinirpaaq National Park, Northern Ellesmere Island, Nunavut). From a socio-economic perspective, understanding present-day contaminant loadings, water quality and climate change impacts is important for predicting how the abundances and quality of certain organisms used as Inuit traditional foods may be altered by future human activities.

du pergélisol et la fonte des glaces, une augmentation du ruissellement superficiel et l'accroissement de la productivité des paysages. Les activités humaines ont aussi généré des rejets sans précédent de contaminants dans l'atmosphère, dont bon nombre se sont infiltrés et continuent de s'infiltrer dans l'Extrême-Arctique. Malheureusement, dans de nombreuses régions de l'Extrême-Arctique, combien de changements sont déjà survenus depuis le début de l'industrialisation et quel est l'état de santé actuel de l'écosystème arctique en général demeurent essentiellement inconnus. Nous contrôlons les charges de contaminants, la qualité de l'eau et les incidences des changements climatiques (p. ex. les niveaux de productivité) dans le plus grand lac au monde au nord de 74° de latitude (lac Hazen, Parc national Quttinirpaaq, nord de l'île Ellesmere, Nunavut). D'un point de vue socio-économique, il est important de comprendre les charges de contaminants, la qualité de l'eau et les incidences des changements climatiques pour être en mesure de prédire comment les activités humaines futures peuvent nuire à l'abondance et à la qualité de certains organismes utilisés comme aliments traditionnels par les Inuits.

Key messages

- Concentrations of mercury (Hg), including the bioaccumulative form methyl Hg (MeHg), are high in spring snowpacks on Lake Hazen, but remain low within lake waters.
- Likely due to climate change, since 2005, there has been a significant increase in glacial melt in the Lake Hazen watershed, resulting in significant increases in inputs of water and sediments to the lake.
- These changes in water and sediment inputs are altering water quality and biogeochemical processes in Lake Hazen.

Messages clés

- Les concentrations de mercure (Hg), y compris sa forme bioaccumulatrice (méthylmercure), sont élevées dans le manteau neigeux du lac Hazen au printemps, mais elles demeurent faibles dans les eaux du lac.
- La fonte des glaces a considérablement accéléré depuis 2005 dans le bassin hydrologique du lac Hazen, un phénomène probablement attribuable aux changements climatiques qui ont entraîné d'importantes hausses des apports d'eau et de sédiments dans le lac.
- Ces changements dans les apports d'eau et de sédiments dégradent la qualité de l'eau et altèrent les processus biogéochimiques dans le lac Hazen.

Objectives

The overarching objective of our research program is to:

- Quantify past and present-day contaminant loadings, water quality and climate change impacts in Canada's high Arctic Great Lake (Lake Hazen).

Our particular objectives are to:

- Determine how freshwater ecosystem health in Lake Hazen has changed over the past hundred to thousand years.
- Quantify the current state of Lake Hazen ecosystem health from which all future monitoring efforts can be compared.
- Investigate linkages between climate change and contaminant loadings to Lake Hazen, two issues that will accelerate in importance in the future.

Introduction

Freshwater lakes, ponds, wetlands, and streams can be very productive systems on the polar landscape, and provide valuable resources to many organisms, including waterfowl, fish and humans. Unfortunately, human-induced climate change is altering polar ecosystems at unprecedented rates (ACIA 2004, Climate Change 2007). How freshwater ecosystems will change in a much warmer and wetter climate is currently not known. By studying both water chemistry and lake sediment cores, Arctic lakes can provide both short- and long-term perspectives on environmental change, including trends in long-range atmospheric transport and deposition of contaminants.

Lake Hazen, situated in Quttinirpaaq National Park on the northern tip of Ellesmere Island, with a surface area of approximately 540 km^2 and a maximum depth of 267 m, is the world's largest lake north of 74° latitude. Also, with a volume of 51.4 km3, Lake Hazen is the largest lake north of the Arctic Circle. Lake Hazen is extremely nutrient poor, with low plankton productivity. Arctic char (Salvelinus alpinus) is the only fish species in Lake Hazen (Köck et al. 2011). Lake Hazen's remote location within a protected National Park makes it THE ideal lake for monitoring both past and future changes in water quality in high Arctic lakes because there are no direct human impacts on the watershed itself, nor will there be as long as the National Park exists. Furthermore, a significant portion of the watershed is comprised of ice caps and glaciers that are sensitive to climate change, and the large size of the lake and watershed provides an integrated regional signal for the study of contaminants and climate impacts on freshwater ecosystems. Therefore, we can be confident that the only drivers of change in water quality are long-range atmospheric transport of contaminants to the Lake Hazen watershed from distance sources, and/or global climate change. For example, glaciers in the Lake Hazen watershed may store a legacy of pollutants that were historically deposited there, but these pollutants are likely now being released due to recent accelerated glacial melt (Gardner et al. 2011). Surprisingly, though, there is very little historical or present-day water quality data available for Lake Hazen.

The overall goal of our research is to analyze water and sediment samples to develop knowledge of long-term trends in contaminant loadings, chemistry, and the biology of Lake Hazen. Our 1st goal is to collect water samples at numerous depths throughout the water column at the deepest point in Lake Hazen, and analyze them for a suite of contaminant and water chemistry parameters. This will not only provide a detailed baseline dataset from which all future water monitoring of Lake Hazen can be compared to, but also data on surface waters to compare to samples collected previously to determine if there have been recent changes in water quality. Our 2nd goal is to collect and analyze sediment cores from 3 sites in the deepest zones of Lake Hazen. The sediment core analyses will provide a long-term record of environmental change, including trends in long-range atmospheric transport and deposition of contaminants, rates of glacial melt in the Lake Hazen watershed, and changes in algal community composition over time in Lake Hazen. Finally, our 3rd goal is to put in place a long-term water quality monitoring program for Lake Hazen that will help assess impacts of climate warming and contaminant deposition in the high Arctic.

Activities in 2012-2013

We were at the Lake Hazen field site from 29 May – 5 June 2012. During this short time period, the landscape went from being snow-covered to snow-barren following an incredibly rapid spring snowmelt and runoff period. Snow meltwater on the lake surface and the surrounding watershed drained into Lake Hazen while we were there sampling.

Lake Hazen depth profile

We collected samples from 14 depths at the deepest point in Lake Hazen (Figure 1). A number of parameters were measured immediately on site (temperature, pH, dissolved oxygen [O2], conductivity) using a calibrated YSI multimeter, whereas water, suspended particulate matter and zooplankton samples were also collected for a wide range of chemical and contaminant (e.g., total Hg [THg], MeHg and perfluorinated contaminants [PFCs]) analyses. Samples were initially processed and preserved in the clean room of the Lake Hazen/Quttinirpaaq Field Laboratory designated for water-chemistry research, prior to being shipped south for analyses.

All general water quality analyses were completed in the University of Alberta Biogeochemical Analytical Service Laboratory (BASL). The University of Alberta BASL was established in the 1980s as a premier global research, teaching and service facility. It provides cost-effective analytical chemistry services in environmental, ecological and medical disciplines for University researchers, government agencies and private sectors around the world. The BASL holds a proficiency laboratory status with CALA, an accreditation body in Canada for ISO 17025. Water samples collected for THg and MeHg analyses were analyzed in the internationally-intercalibrated University of Alberta BASL Class-100 Low-level Hg Analytical Unit using standard EPA protocols as described by St.Louis et al. 2007 and Lehnherr et al. 2011.

PFCs such as PFOS and PFOA were determined at the Canadian Centre for Inland Waters (CCIW; Burlington, ON) laboratory under clean room conditions (Class 10000 equivalent lab with carbon/HEPA air filtration) using 1L water samples. In the laboratory the water was extracted using a weak anion exchange resin, and then the extract analyzed by liquid chromatography-tandem mass spectrometry (LC-MS/MS).

Sediment cores

We collected 3 undisturbed sediment cores at each of 3 different sites in the deepest regions of Lake Hazen (9 cores in total; Figure 1). We strategically sampled these different sites to determine if we could detect higher loadings of contaminants into Lake Hazen at the mouth of a glacial runoff river (Blister Creek; Site 1) than in other regions of the lake either tucked behind Johns Island (Site 2) or NE of the Snowgoose and Abbe river outlets, both of which are major glacial runoff rivers (Site 3). All cores were sectioned in the Lake Hazen/Quttinirpaaq Field Laboratory the day they were collected, and samples were immediately frozen on-site. A number of these cores are currently being dated using 210Pb and 137Cs profiling to determine the age of each core section over the past 150 years. Once we have successfully dated these cores with certainty, we will proceed to analyze the core sections at CCIW laboratories for a wide range of contaminants, including PCBs, legacy POPs and BFRs, PFCs, Hg and multi-elements like lead, cadmium and aluminum. These cores will also be analyzed for their organic carbon and algal carbon content (including RockEval and chlorophyll) and microfossils to help us understand climate-related changes that have occurred in Lake Hazen and its watershed, and how those changes might have impacted contaminant loadings to the lake. The remainder of the cores were collected for archival purposes, and are currently being stored at Environment Canada's CCIW.

Capacity Building

Through permitting to conduct our research in Quttinirpaaq National Park, we have a responsibility and obligation to inform northern communities about our research activities and scientific findings. For example, residents of both Grise Fiord and Resolute Bay are members of the Joint Park Management Committee (JPMC), which help review research programs within Quttinirpaaq National Park for permitting purposes, and help disseminate research results to communities via translated reports. We have also collaborated and interacted with Inuit and other northern employees of Parks Canada while at the Lake Hazen field site, involving them directly with our water chemistry and lake sediment sampling/processing activities, thus providing training in scientific skills, and sharing our research objectives and findings. Parks Canada aims to hire beneficiaries from the communities of Resolute Bay and Grise Fiord each summer as patrollers in Quttinirpaaq National Park. We see our involvement of Parks Canada individuals in our field campaigns as being extremely useful for the development of future water quality monitoring projects conducted on lakes and streams both in Canada's northern National Parks, and communities throughout Nunavut. We also used 2012 Northern Contaminants Program funding to train an undergraduate student through the University of Alberta.

Communications

We provide an annual report to the Parks Canada Joint Parks Management Committee detailing our research findings as per their permitting requirements. This report contains plain language summaries, and is translated into Inuktitut for distribution into the communities of Resolute Bay and Grise Fiord. We hope that the beneficiaries hired by Parks Canada will return to their communities to discuss the research program, as well as potentially train fellow community members how to establish monitoring programs of their own. We have, and will be in the future, disseminating our research results via presentations and posters to Nunavut community members that attend the Northern Contaminants Program meeting annually hosted by Aboriginal Affairs and Northern Development Canada, as well as the ArcticNet Annual Scientific Meeting. Our research will be disseminated via publication in peer-reviewed scientific journals to inform other scientists about our findings, as well as to generate future research programs that will build on our own program. Finally, we are producing a video documentary to provide a historical documentation as to why we conducted the research, our research activities, and instruction on how to conduct similar sampling in the future. This short scientific outreach documentary on DVD will be readily distributed to any interested communities and agencies (e.g., AANDC, Parks Canada). This video project was initiated during our 2012 sampling campaign, and will continue while at Lake Hazen in 2013.

Traditional Knowledge Integration

Our activities in terms of over land and over ice travel at Lake Hazen utilize the knowledge of the Inuit employees of Parks Canada. In particular, their intimate knowledge of ice conditions is extremely crucial for safely conducting the work, much of which will be done close to ice breakup. Parks Canada utilizes the knowledge of the Joint Parks Management Committee to guide them using TK. Also, with a goal of 80%

Inuit employees, Parks Canada hopes that TK is shared amongst staff, and that their actions are reflected in this.

Results

Progress on this research program has already gone beyond our initial expectations. As previously stated, during this short time period, the landscape went from being snow-covered to snow-barren following an incredibly rapid spring snowmelt and runoff period. Being at the site during this period worked very much to our advantage, providing intriguing results that we will now pursue with an additional field sampling campaign in May 2013.

Lake Hazen depth profile:
Here we present a few highlights from the profile sampling.

Lake Hazen was thermally stratified under the ice, with colder, less dense water near the surface (Figure 2). Dissolve O_2 started being consumed, and carbon dioxide (CO_2) (and methane [CH_4]) produced, in the bottom 30 meters of the lake (Figure 2). This clearly shows that despite Lake Hazen being extremely nutrient poor, there is enough organic matter in the sediments of the lake for microbial activity to be occurring there and consuming O_2 year-round. However, in 2012, the bottom waters of Lake Hazen were not completely anaerobic, which has important implications for the types of microbial processes that might more typically occur there (see below).

Throughout most of the water column, concentrations of THg were quite low (less than 0.4 ng/L), and concentrations of MeHg were below our low detection limit of 0.015 ng/L (Figure 3). However, concentrations of both THg and MeHg were high in water we collected just below the ice surface (Figure 3). During the 3-day period over which we sampled the water column, snow meltwater on the lake surface and the surrounding watershed drained into the surface waters of Lake Hazen. The higher concentrations of THg and MeHg in the surface waters suggests that there is a very significant load of THg and MeHg in snowpacks, as has previously been observed elsewhere in the high Arctic (e.g., St.Louis et al. 2007). This is of potential concern because this snowpack load of MeHg gets flushed into Lake Hazen during the onset of the spring peak in productivity, initiating the bioaccumulation process while the lake is still mostly ice covered and thus preventing the photodegradation of MeHg (Lehnherr et al. 2012). We are currently still determining if the same is true for the PFCs we also sampled in the water column of Lake Hazen.

Sediment cores: Again, we collected 3 undisturbed sediment cores at each of 3 different sites in the deepest regions of Lake Hazen (9 cores in total; Figure 1). A number of these cores are currently being dated using 210Pb and 137Cs profiling to determine the age of each core section over the past 150 years. As stated above, once we have successfully dated these cores with certainty, we will proceed to analyze the core sections for a wide range of contaminants (including PCBs, legacy POPs and BFRs, PFCs, THg and multi-elements like lead, cadmium and aluminum), as well as their organic carbon and algal carbon content, and microfossils to help us understand climate-related changes that have occurred in Lake Hazen and its watershed, and how those changes might have impacted contaminant loadings to the lake. One preliminary finding from simple observations of sedimentary layering in the cores and our initial dating measurements is that sedimentation rates have increased significantly in the past decade.

Discussion and Conclusions

Three major questions have already arisen from our 2012 sampling campaign that we plan to address during a return trip to Lake Hazen in May 2013 in order for us to fully understand our results:

1. It appears as if THg and MeHg, and possibly other emerging contaminants such as PFCs, build up in Lake Hazen watershed snowpacks over the 8-9 month Arctic snow accumulation period, and get flushed into Lake Hazen during the important period

in which there is a spring peak in ecosystem productivity. As a result, we are proposing to arrive at Lake Hazen in mid-May 2013 prior to the beginning of the snowmelt period to sample the snowpack on the surface of Lake Hazen for THg, MeHg and PFCs to quantify the net areal atmospheric loadings of these contaminants to the watershed. This will also give us an opportunity to resample the water column of Lake Hazen without snowmelt entering Lake Hazen and impacting the water chemistry of surface waters.

2. The ratio of dissolved CO_2:CH_4 in the very bottom waters of Lake Hazen was approximately 400:1 in 2012 (concentrations: 4000 µAtm:10 µAtm). However, in 2005 when we were sampling only surface waters of Lake Hazen, the ratio of CO_2:CH_4 in surface waters mixed up from depth following a windstorm was 0.5:1 (concentrations: 750 µAtm:1500 µAtm). This clearly shows that the bottom region of Lake Hazen can become highly deprived of dissolve O_2 (anaerobic) when the water column does not thoroughly mix for a few years. We know this because CH_4 can only be produced, and not be oxidized to CO_2, under anaerobic conditions. As summer ice cover on Lake Hazen is likely to decrease as a result of climate change, the instances of wind induced complete water column mixing are likely to increase. The anaerobic/aerobic conditions at the bottom of the lake has important implications for what type of microbial processes can occur at any given time. For example, microbial Hg methylation, which converts inorganic Hg into the bioaccumulative and toxic MeHg form, primarily occurs in or just above bottom sediments and is carried out by iron-reducing and sulfate-reducing bacteria, both of which are anaerobes. As a result, one reason we may not have seen detectable concentrations of MeHg in the bottom waters of Lake Hazen in 2012 is because the bottom waters were still slightly oxygenated. However, our 2005 CO_2 and CH_4 samples suggest this is not always the case. As a result, we wish to resample the Lake Hazen water column in 2013 to determine if the low dissolved O_2 bottom region is bigger, smaller or the same as in 2012. Additional analysis of chironomid microfossils in sediments will also allow us to look at how redox conditions in Lake Hazen have changed over time, and the potential effect this might have on contaminant biogeochemistry.

3. As stated above, preliminary findings from visual observations of sedimentary layering and initial dating measurements in the cores collected from Lake Hazen in 2012 suggest that sedimentation rates have increased significantly in the past decade. This increased rate of sedimentation is likely the result of climatic warming in the Lake Hazen watershed, which is accelerating glacial melt and the input of meltwater carrying high loads of glacial sediments into the lake. In fact, water discharge measurements taken at the Ruggles River (the outflow of Lake Hazen) have shown that water discharge from the lake have increased significantly since ~2007. This accelerated melt is also likely releasing contaminants stored in glaciers over the past 50-100 years. As a result, we will be collecting a number of new sediment cores from the deepest point in the lake in 2013, and bring them back intact so that we can resolve very detailed changes in glacial sediment input using graded grain size analyses and fine scale resolution of sedimentary elemental geochemistry. We will also collect an additional core from the deepest part of the lake for the analyses of Hg stable isotopes. Sherman et al. (2010) found that Hg deposited in surface snow in arctic Alaska through "Atmospheric Mercury Depletion Events" (AMDEs) underwent mass independent fractionation (MIF), wherein the odd-mass number isotopes of Hg were preferentially reduced and emitted. This distinctive negative MIF for Hg in snow may also be evident in Arctic lake sediments (e.g., Gantner et al. 2009), including those from Lake Hazen. The goal of this Hg stable isotope component of the study would be to determine historical trends of Hg stable isotope ratios in sediment based on the hypothesis that increasing atmospheric Hg concentrations during the 20th century would have resulted in a shift to negative Hg MIF, characteristic of AMDEs.

Figure 1: A bathymetric map of Lake Hazen, with its location on Ellesmere Island illustrated on the inset map. Our 2012 water sampling site and three sediment-coring sites are identified on the map.

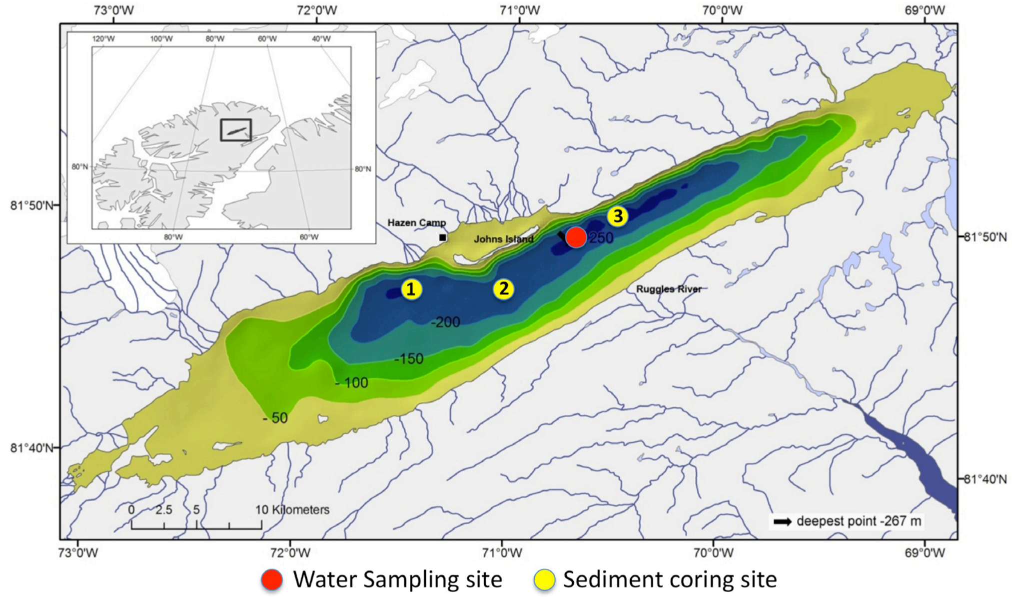


Figure 2: Water column profile of temperature, dissolved oxygen (O2) and dissolved carbon dioxide (CO2) taken at the deepest point in Lake Hazen.

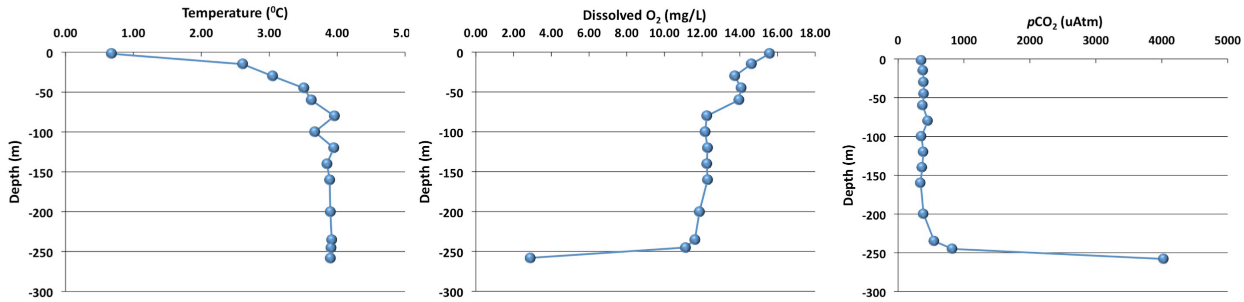
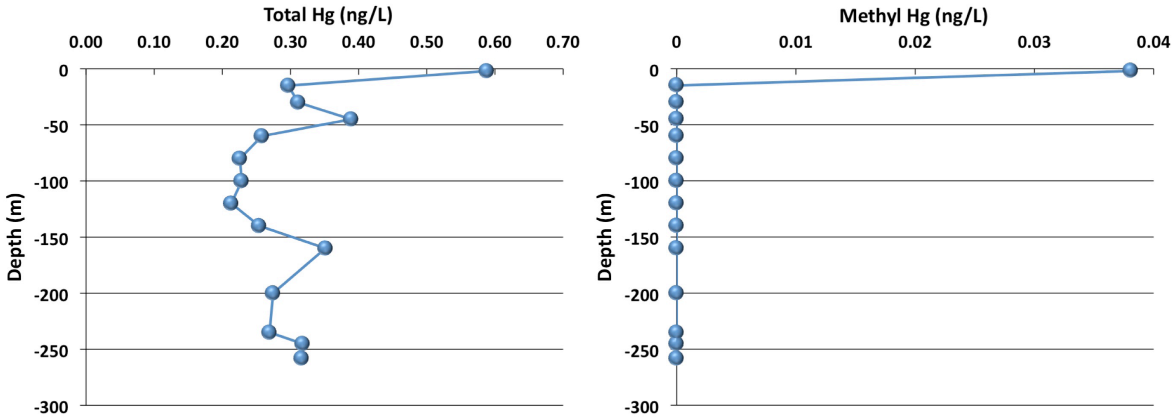


Figure 3: Water column profile of total mercury (Total Hg) and methylmercury (Methyl Hg) taken at the deepest point in Lake Hazen. Note that concentrations of Methyl Hg were below our detection limit of 0.015 ng/L throughout most of the water column.



Expected Project Completion Date:

December 2014

Acknowledgments

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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 has determined the radioactive contaminant levels in two important and valued country food species in the Western Canadian Arctic; caribou and beluga whale. These measurements have determined that contaminant levels in these resources have not been affected by the Fukushima accident.

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. Le projet a permis de déterminer les teneurs en contaminants radioactifs chez deux espèces importantes et valorisées dans l'alimentation traditionnelle dans l'ouest de l'Arctique canadien, à savoir le caribou et le béluga. Les mesures ont permis d'établir que les teneurs en contaminants dans ces ressources n'ont pas été affectées par l'accident.

Key Messages

- The Porcupine caribou were not affected by radioactivity released from the Fukushima accident on March 11, 2011.
- The Eastern Beaufort Sea beluga whale population that winters in the Bering sea were not affected by radioactivity released from the Fukushima accident on March 11, 2011.
- Both of these animals continue to be healthy food choices, with respect to radionuclides from a nuclear accident.

Messages clés

- **Les caribous de la Porcupine n'ont pas été touchés par la radioactivité libérée lors de l'accident de Fukushima le 11 mars 2011.**
- La population de bélugas de l'est de la mer de Beaufort, qui passe l'hiver dans la mer de Béring, n'a pas été touchée par la radioactivité libérée lors de l'accident de Fukushima le 11 mars 2011.
- Les deux espèces constituent des aliments sains, en ce qui concerne les radionucléides résultant d'un accident nucléaire.

Objectives

- To determine if radioactivity from the Fukushima accident has affected Canadian Arctic Porcupine caribou and the eastern Beaufort Sea beluga population.

Introduction

This project determined radioactive contaminant levels in Canadian Arctic caribou and beluga whales, in response to the Fukushima Daiichi nuclear accident, which began on March 11, 2011. These measurements determined 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 was important to verify this for the Fukushima nuclear accident to ensure food safety and address concerns by northerners.

It was equally important to ensure food safety and address the concerns raised by community members from the Inuvialuit Settlement Region regarding beluga. As such we have measured levels in the Beaufort Sea beluga population. This population winters in the Bering Sea.

This project has worked in cooperation with two other Northern Contaminant Program (NCP) projects to measure radioactivity in caribou and beluga. It has given scientists a better understanding of radioactive contaminants in the Arctic and determined whether the releases of radioactivity as result of the Fukushima accident have affected these important food sources in the north. Radioactivity measurements have been performed on samples of caribou and beluga from these two other NCP projects and used samples obtained before and after the accident.

Gamma ray spectroscopy was used to measure the gamma ray energy spectra of the samples. The locations of peaks in the spectra were used to identify radionuclides in the samples. Anthropogenic radionuclides were searched for. Specifically Cs-134 and Cs-137 were searched for. K-40, a natural radionuclide was also quantified as a control. K-40 is present in both caribou and beluga at a level of about 100 Bq/kg. This isotope was used as our control for the study. Around the Fukushima accident site, the ratio of the activity concentrations of Cs-134 and Cs-137 was 1:1 (C.E. Siefert, 2012). The half-lives of these two isotopes of cesium are different:

Cs-134 has a half-life of about 2 years and Cs-137 has a half-life of about 30 years. So if one observes both of these isotopes in a sample, they most likely originated from the Fukushima accident. Because Cs-137 has such a relatively long half-life, it is still in the environment from atmospheric nuclear weapons tests from the 1960s.

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

Activities in 2012-2013

Gamma-ray spectroscopy measurements of samples of caribou, lichens, mushrooms, and beluga have been done at the Radiation Protection Bureau at Health Canada. Samples were obtained both before and after the event. All of these samples had been homogenized by Environment Canada, Burlington, Ontario. For the beluga samples, special care had to be done to ensure that the samples were homogenous; some of the tendons in the samples did not grind up into a powder. These tendons were carefully removed from the samples, in such a manner to not contaminate the samples. The Inuit do not eat these tendons, so the removal of these samples does not affect the results.

The densities and sizes of all the samples were determined. The composition of the lichen and mushroom samples were determined from a literature search. The caribou and beluga muscle samples were assumed to have the same composition as human muscle. It has been found in this study that at the energies of the gamma rays studied that the exact composition of the samples does not matter nearly as much as the density of the samples. This effect has been seen in other studies as well (see Thomson et al. 2013 figures 1a and 1b for energies greater than 100 keV). Using all of this information, the efficiency of the detection system was determined through simulation (Kawrakow and Rogers 2003) for 3 radioisotopes of interest, namely Cs-134, Cs-137, and K-40.

The gamma-ray energy spectra of the caribou, lichens, mushroom, and beluga samples were all analyzed to determine the quantities of above three isotopes. The photopeaks of the gamma rays observed in the energy spectra were identified. The identified peaks were analyzed to see if any other anthropogenic radioisotopes were present. The naturally occurring radioactive material was not quantified (other than K-40 which was used as a control).

Results and Discussion

If there was atmospheric fallout from Fukushima in the range of the Porcupine caribou, it could enter the human food supply by depositing on the lichens and mushrooms, which would then accumulate the cesium. The caribou would eat the lichens and mushrooms, and the cesium would accumulate in the caribou. For this reason, both mushrooms and lichens were sampled in the area of the Porcupine caribou herd. The results of the gamma ray spectroscopic analysis for the lichens and the mushrooms are shown in tables 1 and 2 respectively. Note that only lichens collected post-Fukushima were available for analysis. There was no Cs-134 found in any of the mushrooms and lichen samples. There were some lichens samples that did not have any Cs-137 or K-40, so a geometric mean was not calculated.

The K-40 levels in the mushrooms were within one standard deviation of each other, before and after the accident as expected. The Cs-137 levels in the mushrooms were slightly lower after the accident.

Since no Cs-134 was detected in the mushrooms and none in the lichens, one would expect that there would be no Cs-134 in the caribou.

Table 1: Radiation concentrations in lichens collected from the Porcupine caribou winter range (YT) post-Fukushima.

Bq·kg^{-1} ww	Post-Fukushima Lichens	
N=11	Cs-137	K-40
Range	0 – 13.8	0 -30
Arithmetic mean	3.92	7.48
Arithmetic standard deviation	4.84	14.05

Table 2: Radiation concentrations in mushrooms collected from the Porcupine caribou winter range (YT) pre- and post-Fukushima

Bq·kg^{-1} ww	Pre-Fukushima Mushrooms		Post-Fukushima Mushrooms	
N=6,6	Cs-137	K-40	Cs-137	K-40
Geometric mean	10.2	80.98	9.1	71.9
Range	2.2 - 35	63 -107	0 - 19	40 -99
Arithmetic mean	13.7	82.6	9.2	74.8
Arithmetic standard deviation	11.3	17.8	7.4	20.7

Table 3: Radiation concentrations in Porcupine caribou muscle tissue collected pre- and post-Fukushima.

Bq·kg^{-1} ww	Pre-Fukushima Caribou		Post-Fukushima Caribou	
N=20,14	Cs-137	K-40	Cs-137	K-40
Geometric mean	18.8	80.1	9.1	76.4
Range	9.4 – 46	26 – 116	3.6 – 20.2	42 - 98
Arithmetic mean	20.8	84.1	10.6	78.0
Arithmetic standard deviation	9.7	23.3	5.4	15.4

Table 4: The beluga results of this study.

Bq·kg^{-1} ww	Pre-Fukushima beluga		Post-Fukushima beluga	
N=19,22	Cs-137	K-40	Cs-137	K-40
Geometric mean	-	87.2	-	89.2
Range	-	65.4 – 112	-	68.8 – 108
Arithmetic mean	-	88.0	-	89.9
Arithmetic standard deviation	-	12.5	-	10.8

Radioactivity concentrations in the caribou samples are presented in Table 3. In all the caribou measurements, there was no indication of Cs-134 as expected from the mushroom and lichen results. .The minimum detectable concentration (MDC) for this radioisotope will be calculated and presented at a later date. The levels of K-40 in the samples are consistent with previous measurements which have a value near 100 Bq·kg-1 wet weight (ww). This indicates that there are no major systematic problems with the work. The Cs-137 levels in the Caribou were lower after the Fukushima accident. This fact combined with the absence of Cs-134 indicates that the Cs-137 is most likely from previous atmospheric weapons tests.

By using the measured values for the activity concentrations for just the Porcupine caribou herd from MacDonald et al (2007), and by grouping the geometric means of the activity concentrations by year, we can estimate the environmental half-life of Cs-137 in this herd (see Figure 1). Fitting this data, one can obtain the effective half-life in the environment for this herd, which is a half-life of 6.9 ± 0.6 years, which is consistent with the values reported in MacDonald et al (2007). The two values in the figure at 2009 and 2011 are from this study. The error bars for this figure were based on the geometric standard deviations, with appropriate error analysis applied. The data was fit using MINUIT, where each data point was weighted by its error.

If one uses the ICRP 72 dose coefficients (ICRP 72 1995), one can calculate the amount of caribou a person would have to eat to hit the public dose limit of 1 mSv/year. This is the dose limit that an individual should not exceed. A person would have to consume 10 – 13 kg of caribou each and every day to reach the dose limit of 1 mSv·year-1.

If one uses the conservative value of the 90% percentile of the caribou consumption rate from the survey that was done in the paper by Schuster et al. (2011), namely 396 g·day-1, and uses the corresponding ICRP 72 dose coefficient for an adult for Cs-137, one finds that the dose rate to someone from the Cs-137 in caribou meat is about 0.04 mSv·year-1. This is well below the public dose rate limit of 1 mSv·year-1.

The results of measurements on the beluga samples are presented in table 4. The K-40 values again are close to our control value of 100 Bq·kg-1 ww. There were no unusual radionuclides found in the individual spectra. The natural occurring radioactive material was not quantified, except for the K-40. There was no Cs-134 observed in the spectra. If the pre-Fukushima gamma-ray energy spectra are added together, one still does not find Cs-137 in the spectrum and finds an activity concentration of 99.6 Bq·kg-1 for K-40. Similarly for the post-Fukushima summed spectrum, one finds a K-40 activity concentration of 101.78 Bq·kg-1 and a Cs-137 activity concentration of 0.63 +/- 0.23 Bq·kg-1 ww. Note this value is 33 times smaller than the caribou results.

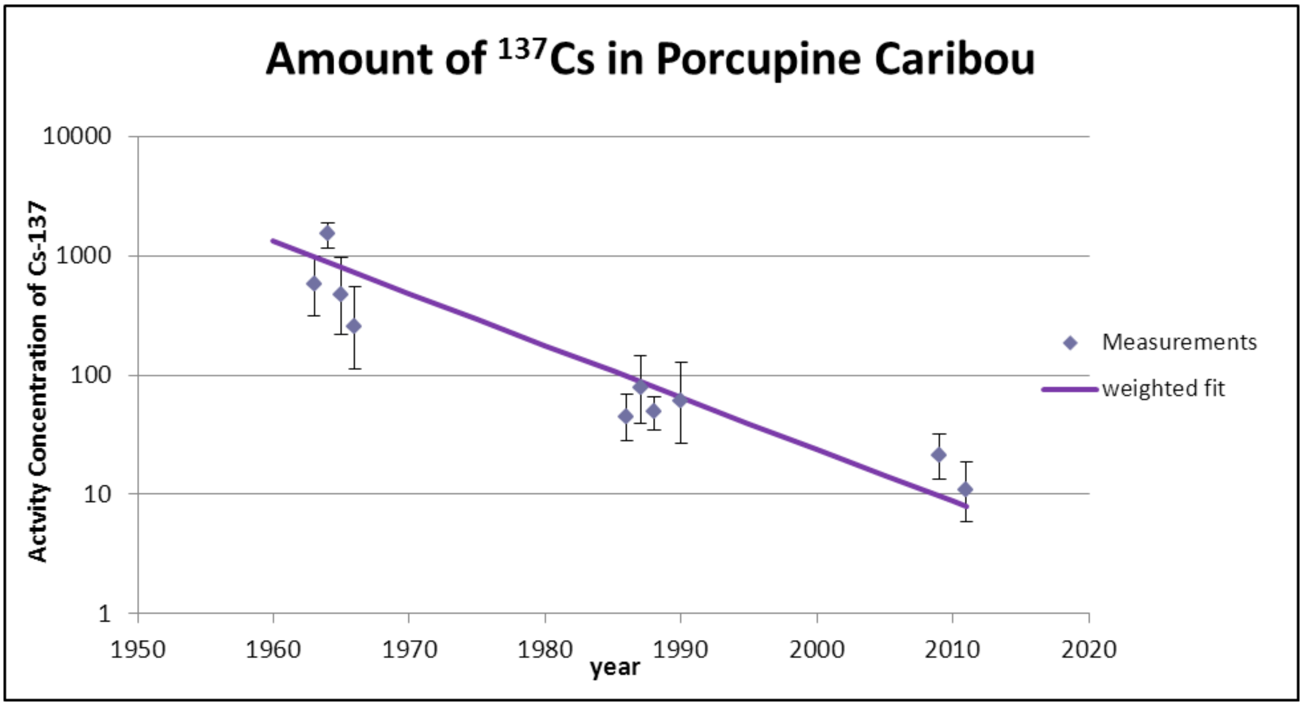
If one does the same calculation as for the caribou, one finds that to get to the public dose limit of 1 mSv·year-1, one would need to eat between 700 and 1000 pounds of beluga each and every day for a year to reach the recommended dose limit.

Another number that the caribou and the beluga activity concentration values can be compared to is the Health Canada recommended action levels for radionuclides of potential significance to dose from the ingestion of contaminated food (Health Canada 2000). The action level for caribou and beluga for Cs-137 is 1000 Bq·kg-1, Concentrations found in both caribou and beluga are well below this level.

Expected Project Completion Date

Most of the work for this project is finished. The last set of measurements that will be done are some measurements of beluga prey samples. Once these samples arrive at the Radiation Protection Bureau the arrangements will be made to have the measurements done.

Figure 1: The geometric means of the activity concentrations in the Porcupine caribou values taken from MacDonald et al. (2007), the last two data points are from this study. The error bars are 1 sigma geometric standard deviations.



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

Contaminants existants et nouveaux chez les populations déclinantes du Goéland bourgmestre de l'Arctique canadien : relations avec l'utilisation annuelle de l'habitat, le régime alimentaire et les effets biologiques

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Abstract

In this NCP-funded project we investigated in glaucous gull (*Larus hyperboreus*) breeding colonies in Eastern Nunavut (islands off Cape Dorset), the influence of diet on the bioaccumulation profiles of established contaminants (mercury, legacy organochlorines, and PBDEs) and a suite of emerging halogenated flame retardants (HFRs). Stable isotope profiles of carbon and nitrogen in liver and two feather types inferred diet of glaucous gulls breeding in this area, and varied somewhat between winter, breeding and post-breeding

Résumé

Dans le cadre de ce projet financé par le PLCN, nous avons étudié des colonies de nidification du Goéland bourgmestre (*Larus hyperboreus*) dans l'est du Nunavut (îles au large de Cape Dorset), l'influence de son régime alimentaire sur les profils de bioaccumulation de contaminants existants (mercure, organochlorés hérités du passé et PBDE) et une gamme de produits ignifuges halogénés (PIH) nouveaux. Les profils des isotopes stables du carbone et de l'azote dans le foie et deux types de plume nous ont permis d'inférer le régime

periods. Concentrations of PCBs, several chlorinated pesticides and by-products, and PBDEs were found to be low in liver of glaucous gulls from Cape Dorset area compared to other circumpolar populations (e.g., Svalbard, Greenland). Mercury and methylmercury concentrations in liver, however, were higher than reported elsewhere for glaucous gulls. Six as yet unstudied HFRs in Canadian Arctic birds were detected in glaucous gull liver, although at low levels. Some of these emerging HFRs have been identified as replacement products of recently or soon to be banned PBDE mixtures (penta-, octa-, and deca-BDE). The profile of nitrogen stable isotope ($\delta^{15}N$) in liver and two feather types (breast and wing) was associated with concentrations of several of these contaminants, thus providing information on their potential dietary sources during three periods of the year. Using the glaucous gull as bioindicator species provides clear evidence that Cape Dorset marine food web accumulates a complex mixture of legacy and more recently introduced chemicals of potential health concern to Arctic wildlife.

alimentaire des individus nidifiant dans cette région; il différait quelque peu entre l'hiver, la période de nidification et la période après la reproduction. Les concentrations de BPC, de plusieurs pesticides chlorés et de leurs sous-produits et de PBDE étaient faibles dans le foie des individus provenant de la région de Cape Dorset en comparaison de populations d'autres régions circumpolaires (p. ex. Svalbard, Groenland). Les concentrations de mercure et de méthylmercure dans le foie étaient toutefois plus élevées que celles signalées ailleurs pour le Goéland bourgmestre. Six PIH qui n'ont pas encore fait l'objet d'études chez les oiseaux de l'Arctique canadien ont été détectés dans le foie de ce goéland, quoique à de bas niveaux. Certains de ces PIH nouveaux ont été identifiés comme des produits de remplacement de mélanges de PBDE qui ont été récemment interdits ou qui le seront bientôt (penta, octa et décaBDE). Le profil des isotopes stables de l'azote ($\delta^{15}N$) dans le foie et deux types de plume (plumes de poitrine et rémiges) était associé à des concentrations de plusieurs de ces contaminants et, de ce fait, a fourni de l'information sur leurs sources alimentaires potentielles durant trois périodes de l'année. L'utilisation du Goéland bourgmestre comme espèce bioindicatrice prouve sans équivoque que le réseau trophique marin de Cape Dorset accumule un mélange complexe de produits chimiques hérités du passé et de produits chimiques récemment introduits qui peuvent présenter un danger pour la santé de la faune de l'Arctique.

Key Messages

- Stable isotope (carbon and nitrogen) analysis in liver and two feather types of adult glaucous gulls breeding around Cape Dorset (Eastern Nunavut) suggests dietary variations throughout the year (i.e., breeding period, fall and winter).
- Legacy organochlorines (PCBs and several pesticides and by-products) and PBDEs determined in glaucous gull liver from Cape Dorset were lower than those reported elsewhere in circumpolar glaucous gull

Messages clés

- L'analyse des isotopes stables (carbone et azote) présents dans le foie et deux types de plumes d'individus adultes du Goéland bourgmestre nidifiant près de Cape Dorset (est du Nunavut) laisse supposer des variations de leur régime alimentaire tout au long de l'année (c.-à-d. période de nidification, automne et hiver).
- Les concentrations de composés organochlorés hérités du passé (BPC et plusieurs pesticides et leurs sous-produits) et

populations. Exposure to mercury and methylmercury, however, appears to be elevated in this particular area of the Canadian Arctic.

- A series of six emerging halogenated flame retardants were detected in Cape Dorset glaucous gull liver, some of which have been identified as replacement products for the recently banned PBDE commercial mixtures.

de PBDE mesurées dans le foie du Goéland bourgmestre de Cape Dorset étaient moins élevées que celles signalées ailleurs chez des populations de ce goéland d'autres régions circumpolaires. Par contre, l'exposition au mercure et au méthylmercure semble élevée dans cette région de l'Arctique canadien.

- Six produits ignifuges halogénés nouveaux ont été détectés dans le foie du Goéland bourgmestre de Cape Dorset, dont certains ont été identifiés comme des produits de remplacement de mélanges commerciaux de PBDE récemment interdits.

Objectives

The objective of the present project was twofold: 1) screen for a comprehensive suite of established and emerging halogenated organic contaminants and mercury in glaucous gulls breeding around Cape Dorset (Eastern Nunavut) in the Canadian Arctic, and 2) investigate the influence of diet on the bioaccumulation profiles of these contaminants.

Introduction

Large gulls (Laridae) in the Arctic are predominantly omnivorous and occupy high trophic levels in the marine food web. As a consequence, they are chronically exposed to a wide array and occasionally elevated concentrations of trace elements and organic contaminants (Letcher et al. 2010; Verreault et al. 2010). These include mercury, legacy organochlorines (e.g., PCBs, DDT, chlordanes, etc.), but also an increasingly more complex "cocktail" of emerging contaminants, in which many may fulfill the criteria of persistence, propensity for bioaccumulation and toxicity (PBT) (Chemicals Management Plan 2011). Among these, a range of additive compounds in consumer and industrial products to achieve fire safety standards, the halogenated flame retardants (HFRs), have received notorious attention in recent years.

Established HFRs such as the PBDEs (two commercial mixtures: penta- and octa-BDE) have recently (2009) been restricted under the Stockholm Convention (2011). A growing body of evidence suggests that several biological systems (e.g., mainly endocrine and immune systems) and the general health of chronically-exposed birds (including gulls) to PBDEs can be adversely affected (Legler 2008). In response to international regulations on PBDEs, emerging HFR classes are being used by the chemical industry as alternative or replacement products to the recently banned penta- and octa-BDE mixtures. Examples of emerging HFRs of growing environmental concern are: 1,2-bis(2,4,6-tribromophenoxy)ethane (BTBPE), pentabromoethylbenzene (PBEB), bis(2-ethylhexyl)-tetrabromo phthalate (BEHTBP), Dechlorane Plus (DP), and decabromodiphenyl ethane (DBDPE) (Covaci et al. 2011; Sverko et al. 2011). Some of these emerging HFRs have been positively identified and quantified in eggs of Great Lakes herring gulls (*Larus argentatus*) (Gauthier et al. 2007, 2009; Gauthier and Letcher 2009), liver and plasma of ring-billed gulls (*Larus delawarensis*) from the greater Montreal area (Gentes et al. 2012) and plasma and eggs of Norwegian Arctic (Svalbard) glaucous gulls (Verreault et al. 2007a). Analyses based on archived herring gull eggs collected from several Areas of Concern within the Great Lakes basin have demonstrated that the concentrations of certain of these emerging HFRs have been increasing temporally over the last decades (Gauthier et al. 2009; Gauthier and Letcher 2009). Despite a sustained effort in surveying emerging HFRs in Great Lakes gulls, their occurrence in susceptible birds spanning the Canadian Arctic regions has not been the subject of any studies (Chen and Hale 2010; Letcher et al. 2010; Covaci et al. 2011; Sverko et al. 2011). The biological effects of emerging HFRs in avian wildlife are to date largely unstudied (Chen and Hale 2010; Covaci et al. 2011; Sverko et al. 2011; Marteinson et al. 2012), thus warranting investigations in the most susceptible species, which includes top predator gulls breeding in the Canadian Arctic (Fisk et al. 2005; Letcher et al. 2010; Wayland et al. 2010).

The present study reports on concentrations of mercury, organochlorines (e.g., PCBs, DDT, chlordanes, etc.) and HFRs (PBDEs and emerging compounds) in glaucous gulls breeding on islands off Cape Dorset, Eastern Nunavut. This is the first report of these contaminants in glaucous gulls or any other seabirds from this region of Nunavut, and the first screening of emerging HFRs in seabirds from the Canadian Arctic. The influence of diet on the bioaccumulation profiles is investigated using stable isotopes of carbon ($\delta^{15}N$) and nitrogen (d15N) in feathers (breast and wing) and liver that integrated nutrients (and contaminants) during different periods of the year (fall, winter, and breeding period) as they reflect nutrient and energy assimilation from the diet at the time of tissue synthesis (Kelly 2000; Post 2002).

Figure 1: Map of the Canadian Arctic showing the two study sites (red stars): Prince Leopold Island and Cape Dorset, Nunavut.

Activities in 2012-2013

Sample collection

Samples (liver, feathers, blood, and eggs) of adult breeding glaucous gulls ($n = 31$) were successfully collected in June-July 2012 from colonies situated on islands off the community of Cape Dorset (Eastern Nunavut) (Figure 1) by the field team of J. Verreault. This team included two local hunters recruited via the Aiviq Hunters and Trappers Association (Cape Dorset HTA) who actively participated in field logistics and sample collection. Frozen glaucous gull samples for contaminant and stable isotope analyses were shipped to the Université du Québec à Montréal (UQAM) lab (Montreal, QC), and stored at -20°C until analysis. Moreover, in July 2012, light-based geolocators were deployed on five adult breeding glaucous gulls in Prince Leopold Island (Figure 1) as part of the annual seabird population monitoring and research led by project team members (M. Mallory and A. Gaston). These geolocators will be recovered in 2013 by the same team.

Stable isotope analysis

Stable carbon (13C) and nitrogen (15N) isotope analyses in liver and feather (one breast and one wing (secondary) feather) samples were conducted at the Centre de recherche en géochimie et géodynamique (GEOTOP), Université du Québec à Montréal (Montreal, QC) according to methods described by Caron-Beaudoin et al. (2013). Isotopic measurements were performed in duplicates using a continuous flow isotope ratio mass spectrometer (Micromass Isoprime, Cheadle, UK) coupled to an elementary analyzer (Carlo Erba NC1500, Milan, Italy). Results were expressed in delta notation (δ) relative to an international standard (Rstandard= Vienna PeeDee Belemnite (VPDB) for d13C and atmospheric air (AIR) for d15N) in per mil (‰) according to the equation: [dX = [(Rsample/Rstandard) -1] x 1000], where X denoted either 13C or 15N, and R represented the ratio of 13C:12C or 15N:14N.

Mercury analysis

Mercury (Hg) and methylmercury (MeHg) analyses were conducted at the Centre de recherche en géochimie et géodynamique (GEOTOP), Université du Québec à Montréal (Montreal, QC) using methods by Pichet et al. (1999). Total Hg and MeHg concentrations were determined using atomic fluorescence. Analytical accuracy for total Hg and MeHg was determined by analyzing blank samples with each sample set, as well as two standard reference materials: Mess-3 (marine sediment) and Tort-2 (lobster hepatopancreas) obtained from the Canadian National Research Council. Results of reference materials were within the certified range for both methods and nominal detection limits were 0.06 ng/g dry weight for total Hg and 0.82 ng/g dry weight for MeHg.

Legacy organochlorine analysis

Glaucous liver samples were analyzed for legacy organochlorines (see full compound list in Table 1) at the Great Lakes Institute for Environmental Research (GLIER) at the University of Windsor (Windsor, ON) according to the Canadian Association for Environmental Analytical Laboratories (CAEAL)-accredited standard operating procedures (Environment Canada 1989). Chemical extraction and clean-up of PCBs and organochlorine pesticides and by-products followed the procedures of Lazar et al. (1992). Lipids were determined gravimetrically. Chemical analysis was performed using a Hewlett-Packard 5890 gas chromatograph with 5973 mass selective detector (GC-MSD) operated in the electron impact (EI) mode, and using selected ion monitoring (SIM). For every batch of five samples, a MSD-PCB standard prepared from Aroclor 1242, 1254 and 1260 mixtures (AccuStandards, CT), two organochlorine pesticide standards (Supelco, PA), a method blank and one in-house reference tissue (GLIER Detroit River fish homogenate) were also analyzed. Blanks and reference tissue, quantified during each batch of sample extractions, were in compliance with the normal quality assurance procedures instituted by

GLIER's CAEAL certified organic analytical laboratory. Internal standard recoveries from samples and reference materials averaged 88.7 ± 0.86% (mean ± SE) and 88.3 ± 1.72% for CB-34 and BDE-71, respectively. The recovery efficiency was high and, therefore, residue concentrations were not recovery-corrected. The analyte-specific detection limits ranged between 0.004 and 0.05 ng/g wet weight.

PBDEs and emerging halogenated flame retardant analysis

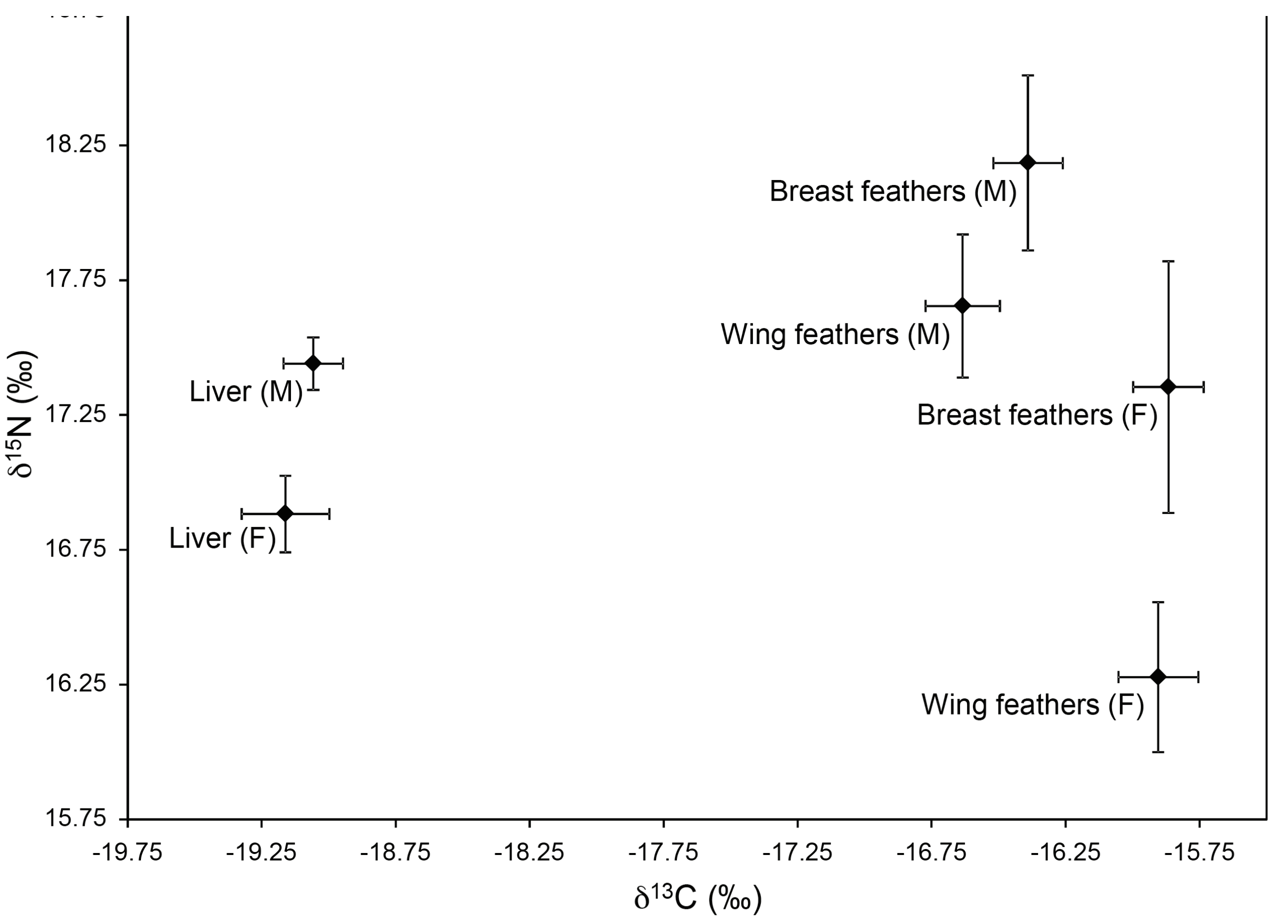
Glaucous liver samples were analyzed for PBDEs and eight emerging halogenated flame retardant (see full compound list in Table 2) at the Université du Québec à Montréal (Montreal, QC). Briefly, liver aliquots were ground with diatomaceous earth, spiked with four internal standards (BDE-30, BDE-156, 13C-*syn*-DP and 13C-*anti*-DP), and extracted with dichloromethane:*n*-hexanes (50:50) using a pressurized liquid extraction system (PLE) (Fluid Management Systems, Watertown, MA). Lipids were determined gravimetrically. Sample clean-up was achieved using a PBDE-free silica acid-basic-neutral (ABN) column followed by a PBDE-free neutral alumina column with dichloromethane:*n*-hexanes (50:50) (Fluid Management Systems). Identification and quantification of target PBDEs/HFRs was performed using a gas chromatograph (GC) coupled to a single quadrupole mass spectrometer (MS) (Agilent Technologies 5975C Series, Palo Alto, CA) operating in the electron capture negative ionization mode (GC/MS-ECNI) following methods by Gentes et al. (2012). Quantification of PBDEs/HFRs was achieved using selected ion monitoring (SIM) mode. Procedures included method blanks and injection of standard reference material (SRM) (NIST 1947 Lake Michigan fish tissue) for each batch of ten samples. Background contamination of method blanks was negligible and no blank correction was necessary except for BDE-47, BDE-99, BEHTBP, DBDPE, and *syn*- and *anti*-DP. Mean (± SE) internal standard recoveries from samples, blanks and SRM were as follows: BDE-30 (91.6 ± 1.62%), BDE-156 (98.2 ± 2.22%), 13C-*syn*-DP (97.9 ± 2.07%) and 13C-*anti*-DP (99.4 ± 1.92%). Concentrations of PBDEs/HFRs in all samples were quantified using an internal standard approach, and thus all analyte concentrations were inherently recovery-corrected. PBDE concentrations (seven congeners) determined in SRM 1947 showed less than 21.9% deviation from certified values. This laboratory has participated in an inter-laboratory comparison for these analytes with the National Wildlife Research Centre/Environment Canada (Ottawa, ON), which has been certified by the CAEAL. Method limits of detection (MLODs) and method limits of quantification (MLOQs) were based on replicate analyses ($n = 8$) of matrix samples spiked at a concentration of 3-5 times the estimated detection limit. MLODs (defined as S/N = 3) and MLOQs (minimum amount of analyte producing a peak with a signal to noise ratio (S/N) of 10) varied between 0.01-0.48 and 0.01-1.58 ng/g wet weight, respectively.

Results

Stable isotope profiles

Diet of female and male glaucous gulls was investigated using δ15N and δ13C analysis in breast and wing (secondary) feathers, as well as in liver (Figure 2). Males exhibited significantly higher δ15N values compared to females in wing feathers ($p = 0.001$) and liver ($p = 0.002$), but not in breast feathers ($p = 0.14$). Furthermore, 13C was more depleted in wing ($p = 0.001$) and breast feathers ($p = 0.009$) of males relative to females, but not in liver ($p = 0.59$). In males, breast feather δ15N values were highest, but only significantly when compared to liver ($p = 0.04$). Also in males, δ13C was lowest in liver ($p < 0.001$), although no difference was noted between the two feather types. In females, breast feather δ15N values also were highest, but significantly ($p = 0.02$) only when compared to wing feathers. Moreover, in females, and consistently to males, δ13C was lowest in liver ($p < 0.001$), while no difference was noted between wing and breast feathers.

Figure 2: Mean (± SE) ɗ13C and ɗ15N (‰) in breast and wing (secondary) feathers, and liver of female and male glaucous gulls (Larus hyperboreus) breeding off Cape Dorset, Nunavut.



Mercury and legacy organochlorines

Total Hg and all legacy organochlorine classes (ΣCBz, OCS, Mirex, ΣHCH, ΣDDT, ΣCHL, Dieldrin, and SPCB) were significantly highest ($p \leq 0.05$) in liver of male glaucous gulls relative to females, whereas no difference was found between sexes for MeHg in a subset of liver samples ($p = 0.78$) (Table 1). In males and females combined, concentrations of most of these organochlorines were positively correlated with δ15N in breast feathers ($0.36 > r < 0.45$; $0.01 > p < 0.05$), although such association was not found for Total Hg and Dieldrin. Significant positive correlations were also uncovered between ΣCBz, Mirex, ΣDDT, ΣCHL and SPCB concentrations, and wing feather δ15N ($0.39 > r < 0.46$; $0.03 > p < 0.009$). Only Total Hg ($r = 0.51$; $p = 0.003$) and ΣCHL ($r = 0.40$; $p = 0.02$) concentrations yielded positive correlations with liver δ15N. Negative correlations were found between ΣCHL ($r = -0.39$; $p = 0.03$) and Dieldrin ($r = -0.47$; $p = 0.008$) concentrations, and d13C in wing feathers.

Table 1. Lipid content (%), moisture (%) and concentrations of mercury (Hg and MeHg; µg/g dry weight), organochlorines and PCBs (ng/g wet weight) in liver of female and male glaucous gulls (Larus hyperboreus) breeding off Cape Dorset, Nunavut.

	Females (n = 14)			Males (n = 17)		
	Samples >MLOD	Mean ± SE	Range	Samples >MLOD	Mean ± SE	Range
Lipid content (%)	-	5.38 ± 0.65	2.99 – 11.1	-	4.12 ± 0.27	1.79 – 5.78
Moisture (%)	-	67.3 ± 0.36	64.3 – 68.9	-	69.7 ± 1.34	64.7 – 90.3
Mercury						
Total Hg	100%	7.04 ± 0.63	2.80 – 11.6	100%	9.74 ± 1.09	3.55 – 20.0
MeHg [1]	100%	1.19 ± 0.72	0.23 – 4.08	100%	0.98 ± 0.20	0.45 – 1.33
Organochlorines						
SCBz [2]	100%	56.2 ± 4.99	26.3 – 88.4	100%	87.8 ± 7.99	52.9 – 157
OCS	100%	0.44 ± 0.1	0.24 – 0.88	100%	0.62 ± 0.1	0.38 – 1.17
Mirex	100%	7.07 ± 0.84	2.22 – 13.8	100%	15.1 ± 1.24	6.29 – 23.9
SHCH [3]	100%	10.4 ± 1.46	5.13 – 26.2	100%	16.5 ± 1.73	8.3 – 29.7
SDDT [4]	100%	233 ± 33.2	85.7 – 433	100%	519 ± 45.9	244 – 891
SCHL [5]	100%	128 ± 13.4	65.5 – 267	100%	250 ± 21.2	127 – 413
Dieldrin	100%	35.6 ± 3.45	18.7 – 68.6	100%	53.8 ± 5.09	24.4 – 112
SPCB [6]	100%	346 ± 63.9	118 – 951	100%	716 ± 59.5	302 – 1,175

1 MeHg was analyzed in a subset of five females and five males.
2 Sum of 1,2,4,5-TCB, 1,2,3,4-TCB, QCB, and HCB.
3 Sum of a-HCH, b-HCH, and g-HCH.
4 Sum of p,p'-DDE, p,p'-DDD, and p,p'-DDT.
5 Sum of trans-nonachlor, oxychlordane, trans-chlordane, cis-chlordane, cis-nonachlor, and heptachlor epoxide.
6 Sum of PCB-18/17, -31/28, -33, -52, -49, -44, -74, -70, -95, -101, -99, -87, -110, -151/82, -149, -118, -153, -105/132, -138, -158, -187, -183, -128, -177, -156/171, -180, -191, -170, -199, -195/208, -194, -205, -206, and -209.

PBDEs and emerging halogenated flame retardants

PBDEs were detected in the majority of liver samples of glaucous gulls (Table 2). Most abundant PBDE congeners were BDE-47, -100, -99, -154/BB-153, and -153 (Figure 3). Screening of liver samples for emerging HFRs (Table 2) revealed detection frequencies above 50% (in males only) for the following three compounds: HBB and DP (*anti* and *syn* isomers). Other detected compounds (ranging between 12 and 47% detection frequency) in males and females included PBEB, EHTBB, and BEHTBP.

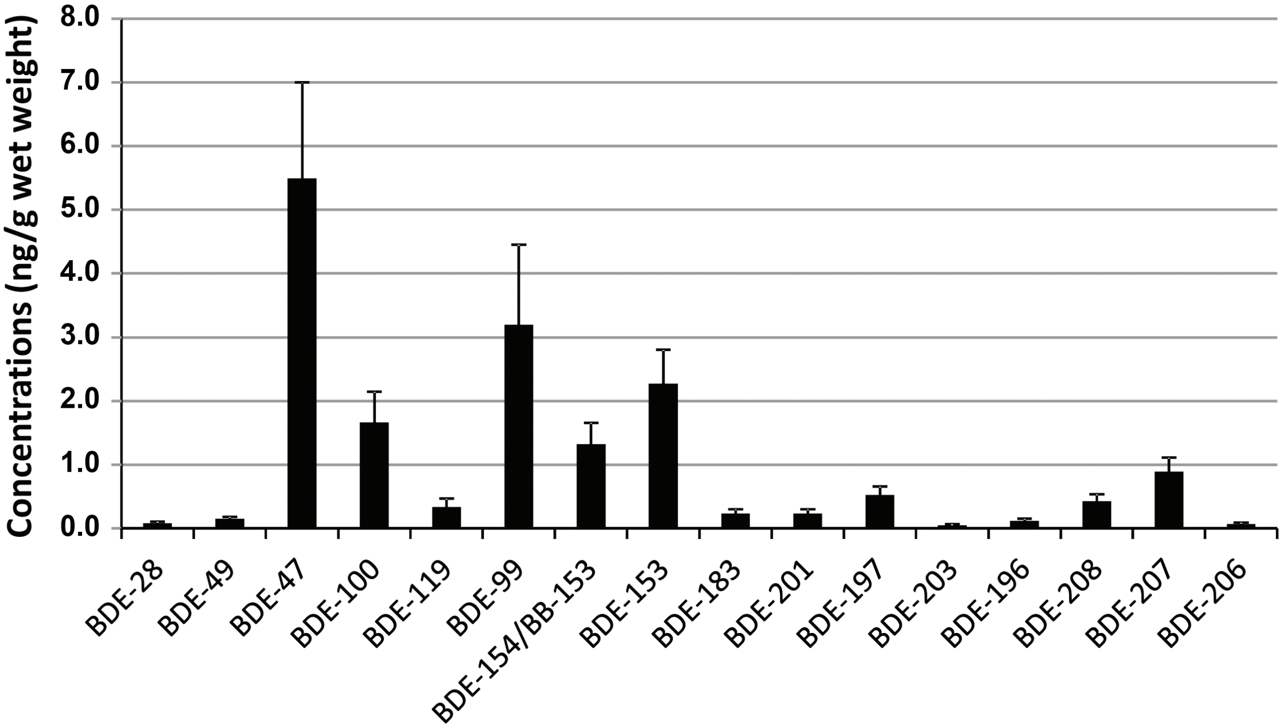
1 Sum of BDE-1, -2, -3, -10, -7, -15, -17, -28, -49, -71, -47, -66, -77, -100 , -119, -99, -85, -126, -154/BB-153, -153, -139, -140, -138, -184, -183, -191, -180, -171, -201, -197, -203, -196, -205, -208, -207, and -206.

In males, concentrations of ΣDP (sum of *anti* and *syn* isomers) were negatively correlated with δ15N in breast (r = -0.49; p = 0.04) and wing feathers (r = -0.69; p = 0.002).

Table 2. Lipid content (%) and concentrations of PBDEs and selected emerging halogenated flame retardants (ng/g wet weight) in liver of female and male glaucous gulls (Larus hyperboreus) breeding off Cape Dorset, Nunavut. Means were computed only if at least 50% of the samples had concentrations above the analyte-specific MLOD.

	Females (n = 14)			Males (n = 17)		
	Samples >MLOD	Mean ± SE	Range	Samples >MLOD	Mean ± SE	Range
Lipid content (%)	-	6.22 ± 0.64	4.33 – 13.4	-	±	-
SPBDE [1]	93%	7.24 ± 3.07	<MLOD – 34.6	94%	24.5 ± 5.46	<MLOD – 66.3
Emerging HFRs						
DBDPE	0%	-	<MLOD	0%	-	<MLOD
PBEB	29%	-	<MLOD – 0.01	47%	-	<MLOD – 0.01
HBB	29%	-	<MLOD – 0.53	59%	0.07 ± 0.02	<MLOD – 0.32
BTBPE	0%	-	<MLOD	0%	-	<MLOD
EHTBB	36%	-	<MLOD – 0.92	47%	-	<MLOD – 0.85
BEHTBP	21%	-	<MLOD – 2.05	12%	-	<MLOD – 2.58
syn-DP	21%	-	<MLOD – 0.30	65%	0.18 ± 0.06	<MLOD – 0.71
anti-DP	21%	-	<MLOD – 0.42	59%	0.16 ± 0.05	<MLOD – 0.77

Figure 3. Mean (± SE) concentrations (ng/g wet weight) of 16 PBDE congeners detected in at least 50% of the liver samples of male glaucous gulls (Larus hyperboreus) breeding off Cape Dorset, Nunavut.



Discussion and Conclusions

Stable isotope profiles

Consumers generally exhibit tissue enrichment of δ15N by 2-5‰ at each trophic level, while δ13C shows limited trophic enrichment (0-2‰) (Kelly 2000). However, this is largely dependent on the tissue-consumer-prey combination (Bearhop et al. 2002). Based on estimated half-lives of carbon and nitrogen in avian tissues, two feather types and liver were selected to investigate dietary component assimilation over short time frames (Hobson and Clark 1992, 1993; Bearhop et al. 2006; Martinez del Rio et al. 2009). Based in part on knowledge of feather molting sequence in glaucous gulls, this corresponded to the post-breeding period (wing feathers: October-November 2011), winter (breast feathers: January-March 2012), and the breeding period (liver: June-July 2012) (Gaston A., personal communication). Results suggested that glaucous gulls breeding in this particular location (islands off Cape Dorset) exhibit either a degree of dietary variations throughout the year, and appear to feed higher up in the food chain during the winter compared to the breeding period, or that these areas differed in isoscape (Phillips et al. 2009). Overall, males also fed upon higher trophic level preys than females during all periods encompassed by stable isotope analyses.

Mercury and legacy organochlorines

Total Hg and MeHg concentrations were found to be fairly elevated in liver of Cape Dorset glaucous gulls (males and females) relative to those reported in breeding glaucous gull liver collected in Svalbard in the Norwegian Arctic (Total Hg: 1.17 µg/g wet weight; MeHg: 0.74 µg/g wet weight) (Jaeger et al. 2009). This may indicate substantial local exposure of Hg and its methylated form in the Canadian Arctic marine food web, as also evidenced by the significant positive association between total Hg and liver δ15N in this species. In contrast, SPCB concentrations determined in present glaucous gull (combined sexes) liver were 37-fold lower than those reported in liver of the same species breeding in Svalbard (mean: 20,114 ng/g wet weight) (Verreault et al. 2007b). Similar concentration trends (Svalbard >> Nunavut) were also found for most organochlorines determined in present study (Verreault et al. 2007b, 2010). These trends are in line with studies to date that have reported higher PCB and organochlorine concentrations in tissues of European Arctic marine species compared to those from the Canadian Arctic as a result of differential atmospheric influx of these contaminants to northern regions (e.g., Gulf Stream in Europe) (Fisk et al. 2005; Letcher et al. 2010).

PBDEs and emerging halogenated flame retardants

SPBDE concentrations determined in present glaucous gull (combined sexes) liver were approximately 12-fold lower than those reported (mean: 205 ng/g wet weight) in liver of a medium-size gull, the ring-billed gull (*Larus delawarensis*), breeding in the greater Montreal-area (QC) (Gentes et al. 2012). Concentrations of SPBDE in liver of present glaucous gulls also were substantially lower (31-fold) than those reported in liver of breeding individuals collected from Svalbard (mean: 522 ng/g wet weight) (Verreault et al. 2007b). These results are consistent with the global trends highlighted in Letcher et al. (2010), which demonstrated that European (Norwegian) Arctic seabirds exhibit higher PBDE burdens that those from the Canadian Arctic. This study revealed for the first time the presence of certain emerging HFRs in tissues of birds from the Canadian Arctic including HBB, DP (*anti* and *syn* isomers), PBEB, EHTBB, and BEHTBP. Possibly the most striking finding in the current-use HFR was the high occurrence of *anti*- and *syn*-DP, which were detected in at least 59% of liver samples in males. DP was initially marketed in the 1960s as a replacement product for the banned pesticide Dechlorane (i.e., mirex), and the only known production facility of DP in North America (OxyChem) is located in Niagara Falls, NY (Gauthier and Letcher 2009). DP has been suggested as a possible replacement product for deca-BDE (Hoh et al. 2006). Interestingly, DP isomers were negatively related to δ15N determined in both breast and wing feathers of male glaucous gulls. This may suggest that exposure of DP is associated with diet that is more characteristic of that in post-breeding period and in wintering sites, and perhaps also that lower trophic level organisms in these areas accumulate higher concentrations of DP isomers. Moreover, worthwhile mentioning was the frequent detection of EHTBB and BEHTBP in male and female glaucous liver. These compounds are found in Firemaster 550, Firemaster BZ-54 and DP-45 that are currently marketed by Chemtura Corporation (formerly Great Lakes Chemicals) as replacement products for the banned penta-BDE (Klosterhaus et al. 2008).

In conclusion, analysis of mercury and a range of organohalogens in liver of glaucous gulls collected from Cape Dorset (Nunavut) demonstrated that this top predator-scavenger species accumulates a wide array of chemicals of environmental concern. Among these contaminants are those subjected to global bans or restrictions in North America (e.g., legacy organochlorines, penta- and octa-PBDE mixtures, and mercury). In addition, some currently produced chemicals that lack any global use regulation (e.g., emerging HFRs) were detected in these gulls, although at low levels. Concentrations of legacy organochlorines (PCBs, OCS, DDTs, HCHs, CHLs, CBzs, dieldrin, and mirex) and PBDEs in liver of Cape Dorset glaucous gulls generally were in the lower range among circumpolar glaucous gull populations (Letcher at al. 2010; Verreault et al. 2010). The exception to this was Hg and MeHg concentrations that appear to be elevated in this region of the Canadian Arctic and compared to Svalbard area.

Expected Project Completion Date

This is a new project under NCP that was intended to last three years. No fieldwork will be conducted in Cape Dorset during the 2013-2014 fiscal year as the research team wished to thoroughly analyze and interpret the data before planning for a second field season. However, the five geolocators deployed in Prince Leopold Island by project team members (M. Mallory and A. Gaston) will be recovered in July 2013 as part of ongoing seabird population monitoring and research projects.

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

Tendances temporelles des niveaux de mercure chez les poissons de lacs visés par des avis sanitaires périmés dans les Territoires du Nord-Ouest, au Canada

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Abstract

The Government of the Northwest Territories (GNWT) Department of Health and Social Services (HSS) has the responsibility to provide generic advice on the consumption and safe handling of country foods which play an important role in the way of life for aboriginal people in the Northwest Territories (NWT). It is important that contaminant data is up-to-date which requires continual monitoring and evaluation. The GNWT-HSS proposed to test six lakes for mercury levels in fish muscle; five of which had public health advisories that dated back to the 1990's. The goal of the project was to collect and sample the muscle from 20 fish from Lac á Jacques, Manuel Lake and Turton Lake,

Résumé

Le ministère de la Santé et des services sociaux (MSSS) du gouvernement des Territoires du Nord-Ouest (GTNO) a la responsabilité de fournir de l'information générale sur la manipulation sécuritaire et la consommation d'aliments traditionnels qui jouent un rôle important dans le mode de vie des Autochtones dans les Territoires du Nord-Ouest (T. N.-O.). 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 MSSS du GTNO a proposé de vérifier les concentrations de mercure dans le tissu musculaire de poissons de six lacs, dont cinq étaient visés par des avis sanitaires

within the Sahtu region of the NWT; as well as Gargan Lake, Little Doctor Lake and Trout Lake, within the Dehcho region of the NWT. The target species included Northern Pike (*Esox lucius*) and Walleye (*Sander vitreus*) from Lac á Jacques, Lake Trout (*Salvelinus namaycush*) from Turton Lake, Northern Pike from Manuel Lake, Walleye and Northern Pike from Little Doctor Lake, Northern Pike from Gargan Lake and Lake Trout from Trout Lake.

Collections and sampling of the target species from Manuel Lake, Trout Lake and Gargan Lake were successful. Fish from Turton Lake and Lac á Jacques were not collected. Little Doctor Lake had fish collected but it resulted in too small of a sample size. The mean mercury concentration for the Northern Pike (n=18) from Manuel Lake was 0.40 µg·g-1. Results are still pending from Trout Lake and Gargan Lake fish. The results will be posted on the GNWT-HSS website and if elevated the involved communities will be informed, proper messaging will be in place and fish consumption advisories/information updated.

remontant aux années 1990. Le but du projet était de collecter et d'échantillonner le tissu musculaire de 20 poissons prélevés dans le Lac à Jacques et les lacs Manuel et Turton, situés dans la région du Sahtu, ainsi que dans les lacs Gargan, Little Doctor et Trout, situés dans la région du Deh Cho. Les espèces ciblées étaient le grand brochet (Esox lucius) et le doré jaune (Sander vitreus) du Lac à Jacques, le touladi (Salvelinus namaycush) du lac Turton, le grand brochet du lac Manuel, le doré jaune et le grand brochet du lac Little Doctor, le grand brochet du lac Gargan et le touladi du lac Trout.

Les collectes et les échantillonnages des espèces ciblées dans les lacs Manuel, Trout et Gargan ont été fructueux. Des poissons n'ont pas été prélevés dans le lac Turton et le Lac à Jacques. Des poissons ont été prélevés dans le lac Little Doctor, mais l'échantillon était trop petit. La concentration moyenne de mercure chez le grand brochet (n = 18) du lac Manuel s'élevait à 0,40 µg g^{-1}. Les résultats sont encore à venir pour les poissons des lacs Trout et Gargan. Ils seront affichés sur le site Web du MSSS du GTNO et, si les concentrations sont élevées, les collectivités concernées seront informées, les messages appropriés seront transmis et les avis et l'information sur la consommation de poisson seront mis à jour.

Key Messages

- It is the responsibility of the GNWT to provide consumption advice for country foods that are important to people in the NWT. In order to fulfil this responsibility, ongoing research and monitoring must continue so that up-to-date information can be communicated properly back to the people of the NWT.
- The more people that are informed about contaminant issues within food in combination with proper messaging and communication set in place, the better decisions can be made regarding healthy choices.
- Advisories indicate that larger predatory fish (walleye, northern pike or lake trout), are

Messages clés

- Il incombe au GTNO de fournir des avis sur la consommation d'aliments traditionnels qui sont importants pour les habitants des T. N.-O. Afin que le GTNO puisse s'acquitter de ce mandat, les activités de recherche et de surveillance doivent se poursuivre afin que des renseignements à jour soient communiqués adéquatement aux Ténois.
- Plus élevé sera le nombre de personnes informées des problèmes de contaminants dans les aliments, en combinaison avec la diffusion de messages et d'avis appropriés, meilleures seront les décisions qui seront prises au sujet des choix sains.
- Les avis indiquent que les gros poissons prédateurs (doré jaune, grand brochet,

safe to eat in small amounts. The amount depends on the level of mercury in the fish. Fish that are lower in the food chain (whitefish, sucker or grayling) are safe to eat in large amounts.

touladi) peuvent être consommés en petite quantité sans danger. La quantité dépend du niveau de mercure dans le poisson. Les poissons qui occupent un niveau inférieur dans la chaîne alimentaire (corégone, suceur, ombre arctique) peuvent être consommés en grande quantité sans danger.

Objectives

- 1) Sample fish from indicated lakes in order to determine if elevated levels are still present and if there is a need to maintain the existing public health advisory.
- 2) Consult with local communities and go over results from the project to be able to provide a better understanding of mercury in fish and to answer any questions or concerns that the people of the communities might have.
- 3) Fill the missing gaps of data that will allow for longitudinal trend analysis.
- 4) Add to baseline information within a comprehensive web-map database and within the NWT Discovery Portal.
- 5) Work with other NCP/CIMP proposals to coordinate communication to communities on contaminants (i.e. George Low's communication proposal, NCP researcher existing core monitoring proposals)

Long term goals:

- To lift advisories and bring a sense of ease to the communities, pertaining to the levels of mercury in fish.
- To keep people and communities informed of elevated levels of mercury in fish in the NWT.

Introduction

While undertaking the phase II 2011-2012 project of "Building Capacity in Knowledge Translation of Northern Contaminants", it was noted that a number of old public health advisories were in place from the mid-1990's. Priorities shifted to update these out-dated public health advisories. Six lakes were proposed for testing of mercury levels in fish muscle (Three located in the Dehcho region and three in the Sahtu region). Five of the lakes were last tested around 15 years ago.

The GNWT is responsible for providing 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 up to date information on contaminants must be part of existing public health messages. Regular review and the incorporation of new information based on current research and the results of NWT studies is part of this process.

The concern over out-dated public health advisories is not a new issue and has been raised by Northern Contaminants Program (NCP) members in the past. Shown below (Table 1), is a list of out-dated public health advisories with consumption guidelines from the 1990's which had not been sampled since. Supporting this, the following statement was made in a report for the 2004-2005 NCP Synopsis. "There presently is not a mechanism in place to validate the necessity of continuing with a consumption advisory once it has been issued. E.g. some advisories have been in place for over 10 years. Stocks are not re-sampled on a regular basis to determine if there have been any changes in contaminant levels. Such a mechanism needs to be developed" (NWT ECC, 2005).

An objective of this project was to create a mechanism that will validate the necessity of continuing with a consumption advisory once it has been issued. Ongoing monitoring needs to be in place for at-risk lakes that are heavily fished so that when levels of mercury in fish in a particular lake rise above a safe limit, responsible decision-makers can be made immediately aware and act in a timely manner.

Since it is not feasible to test every lake for mercury in fish, generic fish advisory messages have been incorporated into the annual NWT Sport Fishing Regulations Guide which can be disseminated with the annual process of obtaining a NWT Sport Fishing License. A map of previous mercury testing sample locations has been produced as well as contaminants information and messaging on the GNWT-HSS website which contains links to an interactive map of current public health advisories for the consumption of fish which have been implemented in the NWT. The NWT mercury in fish database is continually being updated with relevant information and study results. A comprehensive web-map database has been created with an integration of numerous layers of data which enables for visual analysis and can be manipulated in order to create criteria for potential future sample locations. By utilizing these tools, we have achieved the start of an integrated way of thinking and proactive solutions that will help with issues regarding elevated levels of mercury in fish in the NWT.

Table 1: Recommended maximum weekly intake (g/week) of fish in lakes in the NWT, based on concentrations of mercury in the muscle (issued by GNWT Health and Social Services) (NWT ECC, 2005).

Lake	Coordinates (lat,long)	Last year Sampled	Species	Adults	Women of child-bearing age	Children
Gargan	61.25, -120.38	1996	Northern Pike	330	140	65
Lac á Jacques	66.17, -127.4	1995	Northern Pike	200	85	40
		1995	Walleye	390	160	80
Little Doctor	61.88, -123.27	1996	Northern Pike	250	110	50
		1996	Walleye	250	110	50
Manuel	66.97, -128.9	1998	Northern Pike	430	185	85
Sanquez	61.25, -120.47	1996	Northern Pike	275	120	55
		1996	Walleye	370	180	75
Turton	65.81, -126.95	1996	Lake Trout	330	140	65

Table 2: Summary of Mean Mercury Concentrations in Fish Muscle

Lake	Year	Species	N	Hg (μg•g-1)
Manuel	1998	Northern Pike	11	0.54
Turton	1996	Lake Trout	55	0.60
Lac á Jacques	1995	Walleye	20	1.00
	1995	Northern Pike	13	0.59
Little Doctor	1996	Walleye	18	0.75
	1996	Northern Pike	9	0.74
Gargan	1996	Northern Pike	2	0.59

Figure 1: Sample Lake Location in Sahtu Region, NT.

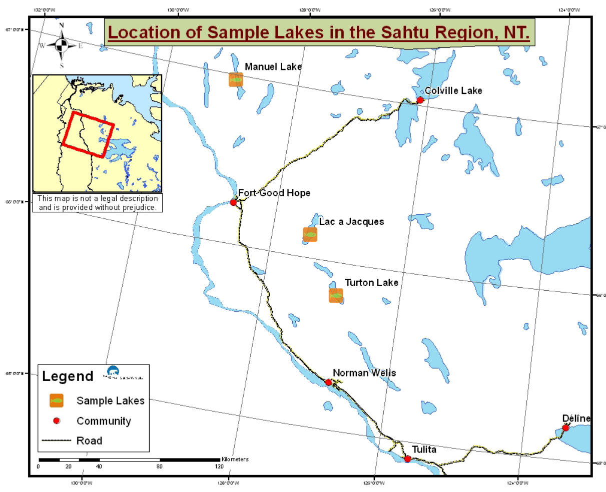
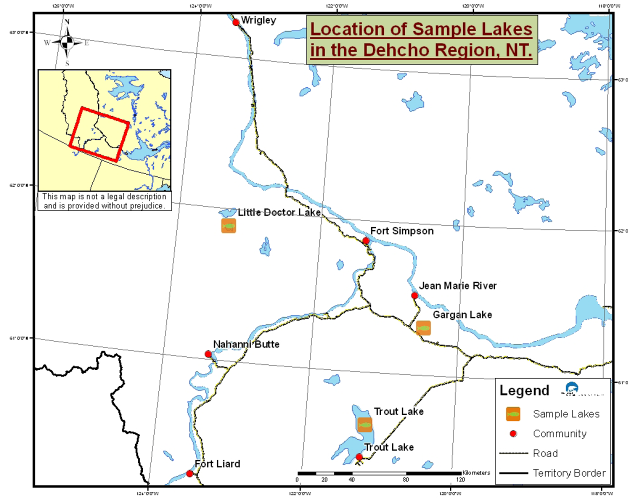


Figure 2: Sample Lake Location in Dehcho Region, NT.



The target for this project was to collect and sample the muscle from 20 fish from each target lake that had an old advisory; they included Lac á Jacques, Manuel Lake and Turton Lake, within the Sahtu region (Figure 1); as well as Gargan Lake, Little Doctor Lake and Trout Lake, within the Dehcho region (Figure 2). The target species included Northern Pike and Walleye from Lac á Jacques, Lake Trout from Turton Lake, Northern Pike from Manuel Lake, Walleye and Northern Pike from Little Doctor Lake and Northern Pike from Gargan Lake. Trout Lake was included in the project as a lake to be tested due to recent data showing a possible decline in mercury in the Lake Trout.

Previous mean mercury concentrations from fish muscle from the out-dated lakes are summarized in the table below (Table 2) (Lockhart et al., 2005).

Activities in 2012-2013

Communications:

In June 2012, meetings with Daniel T'Seleie and Lee Mandeville of Dene Nation, and Cindy Gilday of Sahtu Secretariat Inc., took place to find ways to help inform community members and leaders in the involved communities of the project. Key contacts were discussed and plans were made to help set up fish collections for each sample lake. Later that month, Mark Wasiuta attended the 2012 Dehcho Annual Assembly in Fort Simpson, NT.

In July 2012, he attended the 2012 Dene National Assembly in Whati, NT. to inform leaders of the project as well as to go over project details.

Dr. Kami Kandola attended and presented at the Jean Marie Workshop on the Health Benefits of Fish that took place in the community of Jean Marie, NT. in August 2012.

In September 2012, meetings with members of Dene Nation, Sahtu Secretariat Inc., the president of Yamoga Land Corporation and elder advisors from Fort Good Hope took place at the Tree of Peace in Yellowknife, to inform them of the project. Approval was granted from the Chiefs of the communities; meetings, conversations and arrangements of fish collections continued until February 2013. During the same time, conversations and arrangements for Gargan Lake, Trout Lake and Little Doctor Lake fish collections, in the Dehcho, were occurring and were granted the approval from the Chiefs of the involved communities. Throughout this time, numerous conversations with the involved researchers/ project members had taken place regarding the project.

Capacity Building:

In October 2012, Fred Punch from the community of Trout Lake, NT. collected Lake Trout from Trout Lake, while in February 2013, Mike Low, Dehcho AAROM-Dehcho First Nations, with the help of Mark Wasiuta, from Yellowknife, NT. and Danny Allaire, from Ft. Simpson, NT. collected Northern Pike from Gargan Lake. George Low managed to coordinate the collection for Little Doctor Lake but the number of fish collected was lower than expected and future efforts may be conducted to increase the sample size. Dr. Marlene Evans is conducting the analysis of the fish in the Environment Canada Lab in Saskatoon, SK.; results for Gargan Lake and Trout Lake are still pending.

In December 2012, Wilfred Jackson of Fort Good Hope collected Northern Pike from Manuel Lake. Dr. Gary Stern conducted the analysis of the fish Northern Pike from Manuel Lake in the Department of Fisheries and Oceans Lab in Winnipeg, MB.

In January 2013, GNWT-HSS started a Cumulative Impact Monitoring Program (CIMP) project titled, “Visual Analysis of Predictors for Increased Mercury Levels in Predatory Fish in NWT Lakes”. It involved developing an interactive web-map that is made up of multiple layers of known mercury predictors and can use simple visual analysis to target “hot spots” that would have the potential of elevated levels of mercury in fish muscle within lakes. Ultimately, it would be utilized as a tool by decision-makers for the initiation and criteria of expanding on mercury in fish muscle data within the NWT. The web-map has the potential to also be used as a template for future projects and could help out with gathering baseline data in areas of the NWT where data is sparse.

Results

Northern Pike was collected from Manuel Lake and Gargan Lake, while Lake Trout was collected from Trout Lake. We have received the results from Manuel Lake and are still waiting on results from the lab for the Gargan Lake and Trout Lake samples. The table below (Table 3) summarizes mean mercury in fish muscle results of the project.

Table 3: Summary of Mean Mercury Concentrations in Fish Muscle in 2012-2013

Lake	Species	N	Round wt. (g)	Fork Length (mm)	Hg (µg•g-1)
Manuel	Northern Pike	18	2140.28	605.22	0.404
Gargan	Northern Pike				*
Trout	Lake Trout				*

* - Results pending from Gargan Lake and Trout Lake

Discussion and Conclusions

Once we have received the results from Gargan Lake and Trout Lake, updated information will be posted on the GNWT-HSS website regarding the recent levels. The recent testing will make advisories and updated information more concrete as well as give a better look at the mercury levels of fish in these lakes and provide a temporal analysis to monitor any changes over time. The main goal is the promotion of safe consumption of traditional foods and this will help the GNWT to implement or discard old advisories with confidence in knowing that the data from these lakes are up to date. This project and future projects like this one will help to ensure that the fish in the lakes which had advisories are safe to eat and will allow GNWT HSS to inform community members, as well as other people about levels of mercury in fish in the Northwest Territories (NWT).

Due to funding cutbacks and time restraints, Turton Lake and Lac á Jacques were not able to be sampled as well as some project objectives regarding communications were not fully accomplished. Through future endeavours, we would like to pursue to have the muscle tested from the targeted fish for mercury in these lakes. A larger sample size for Little Doctor Lake would also be sought after.

Large amounts of snow and cold temperatures also made it more difficult to access Turton Lake and Lac á Jacques. The collectors that were lined up to collect from these lakes preferred to take advantage of the warmer temperatures in the month of March to collect fish from these lakes. The snow would have a layer of crust on top which would make for easier traveling over the deep snow. With warmer temperatures in March, it would make for preferable working conditions and less likely for breakdowns due to colder temperatures. By that time, the project was coming to a close, the labs running the analysis had deadlines and funding was running short.

Expected Project Completion Date

The project completion date was March 31, 2013.

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- Fred Punch, Trout Lake, NT.
- Northern Contaminants Program

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

Prévision de l’effet des changements climatiques sur l’exposition aux contaminants dans l’Arctique

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Abstract

Global climate change may potentially influence the fate, transport, bioavailability and bioaccumulation of organic contaminants in the future. The Arctic region is of particular concern in this regard because climate change models project the greatest warming to occur in this region and 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). Through extensive simulations with the global fate and transport model GloboPOP, we sought to predict by how much organic contaminant levels in exposure-relevant environmental compartments in the Arctic can be expected to change in response to currently anticipated

Résumé

Les changements climatiques mondiaux sont susceptibles d’exercer un effet sur le devenir, le transport, la biodisponibilité et la bioaccumulation de contaminants organiques à l’avenir. À cet égard, la région de l’Arctique est particulièrement préoccupante parce que les modèles de changements climatiques prévoient que le réchauffement sera le plus marqué dans cette région et que ses habitants y prélevant des ressources alimentaires locales (p. ex. des phoques) sont fortement exposés à de nombreux contaminants préoccupants (polluants organiques persistants). En faisant des simulations exhaustives avec le modèle du devenir et du transport à l’échelle mondiale GloboPOP, nous avons cherché à prédire

global climate change (specifically changes in temperature, precipitation and sea ice cover). While overall, the predicted changes in contaminant levels in the Arctic are small (within a factor of two), climate-driven changes in the particulate organic carbon dynamics in the Arctic Ocean have the potential to both increase and decrease significantly future exposure of the marine food chain to persistent organic pollutants. Given the many uncertainties related to the potential for enhanced levels of organic matter in the Arctic marine environment to influence human and ecological exposure to neutral organic chemicals, further empirical studies and model development aimed to clarify these aspects are clearly warranted.

dans quelle mesure il peut être attendu que les niveaux de contaminants organiques dans les milieux environnementaux qui y sont exposés dans l'Arctique changeront en réponse aux changements climatiques mondiaux actuellement anticipés (en particulier les changements dans la température, les précipitations et la couverture des glaces de mer). Bien que, dans l'ensemble, les changements prévus dans les niveaux de contaminants dans l'Arctique soient minimes (de l'ordre d'un facteur de deux), les changements induits par le climat dans la dynamique du carbone organique particulaire dans l'océan Arctique peuvent aussi bien accroître que réduire considérablement l'exposition future de la chaîne alimentaire à des polluants organiques persistants. Compte tenu des nombreuses incertitudes quant au potentiel de niveaux accrus de matière organique dans le milieu marin de l'Arctique d'agir sur l'exposition humaine et environnementale à des produits chimiques organiques neutres, des études empiriques plus poussées et d'autres simulations de modèle visant à clarifier ces aspects sont nettement justifiées.

Key messages

- In global-scale model simulations, metrics of contamination of the Arctic environment with organic contaminants (e.g. Arctic sea water concentrations) are relatively insensitive to global climate change, changing only within a factor of two when current climatic conditions are compared with those predicted to occur 100 years from now.
- For legacy contaminants, such as the polychlorinated biphenyls, declines in emissions will likely cause much larger changes in contamination levels in the Arctic environment over the next 100 years, than could be expected to occur as a result of global climate change.
- Climate-driven increases in the particulate organic carbon cycling in the Arctic Ocean (e.g. as a result of higher primary

Messages clés

- Dans des simulations de modèle à l'échelle mondiale, les paramètres de contamination de l'environnement arctique par des contaminants organiques (p. ex. concentrations dans l'eau de l'océan Arctique) sont relativement insensibles aux changements climatiques mondiaux, ne changeant d'un ordre d'un facteur de deux quand les conditions climatiques actuelles sont comparées à celles qui devraient prévaloir dans 100 ans.
- Dans le cas des contaminants hérités du passé, comme les biphényles polychlorés, les déclins des émissions causeront probablement des changements encore plus importants dans les niveaux de contamination du milieu arctique au cours des 100 prochaines années qu'il ne le serait attendu en raison des changements climatiques mondiaux.

productivity or increased terrestrial inputs) have the potential to change ecological exposure to hydrophobic persistent organic contaminants.

- While during time of ongoing primary emissions, dissolved phase concentrations of such contaminants in the Arctic surface ocean are expected to be lower at higher organic carbon concentrations, after emission have ceased the disappearance of contaminants from the Arctic surface ocean may be slower because sediments are more effectively resupplying contaminants to the overlying water column.

- L'accroissement, attribuable aux changements climatiques, du rythme du cycle du carbone organique particulaire dans l'océan Arctique (p. ex. par suite d'une productivité primaire accrue ou d'apports terrestres accrus) peut agir sur l'exposition environnementale à des polluants organiques persistants hydrophobes.

- Bien que, en périodes d'émissions primaires continues, les concentrations en phase dissoute de tels contaminants dans les eaux de surface de l'océan Arctique devraient être moins élevées lorsque les concentrations de carbone organique sont plus élevées, la disparition de contaminants des eaux de surface de l'océan Arctique peut être plus lente, après l'interruption des émissions, parce que les sédiments réapprovisionnent plus efficacement la colonne d'eau surplombante en contaminants.

Objectives

- 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 of 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.

Introduction

The potential influence of global climate change on human and ecological exposure to neutral organic chemicals in both industrialized and remote regions is increasingly gaining the attention of scientists interested in persistent organic pollutants (Macdonald et al. 2003, 2005, Kraemer et al. 2005, Jenssen 2006, Schiedek et al. 2007, lamon et al. 2009, Stern et al. 2012, Kallenborn et al. 2012). For example, climate variables are more frequently being used to interpret spatial and temporal patterns in biomonitoring data for persistent organic pollutants, particularly in the Arctic environment which is already experiencing substantial changes (e.g. warmer temperatures, reduced sea-ice cover) (McKinney at al. 2009, Carrie et al. 2010, Rigét et al. 2010, Bustnes et al. 2010). The public availability of projections of climatic conditions throughout the 21st century (IPCC 2007a and 2007b, Christensen et al. 2007, ACIA 2005) has also facilitated the application of multimedia environmental fate models to explore some of the potential implications of global climate change for contaminant issues (McKone et al. 1996, MacLeod et al. 2005, Dalla Valle et al. 2007, Lamon et al. 2009, Borgå et al. 2010, Ma and Cao 2010, Wöhrnschimmel et al. 2013). Simulations have been conducted for several legacy contaminants such as hexachlorobenzene, polychlorinated biphenyls (PCBs), hexachlorocyclohexanes and polychlorinated dibenzodioxins and -furans using different modeling tools and scenarios. Excluding changes in emissions, model output under the assumed global climate change scenarios is typically less than a factor of two different from model output using contemporary (i.e. 20th century) conditions (Armitage et al. 2011) and both positive (e.g. reduced contaminant levels) and negative (e.g. elevated contaminant levels) outcomes have been reported, depending on the model application and environmental medium being considered (e.g. atmosphere vs. surface water). While modeling these legacy contaminants is useful, these compounds occupy a relatively narrow portion of the range of partitioning property combinations and it is unclear to what extent model output for the compounds simulated to date can be generalized to other compounds. For this reason, there is an obvious rationale to expand the range of partitioning property combinations included in model simulations (Wöhrnschimmel et al. 2013).

The Arctic region will experience the greatest warming over the 21st century (IPCC 2007a and 2007b, Christensen et al. 2007, ACIA 2005) resulting in profound changes to key elements of the ecosystem, particularly the cryosphere (i.e. sea-ice, permafrost, glaciers). The link between reduced sea-ice cover and enhanced primary productivity in the Arctic marine environment is an important consideration (Ellingsen et al. 2008, Lavoie et al. 2010, Arrigo and van Dijken 2011, Slagstad et al. 2011), particularly when considering the fate of hydrophobic organic contaminants. While temporal trend data for Σhexa- and hepta PCBs in burbot were used to hypothesize that increased primary productivity corresponds to enhanced exposure (Carrie et al. 2010), there are numerous studies reporting an inverse relationship between primary productivity and wildlife exposure to persistent organic pollutants (Taylor et al. 1991, Larsson et al. 1992, Dachs et al. 2000, Berglund et al. 2001, Nizzetto et al. 2012). As lower contaminant levels are expected in pelagic organisms inhabiting eutrophic compared to oligotrophic systems (given the same loadings), it is reasonable to hypothesize that a similar response may occur in the Arctic Ocean if primary productivity increases. The extent to which primary productivity will increase in the Arctic Ocean is uncertain and region-specific (ACIA 2005, Ellingsen et al. 2008, Lavoie et al. 2010, Arrigo and van Dijken 2011, Slagstad et al. 2011). Enhanced permafrost melt and coastal erosion in the Arctic are additional pathways for particulate organic carbon inputs to be influenced by global climate change (Payette et al. 2004, Overeem et al. 2011, Ping et al. 2011). As human and ecological exposure to organic contaminants in the Arctic remain a concern (Donaldson et al. 2010, Letcher et al. 2010), there is an interest in improving the understanding of how global climate change may exacerbate or attenuate the possible risks in the future.

Activities in 2012-2013

In this final year of the project, the following main activities were carried out:

- A paper was finalised and published that summarises and documents all of the modifications that had been made to the global fate and distribution model GloboPOP. These modifications had been introduced in order to make the model suitable for investigating the impact of global climate change on the transport and accumulation of persistent organic pollutants in the Arctic. The most important modifications of the model include the description of (i) a seasonal snow cover, (ii) intermittent precipitation, (iii) riverine water flow crossing zonal boundaries in the meridional direction, and (iv) marine shelf sediments in the Arctic Ocean.
- This paper also included an exploration of the impact of these model modifications on the transport and accumulation of persistent organic pollutants in the Arctic. Because the

inclusion of Arctic shelf sediment had the most profound impact, the paper focussed on explaining the mechanisms underlying this impact.

- A second paper was finalised and submitted for publication that seeks to predict comprehensively with the newly modified GloboPOP model the impact of global climate change on the transport and accumulation of persistent organic pollutants in the Arctic. Model results for current climatic conditions were contrasted with model results obtained for a future global climate scenario. This was done for hypothetical scenarios of increasing and decreasing emissions, and for a wide range of hypothetical organic chemicals that vary widely in their partitioning and degradability.
- Input was provided to the CLEAR project consortium in support of exposure and risk assessment activities conducted for Inuit populations inhabiting Greenland. Scenarios were developed that characterize the relative change in the exposure to selected contaminants (PCBs, perfluorinated alkyl acids) under defined global climate change scenarios (i.e. in the future).

This model-based project is conducted entirely in Southern Canada and does not include elements of capacity building and communications in the North, or the integration of traditional knowledge.

Results

In a first step, the contribution of shelf sediments in the Arctic Ocean to the total mass of neutral organic contaminants accumulated in the Arctic environment was studied with the newly modified GloboPOP model using a standardized emission scenario for sets of hypothetical chemicals (Armitage et al. 2013). Shelf sediments in the Arctic Ocean were shown to be important reservoirs for neutral organic chemicals across a wide range of partitioning properties, increasing the total mass in the surface compartments of the Arctic environment by up to 3.5-fold compared to simulations excluding this compartment. The relative change in total mass for hydrophobic organic chemicals with log air-water partition coefficients log $K_{AW} \geq 0$ was greater than for chemicals with properties similar to typical persistent organic pollutants. The simulations for hypothetical chemicals were complemented with a long-term simulation of the global fate and Arctic accumulation of polychlorinated biphenyl congener 153 (PCB-153) using realistic emission estimates (Armitage et al. 2013). Model-generated concentrations in shelf sediments were in reasonable agreement with available monitoring data. The relative importance of shelf sediments in the Arctic Ocean for influencing surface ocean concentrations (and therefore exposure via the pelagic food web) was found to be most pronounced once primary emissions are exhausted and secondary sources dominate.

The modified GloboPOP model was employed to assess the potential influence of climate change on the fate of organic chemicals in the Arctic marine environment (Armitage and Wania, 2013). The adopted strategy involved defining a parameter set representing contemporary conditions (‘before’) and then a modified parameter set incorporating projected changes for a future climate (‘after’). Temperatures, precipitation rates and sea ice coverages for the future climate scenario were defined using regional and global-scale projections for climate change in the latter part of the 21st century (IPCC 2007a and 2007b, Christensen et al. 2007, ACIA 2005). Given the coarse spatial resolution of the model and limited influence reported in previous global-scale modeling exercises (Lamon et al. 2009, Wöhrnschimmel et al. 2013), projected changes to atmospheric and oceanic circulation patterns were not considered. Particulate organic carbon scenarios were included to represent changes such as enhanced primary productivity and terrestrial inputs.

Simulations were conducted for a set of hypothetical chemicals covering a wide range of partitioning property combinations (log KOA

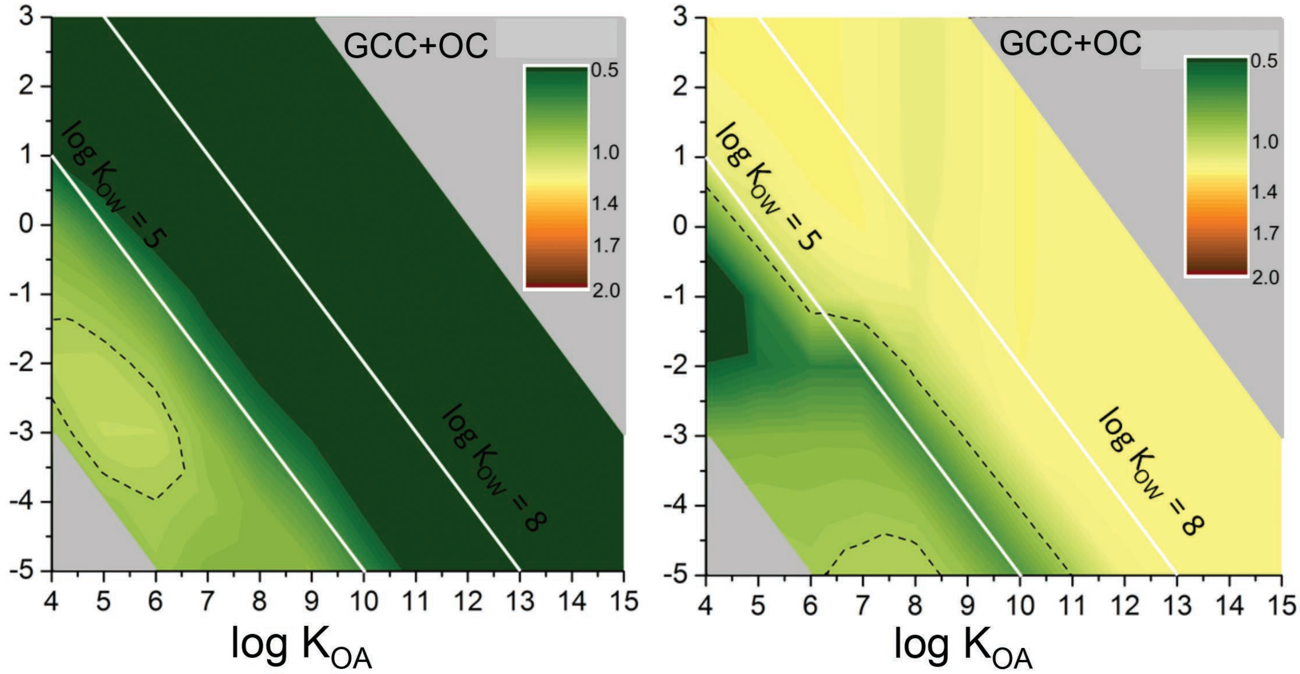
= 4 to 15, log KAW = 3 to -5 where log KOW = log KOA – log KAW and only log KOW values from 1 to 12 are included) using a 40-year emission scenario, which specified a constant (unit) emission rate for 20 years followed by zero emissions for the remaining 20 years. This approach allowed model output to be generated and compared during the primary emission phase (Year 0–20) and as secondary sources (e.g. environmental reservoirs such as boreal forest soils) come to dominate (Year 20–40). Over the latter period, levels in the environment are declining due to degradation and export out of the model domain (e.g. sediment burial, export to deep oceans).

Differences in model output between the default contemporary simulations and future scenarios during the primary emission phase are limited in magnitude (i.e., typically within a factor of two), consistent with other modeling studies. Such results stem from the fact that changes implemented for the global climate change scenarios can act antagonistically (i.e. influences are competing and so tend to balance out). Furthermore, some changes implemented in the global climate change scenarios (e.g. precipitation rates) are limited in magnitude. The changes to particulate organic carbon levels in the Arctic Ocean assumed in the simulations exert a relatively important influence for hydrophobic organic chemicals during the primary emission period, mitigating the potential for exposure via the pelagic food web by reducing freely-dissolved concentrations in the water column (Figure 1A). The changes to particulate organic carbon levels are also influential in the secondary emission/depuration phase (Figure 1B).

Discussion and Conclusions

Increases in average air concentration are predicted under global climate change scenarios for chemicals with log KAW ≥ – 4.5 and log KOA between approximately 7 and 10.5. This behaviour is a combination of

Figure 1A and 1B: Average freely-dissolved concentration in surface ocean water (CO) calculated in the GCC+OC scenario compared to the default scenario. The left panel shows the CO ratio in Year 20, i.e. end of the primary emission phase. The right panel shows the change in the apparent dissipation half-life from the surface ocean between Years 20 and 40, i.e. during the depuration phase. Ratios greater than 1.0 (+) mean that CO (left) or the dissipation half-life (right) under the GCC scenario is higher than under the default scenario. The dotted line indicates a transition from ratios less than 1.0 to those greater than 1.0.



alterations in long-range transport efficiency of such contaminants to the Arctic environment and changes in the net deposition fluxes and accumulation in surface media (e.g. soils and shelf sediments). This combination of partitioning properties overlaps with known persistent organic pollutants such as PCBs. The suggestion that atmospheric concentrations of chemicals with such partitioning properties may increase in direct response to warmer air temperatures is consistent with previous global-scale modeling studies (Lamon et al. 2009, Wöhrnschimmel et al. 2013). However, it is also clear that the responses to the global climate change scenarios seen in the surface compartments (e.g. the surface ocean) are quite different from the responses seen in the atmosphere. Such considerations are relevant when speculating on potential human and ecological health risks associated with exposure to organic contaminants and links to global climate change. Therefore, responses to global climate change are best evaluated from a multimedia perspective, ideally using the most exposure-relevant metrics (e.g. freely-dissolved as opposed to total water concentrations, organic carbon-normalized as opposed to total sediment concentrations).

The model results illustrate the potential importance of future changes to organic carbon levels in the Arctic Ocean. The differences in model output between the various scenarios illustrate that enhanced particulate organic carbon in the Arctic marine environment may be one of the more important considerations for hydrophobic chemicals. During the primary emission phase, enhanced particulate organic carbon in the Arctic marine environment can exert a mitigating influence on exposure to hydrophobic chemicals. Potential changes in particulate organic carbon cycling and sediment-water exchange dynamics linked to global climate change are therefore key processes to consider further, particularly in the context of determining if responses in pelagic food webs are representative of responses in benthos (e.g. benthic fauna inhabiting shelf sediments). Unfortunately, projecting changes to inputs of organic carbon to the Arctic environment due to enhanced primary productivity, permafrost melt, coastal erosion and other alterations to organic carbon cycling is challenging and subject to many data gaps (Yunker et al. 2005).

Expected Project Completion Date:

The project will be completed by October 2013. Within the next few months the submitted paper by Armitage and Wania will be further revised (as and if required) and published. At the beginning of October, results of the overall project will be presented at a meeting of the CLEAR consortium in Copenhagen, Denmark.

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Communications, Capacity, and Outreach

Communication, capacités et la sensibilisation

Yukon Contaminants Committee and AANDC Regional Office Coordination 2012/13

Coordination du Comité des contaminants du Yukon et du bureau régional d'AADNC en 2011-2012

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Abstract

The Yukon Contaminant Committee and AANDC Regional office Yukon have spent over 20 years building an NCP database of contaminants analysis results and a tissue archive of samples. Regionally, the Program supports long term trend monitoring of the Porcupine caribou herd and Lake Trout from Lakes Kusawa and Laberge. The NCP has also provided funding for the Little Fox Lake site to monitor atmospheric mercury entering the Yukon and Western Arctic since 2007. The Regional office of AANDC facilitates this work through funding arrangements.

Résumé

Le Comité des contaminants du Yukon et le bureau régional d'AADNC au Yukon ont mis plus de 20 ans à bâtir une base de données du PLCN qui regroupe des résultats d'analyses des contaminants et des archives de tissus. À l'échelle régionale, le Programme appuie la surveillance des tendances à long terme touchant la harde de caribous de la rivière Porcupine et du lac Trout depuis les lacs Kusawa et Laberge. Le PLCN verse aussi des fonds au site du lac Little Fox pour permettre la surveillance du mercure atmosphérique qui entre au Yukon et dans l'Arctique de l'Ouest depuis 2007. Le bureau régional d'AADNC facilite ces travaux grâce à des ententes financières.

Keys messages

- NCP Yukon Database maintained
- 20 year NCP tissue archive maintained
- AANDC Regional support for research that compliments NCP funded projects in the Yukon

Messages clés

- Administration de la base de données du PLCN au Yukon
- Tenue des archives de tissus du PLCN depuis 20 ans
- Soutien à la recherche par le bureau régional d'AADNC afin de compléter les projets financés par le PLCN au Yukon

Objectives

- Yukon resource for NCP activities
- Point of contact for researchers working on NCP projects in the Yukon
- Maintains the Yukon Contaminants Database and the sample tissue archive for NCP.

Introduction

The Northern Contaminants Program makes use of the Territorial Contaminants Committees as conduits between the Regions and the National Program. In addition to their ongoing role as the contact between the residents of the Yukon and the NCP the YCC is responsible for reviewing all Regional proposals for socio-cultural merit, assists in Aboriginal Partner and other government agency co-ordination, and working with communications strategies within the Yukon. The Yukon also has a database of sample analysis and a tissue archive of samples by monitoring and research programs in the Yukon. These activities require the fiscal support of the National Program.

Activities in 2012-2013

Yukon Region AANDC has supported the Regional office with funding for archive freezer repairs beyond that provided by NCP. It has also supported an active research program at Kusawa Lake to evaluate the effects of climate change on the cycling of mercury in the Lake's food web. A part of this was providing funding to a Champagne Aishihik First Nation graduate student from the University of Northern British Columbia to support their DNA analysis of a sediment core for mercury methylating bacteria. Support was also provided to the Vancouver office of Environment Canada in their CARA mercury study on Kusawa Lake, which has become a joint study with the NCP trend work taking place there.

Additional work included water sampling for oxygen isotopes to determine the percentage of historical water that makes up the flow of Kusawa Lake. Precipitation was also collected in the Whitehorse area for rainfall isotope analysis. This work is in conjunction with the Yukon Research Centre and the University of Victoria. Supporting collections of input waters for sediments was conducted at the same time and will provide for carbon analysis to develop a carbon balance for the Lake. This work is in conjunction with DFO Winnipeg and the University of Manitoba.

In late March, snow and glacial ice samples were collected from the Kusawa area and sent to the University of Ottawa for total mercury analysis and mercury isotopes [Trent University] to provide the initial work toward mercury 'mapping' for the current Yukon. This will also help interpret the main sources of mercury into the Kusawa system. Similar samples of snow were collected for mercury analysis [University of Ottawa] from the Little Fox Lake site to expand the mapping initiative and provide data for mercury flux measurements we hope to do at this site.

The Committee and the Regional NCP office are considered the contact for contaminant issues in the Yukon. In 2012/13 the Regional Office continued to work with the Yukon Health authorities on contaminants in traditional food sources. The Yukon Contaminants Database was updated and the freezers for the long term storage of archive samples were maintained.

Results

Archive freezers were repaired and the archive updated with the 2012 samples. The database was updated with 2011 data in preparation for it being rebuilt in the 2013/14 year and hosted at the Yukon Research Centre.

None if the mercury isotope work undertaken outside of NCP has had time to be reviewed.

Discussion and Conclusions

Results of the Caribou and Lake Trout monitoring work are reported under M-13: Long term trends of halogenated organic contaminants and metals in lake trout from two Yukon Lakes; Kusawa and Laberge (Stern 2012) and M-14: Arctic Caribou Contaminant Monitoring Program (Gamberg 2012).

Expected Project Completion Date

On-going

Acknowledgments

NCP and AANDC Region for funding and operational/administrative support.

Niqiit Avatittinni Committee (NAC)

Comité Niqiit Avatittinni

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Abstract

The Niqiit Avatittinni Committee (NAC) was struck in May 2000 to provide a forum to review and discuss, through a social-cultural lens, Nunavut-based NCP-funded projects and proposals seeking NCP funding. Through its social-cultural review of all Nunavut-based NCP proposals, the committee ensures northern and Inuit interests are being served by scientific research conducted in Nunavut.

In addition, the NAC aims to serve as a resource to Nunavummiut for long-range contaminants information in Nunavut.

Résumé

Le Comité Niqiit Avatittinni a été constitué en mai 2000 afin de permettre l'examen, selon une perspective socioculturelle, des projets financés par le PLCN et des propositions pour lesquelles des fonds sont demandés au Nunavut. En réalisant un examen socioculturel des propositions associées au PLCN dans le territoire, le Comité veille à ce que les recherches scientifiques menées au Nunavut servent les intérêts des Inuits et du Nord.

Le Comité fournit aussi aux Nunavummiut de l'information sur les contaminants transportés sur de longues distances que l'on trouve au Nunavut.

After a year of inactivity the NAC was reinvigorated in November 2012. New and existing members were solicited to participate in the NAC's social-cultural review of 2013-14 NCP proposals. The NAC conducted a thorough social-cultural review of 23 Nunavut-based proposals and made contact with each principal investigator regarding concerns and questions raised during our social-cultural review. The NAC also provided feedback to various NCP researchers on their plain language summary reports. The NAC's NTI co-chair attended the April 2012 NCP Management Committee meeting in Ottawa and both co-chairs attended the October 2012 MC meeting in Whitehorse.

Après une année d'inactivité, le Comité a repris ses travaux en novembre 2012. On a demandé à d'anciens et nouveaux membres de participer à l'examen socioculturel des propositions soumises au PLCN pour 2013-2014. Le Comité a réalisé une analyse approfondie de 23 propositions visant le Nunavut et a contacté chaque enquêteur principal au sujet des préoccupations et des questions soulevées pendant l'exercice. Les membres ont également donné de la rétroaction à divers chercheurs du PLCN sur leurs rapports sommaires en langage simple. Le coprésident représentant NTI a assisté à la rencontre d'avril 2012 du Comité de gestion du PLCN tenue à Ottawa, et les deux coprésidents ont participé à celle d'octobre 2012 à Whitehorse.

Key Messages

- Through its social-cultural review of all Nunavut-based NCP proposals, the Niqiit Avatittinni committee ensures northern and Inuit interests are being served by scientific research conducted in Nunavut.
- The NAC aims to serve as a resource to Nunavummiut for long-range contaminants information in Nunavut.

Messages clés

- En réalisant un examen socioculturel de toutes les propositions associées au PLCN au Nunavut, le Comité Niqiit Avatittinni veille à ce que les recherches scientifiques menées au Nunavut servent les intérêts des Inuits et du Nord.
- Le Comité fournit aux Nunavummiut de l'information sur les contaminants transportés sur de longues distances que l'on trouve au Nunavut.

Objectives

- Through its social-cultural review of all NU-based NCP proposals, the NAC ensures the interests of Nunavummiut are being addressed during research activities, including:
- Local or northern training and capacity building opportunities are pursued by Principal Investigators (PI) whenever possible;
- Inuit Qaujimajatugangit (IQ) is incorporated into the study design and process;
- Research results are appropriately communicated back to participating or nearby communities; and
- Meaningful community consultation is achieved.
- Assist researchers with conversion of NCP-funded contaminant research results into plain language that is understood by Nunavummiut;
- Assist and advise NCP-funded researchers on the relevant methods and distribution of communication materials to communities;
- By way of GN Health representatives on the committee, provide relevant NCP-funded contaminant research results to the Chief Medical Officer of Health (CMOH)
- Work in partnership with communities, researchers, governments, and Inuit organizations when undertaking community outreach related to communicating NCP research results;
- At the request of the Government of Nunavut, provide support to the CMOH and GN-Health in the development, implementation and follow up of nutrition recommendations, food policies, and public health messages resulting from NCP funded contaminants research; and
- Provide advice to communities on securing NCP funding for contaminants research.

Introduction

Multi-stakeholder Regional Contaminants Committees have been operating in each of the territories and Nunavik since the early 1990's and more recently in Nunatsiavut (2007). These committees were established to provide a forum to discuss regional contaminant-related issues among interested stakeholders. The committees provide a link to the Northern Contaminants Program (NCP) secretariat, which has been funding Northern long-range contaminants research since 1991, and foster partnerships among interested stakeholders when developing and delivering public messages concerning contaminants in relation to human health and the environment. The Niqiit Avatittinni Committee was struck in May 2000 and modelled after the NWT Environmental Contaminants Committee. Prior to May 2000, discussions related to contaminant research and issues concerning Nunavut were vetted through this latter committee. Since the NAC's inception, the annual social-cultural review of NCP proposals has been the committee's primary focus. Through its review of all Nunavut-based proposals, the committee ensures northern and Inuit interests are being served by scientific research conducted in Nunavut.

Activities in 2012-13

The following activities were undertaken by NAC in 2012-13:

- NTI co-chair attended April 2012 NCP Management Committee (MC) meeting and both co-chairs attended October 2012 NCP MC meeting

- Reinvigorated NAC by hosting face-to-face NAC meeting/teleconference November 21, 2012
- Expanded NAC membership to include representatives from DFO and GN-DOE
- Extensive changes made to NAC Terms of Reference to more succinctly reflect the committee's purpose and activities
- Hosted face-to-face NAC social-cultural review meeting Feb. 4-6, 2013
- Supported travel for Resolute Bay HTA representative to participate in 2013 social-cultural NCP proposal review meeting
- Completed social-cultural review of 23 Nunavut-based 2013-14 NCP proposals
- Provided detailed feedback via email to each PI regarding their respective proposal
- Provided feedback on plain language summary reports prepared by PIs for community dissemination
- Met with PIs Hayley Hung and Sandy Steffan January 28, 2013 to discuss ways to incorporate traditional knowledge into their respective projects

Capacity Building

Through its social-cultural review, the NAC continued to work towards building capacity in Nunavut by identifying opportunities in NCP proposals where researchers can incorporate Northern employment or provide mentorship to Northerners by collaborating with Inuit and Northerners in their project delivery.

NAC also supported the development of Inuit by supporting the participation of a Resolute Bay HTA representative at our social-cultural face-to-face meeting.

The NAC also worked to build capacity and increase knowledge of long-range contaminants among its membership and member organizations by making committee members aware of public lectures and workshops being given by NCP researchers.

Communications and Consultation

Throughout 2012-13, the NAC continued to work in a consultative manner with its members to determine its purpose, primary activities and when to solicit new members.

The NAC continued to work with Nunavut communities, organizations, and NCP researchers to ensure effective communications of NCP research results in Nunavut. As outlined above, this included assisting researchers with knowledge translation of their research results into plain language and advising on the relevant methods for distribution of communication materials to communities.

NAC continued to help PIs increase the profile and impact of their NCP work by identifying opportunities and venues for PIs to present their work to Nunavummiut.

By way of GN-Health representatives on the committee, the NAC provided relevant NCP-funded contaminant research results to the Chief Medical Officer of Health (CMOH).

In addition, the NAC co-chairs kept committee members aware of all outreach activities being undertaken by PIs in Nunavut and, whenever possible, invited members to participate in these activities for their professional development.

Traditional Knowledge

Through it social-cultural review, NAC identified opportunities where PIs can incorporate Inuit Qaujimajatugangit (IQ) into their respective NCP proposals. The NAC hopes to provide more guidance to researchers in this regard when the NTI-NCP Research in Nunavut fact sheets under development by NTI's research advisor are finalized.

Reports/Supporting Documentation

- November 21, 2012 meeting minutes
- 2013 Social-Cultural Review Summary Report
- Social-cultural review Feb. 4-6, 2013 meeting minutes
- NAC Terms of Reference

Nunavik Nutrition and Health Committee: Coordinating and Learning from Contaminants Research in Nunavik

Comité de la nutrition et de la santé du Nunavik : Coordination et apprentissage fondés sur la recherche sur les contaminants au Nunavik

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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, 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.

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. Il 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 de l'orientation et assure la liaison pour les 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.

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;

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.

- 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*.

- 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 2012-2013 year.

Activities in 2012-2013

In 2012-2013, the committee met face to face three times. Two of the meetings were held in Kuujjuaq, in June 2012 and November 2012. 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 and last two 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 2013-2014, 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 2012-2013:

Review of Research Proposals and Liaison with Researchers

In 2012-2013, 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 Security

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. (The committee also support few studies

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)

In November, the committee met with the Gina Muckle. The data collection for the next phase of the research starts this year. The researche updated the committee about this project. For the first time, they will look at affective development (internalizing problems) since there are now validated questionnaires that can be used because children are older.

The NNHC still believe that it will be important to make sure that people adequately understood the recommendations released in 2011. Since the proposal submitted to the NCP for 2012-2013 was not funded, the PHD is looking for other potential sources of funding for this project.

Results of the Contaminant-nutrient Interaction study in daycare center: Communication of the results

At the November meeting, the NNHC met by teleconference with the researchers to discuss about the long summary of their results submitted few months ago. The committee agreed to create a working group to advise and collaborate with the researchers during the development of their communication plan.

The committee decided to organize a first working session involving few members of the NNHC to discuss in depth of the results and their implications which was held in Québec on December 18, 2012. We discussed more in details the results previously presented to the committee. We also address the communication needs related to the findings. After discussions, we conclude that it would be relevant for the Génup team to make a communication proposal to NCP for 2013-2014 in order to be able to hold two working sessions with NNHC representatives and the research team to discuss results (actual and future) and to define their communication activities (what messages, when, to whom, by what means).

Lead Pellets Shots – Action Plan

In 2011, 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. The agent should be hired in 2013.

Meaning of Food Security for Nunavimmiut

The committee support Léa Laflamme's research project. She is studying community health at Laval University and is supervised by Dr Christopher Fletcher. 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.

At the November meeting, the committee met by teleconference with Léa Laflamme. She had just completed the validation of the results in Inukjuak. The NNHC was provided with her preliminary results. The researcher pointed out through qualitative interviews that social support has a significant positive impact on household food security which means that traditional way of sharing seems to be part of the solution to reduce food insecurity in the region.

The committee suggested her to do the active communication activities in the community of Inukjuak since the results may not be representative of the 14 communities. However, the NNHC believes those results can be quite helpful in helping us think about how to measure food insecurity in the region. They can also be interesting in the perspective of establishing which questions to include in Qanuippitaa to measure this topic. The final results will be communicated to the committee and Inukjuak community in 2013.

Monitoring spatial and temporal trends of environmental pollutants in maternal blood in Nunavik (Éric Dewailly and PHD project)

The NNHC continue to support Dr Eric Dewailly and the Public Health Department in this monitoring project. This year, the recruitment was easier then last year since a research nurse is now traveling in the villages to collect data.

To Build Food Security and to Promote Healthy Weights in Inuit Communities- Phase I

The research team provided a complete report of the results of the two food assessment done in Umiujaq and Kangiqsualujjuaq in the phase 1 of the Food security project (2011-2012). The funding for this project was not renewed by the PHAC for the phase 2. However, the NNHC believes some results of the research could be useful for further intervention to improve food security in Nunavik.

IRM project (Dave St-Amour, financed by CIHR)

Few years ago, Dr St-Amour's IRM project was not supported by NNHC because of its very invasive protocol. The research project was reviewed and simplified and it got funded by the CIHR for this year. The NNHC met with the PI, Dr. Dave St-Amour. This time, the project put the emphasis on MRI procedures (no other testing) and involves a 3 days stay in Montréal for participants. The NNHC met with the PI and we consider that our questions were well answered.

The committee decided to support this research project.

Nunavik Environmental-Health Officer

After 3 years trying to have the new position as Environmental Health Agent through PHAC, they got cut and informed the region that they were unable to open new positions. For now, it has been confirmed that the environmental health agent will be hired under provincial funds this year. The interviews for this agent who will take over with the coordination of the NNHC will be done this fall 2013.

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, Food Security Reference Group Meetings, Nutrition North Canada meetings, among others.

Tuberculosis project in Kangiqsualujjuaq (Dick Menzies)

Serge Déry and Jean-François Proulx regularly updated the committee about this issue. The tuberculosis outbreak in Kangiqsualujjuaq is a very unusual situation because many people got infected and many got sick in a really short period of time. This research project aims to look into further explanations about why this outbreak happened and try to identify factors that might be linked to that event, in order to be able to prevent other outbreaks in the future. Elena traveled to Kangiqsualujjuaq with Dr. Menzies to present the project to local leaders.

The NNHC suggested that any type of publication should first come to the PHD, the NNHC and the community. The committee also suggested rewording the consent form to make it easier to understand for participants. The NNHC wrote a support letter stating that the NNHC reviewed the research project and supports the project.

Berries project (Mélanie Lemire)

In collaboration with NRBHSS and other, the research team would like to work on a pilot project on berries. Last August, members of research team went berry picking in 3 communities for her actual work. Analysis on photochemical, vitamins, nutrients, omega 3 and fiber are underway. There was a great interest in the communities around berries. One of the main barriers to berries consumption seems to be the storage. The pilot project will be to facilitate year long access to berries to way to conserve them longer (ex: drying). The project will be done in collaboration with various regional partners including KRG, NRBHSS, NNHC, KSB and Biopterre.

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.

Core communications and capacity building and outreach in Nunatsiavut

Activités de communication de base, renforcement des capacités et sensibilisation dans Nunatsiavut

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Abstract

During 2012-2013, the Northern Contaminants Researcher (NCR) continued to communicate and educate Nunatsiavummiut about contaminants information, research activities, the benefits of wild foods and any health related issues that affect them on a daily basis. This communication took place using written documents, social media, posters, various media tools and through community feasts. Funding from the Northern Contaminants Program (NCP) also allowed the Nunatsiavut Health and Environment Research Committee (NHERC) to travel to five Nunatsiavut communities to inform residents about contaminate related issues, including ongoing and upcoming NCP research

Résumé

En 2012-2013, le chercheur sur les contaminants dans le Nord a continué de communiquer aux Nunatsiavummiut de l'information sur les contaminants, les activités de recherche, les avantages des aliments sauvages et diverses questions de santé qui les touchent au quotidien. Les renseignements ont été diffusés par l'entremise de documents écrits, des médias sociaux, d'affiches et de divers médias, et aussi à l'occasion de repas communautaires. Les fonds du Programme de lutte contre les contaminants dans le Nord (PLCN) ont aussi permis aux représentants du Comité de recherche sur la santé et l'environnement du Nunatsiavut de se rendre dans cinq collectivités du Nunatsiavut

projects. These meetings also allowed the NHERC to understand the needs and concerns of individual communities within Nunatsiavut. Contaminant results from the Inuit Health Survey (2008) were presented and discussed with Nunatsiavut communities through the NCR and the Director of Environment for the Nunatsiavut Government, Tom Sheldon. The NCR, through the Nain Research Center, also provided information about the benefits of traditional food while hosting community feasts that promoted country food, including seal, char, caribou, ducks and partridges to the residents of Nain. Furthermore, the NCR assisted many visiting researchers with work that is new or ongoing in the Nunatsiavut region, connecting researchers with residents.

afin d'informer les résidants des questions liées aux contaminants, y compris les projets de recherche en cours et à venir du PLCN. Grâce à ces rencontres, le Comité a pu cerner les besoins et les préoccupations des diverses collectivités de la région. Les résultats visant les contaminants issus de l'Étude sur la santé des Inuits (2008) ont été présentés aux collectivités du Nunatsiavut par le chercheur sur les contaminants dans le Nord et le directeur de l'Environnement du gouvernement du Nunatsiavut, Tom Sheldon. Le chercheur a aussi fourni, par l'intermédiaire du Centre de recherche de Nain, de l'information sur les avantages des aliments traditionnels en organisant pour les résidants de Nain des repas communautaires où étaient offerts du phoque, de l'omble, du caribou, du canard et de la perdrix. De plus, le chercheur a aidé nombre de collègues venus d'ailleurs à entreprendre des projets ou à poursuivre des travaux en cours dans la région du Nunatsiavut, en établissant des liens entre eux et les résidants.

Key Messages

- The Northern Contaminants Researcher communicated information about benefits of country food and encouraged Nunatsiavummiut to continue to consume country food, as the benefits outweigh any risk associated with the current contaminant load that the country food may contain. Results from the Inuit Health Survey were used as a tool to emphasize these benefits and risks.
- The NHERC traveled to the five Nunatsiavut communities, presenting to both the community and schools, to inform residents on past, current and upcoming research projects, especially those relating to contaminants. This allowed for questions and feedback from residents on contaminants and research projects of concern within their region. Areas of concern for most communities were contaminants in country food, including char, ringed seal and caribou, as well as the downstream effects of the Muskrat Falls Hydroelectric Development.

Messages clés

- Le chercheur sur les contaminants dans le Nord a communiqué de l'information sur les avantages des aliments traditionnels et encouragé les Nunatsiavummiut à continuer d'en consommer, puisque les bénéfices excèdent les risques qui pourraient être associés aux niveaux de contaminants. Les résultats de l'Étude sur la santé des Inuits ont servi à mettre en lumière les bénéfices et les risques.
- Le Comité de recherche sur la santé et l'environnement du Nunatsiavut s'est rendu dans cinq collectivités du Nunatsiavut afin d'offrir des présentations aux résidants et aux écoles et de les renseigner sur les projets de recherche passés, en cours et à venir, particulièrement au sujet des contaminants. Les résidants ont eu l'occasion de poser des questions et de formuler des commentaires sur les contaminants et les programmes de recherche touchant leur région. La plupart des collectivités se sont dites préoccupées de la présence de contaminants dans les aliments traditionnels, notamment l'omble, le phoque annelé et le caribou, ainsi que des

- The NCR continued to work with researchers traveling to Nunatsiavut to ensure they understand the concerns, culture and traditions of the Inuit in Nunatsiavut. Also, the NCR encouraged the researchers to become more involved within the communities, including hiring and training local residents, helping to build capacity within our region.

- The NCR worked in conjunction with the Inuit Research Advisor and the Research Outreach Coordinator to host community-wide traditional food events, which include a healthy traditional meal (caribou soup, char, seal) in the Nain Research Centre, while browsing through research and contaminant-related information.

- In partnership with the Research Outreach Coordinator, harvesters and researchers, the NCR collected and processed samples for NCP projects, building capacity and reducing costs for the research projects.

effets en aval du projet hydroélectrique de Muskrat Falls.

- Le chercheur a continué de collaborer avec des collègues venus d'ailleurs pour veiller à ce qu'ils comprennent les préoccupations, la culture et les traditions des Inuits du Nunatsiavut. Le chercheur a aussi incité ses homologues à s'associer plus étroitement aux collectivités, notamment en embauchant et en formant des résidants, afin de contribuer au renforcement des capacités dans la région.

- Le chercheur a travaillé conjointement avec le conseiller en recherche inuite et le coordonnateur de la diffusion de la recherche en vue de tenir des activités communautaires liées aux aliments traditionnels, notamment un repas équilibré (soupe de caribou, omble, phoque) au Centre de recherche de Nain, où l'on a aussi communiqué de l'information sur la recherche et les contaminants.

- En partenariat avec le coordonnateur de la diffusion de la recherche, les cueilleurs et d'autres chercheurs, le chercheur sur les contaminants dans le Nord a recueilli et traité des échantillons pour les projets du PLCN, ce qui a permis de renforcer les capacités et de réduire les coûts en vue de la recherche.

Objectives

The objective for the NCR through the NCP is to build communication and capacity, and continue to inform Nunatsiavummiut about contaminant information and research needs.

- Serve a core role on the Inuit Health Survey steering committee for Nunatsiavut, ensuring contaminant-related messaging is appropriate for communities and well understood by Nunatsiavummiut in the short, medium and long term
- Play a critical role in developing the Nain Research Centre as a local hub for contaminant related research in the region.
- Serve as liaison between Inuit and regional/national organizations dealing with contaminants, environment and human health research in Nunatsiavut
- Serve as ambassador for Nunatsiavummiut concerns related to contaminants, environment and health
- Maintain communication with Inuit Tapiriit Kanatami to ensure a national understanding of Labrador Inuit needs for communicating about contaminants, environment and human health issues
- Identify training possibilities with the Inuit Knowledge Center
- Provide assistance to Nunatsiavummiut for informed decision-making related to health and nutrition by continuing to provide information in the Avativut Newsletter regarding the nutritional content of various traditional foods and related recipes
- Play a critical role in the celebration of country foods and their benefits through the community freezer and associated youth outreach program in Nain centred on the harvesting and sharing of country foods.
- 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 community and facilitation of researcher-community relationships
- Provide guidance/advice to the Nunatsiavut Government Department of Lands and Natural Resources and Department of Health and Social Development with regards to contaminant 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
- Compile concerns and suggestions from each community on all issues related to contaminants
- Identify contaminants research needs and priorities in Nunatsiavut
- Provide information to the Nunatsiavut communities of Nain, Hopedale, Postville, Makkovik, and Rigolet about contaminant levels, including results from the Inuit Health Survey (2008), while emphasizing the benefit of country food.
- Participate as a board member for Nasivvik
- Participate on the Nunatsiavut Governments Research Advisory Committee, which reviews research proposals for the Nunatsiavut Region
- Participate as a member of the NCP's Management Committee
- Assists researchers who are coming to Nunatsiavut to conduct research to directly advise and assist in any planning so that any

work being done is culturally relevant to the Nunatsiavut Region

- In conjunction with the Hopedale Community government, inform resident as the status of the PCB clean up in their community

Introduction

The Inuit of Nunatsiavut have always depended on the land and sea for animals, birds, fish and plants to sustain them. Past and present research has shown that contaminants are in the traditional food that is consumed in Nunatsiavut. Presently, contaminant levels in country food have not been of major concern, but needs to be continually monitored as the level of industrial development increases, causing concern in Nunatsiavut.

Climate change is changing the way that Nunatsiavummiut have used the land, with reduced snow cover, thinner and less predictable sea ice and seasonally warmer temperatures. These changes have prevented Inuit in Nunatsiavut from using the traditional routes to access hunting areas and as a result, have affected the diet of Nunatsiavummiut. Furthermore, as a result of a reduction of the George River Caribou Herd and the provincially-imposed five year hunting ban, there has been a shift in diet from caribou to seal and char in Nunatsiavut.

Clean up of the Poly-Chlorinated Biphenyls (PCB's) continues at the abandoned early-warning radar station in Hopedale, Nunatsiavut. Contaminated soil has been removed and shipped out of Hopedale. The staffs of the Environment Division of the Nunatsiavut Government work closely with the AngajukKâk of Hopedale, Wayne Piercy, to ensure that an effective clean up process is taking place. The Nunatsiavut Government has assisted the community with advice about the traditional food (rock cods, sculpins, and seashells) and ongoing monitoring will be important.

The Nunatsiavut Health, Environment and Research Committee has played a large role in providing information to its beneficiaries about the benefits and risks of country food, and ongoing research in Nunatsiavut. The Northern Contaminants Researcher works closely with outside researchers, Inuit Tapiriit Kanatami, NCP, universities and the five Inuit communities to ensure that scientific research is communicated to the people in a proper and culturally relevant way. The NCR, as a member of the committee, keeps members informed about ongoing issues that affect the Inuit in their daily lives so that informed decisions are made by all parties involved.

Activities in 2012-2013

Communication

Through the Tugâpvik Nunatsiavut Newsletter, a publication used by all departments within the Nunatsiavut Government to relay information back to beneficiaries in the region, information has been disseminated to Nunatsiavummiut. The NCR has contributed to the newsletter by writing articles with information about contaminants and the benefits and risks associated with country food, to allow residents to make better informed decisions in their daily lives. The Newsletter is published in English and Inuttitut.

The Northern Contaminants Researcher used the media (OKalaKatiget Society Regional Communication Broadcast Center) to inform communities of activities that are being conducted in our region, so that residents were aware of any research activities in the region before and after each research project is started and completed.

Results from a variety of research projects, including NCP funded projects that the NCR participated in, were presented in both poster and oral presentations at ArcticNet's Annual Scientific Meeting in Vancouver, during December 2012. The NCR was present to answer questions and provide further information about contaminant research in Nunatsiavut. Posters from the meeting are displayed in the Nain

Research Centre to allow residents to view the information at their leisure.

Contaminant related information has been prepared by the NCR for the newly developed Nain Research Centre website, which provides a description of what contaminants are, how they get into the food system and the current status of all contaminant related research projects.

Participation in Research Projects

The Northern Contaminants Researcher continues to collaborate with researchers coming to Nunatsiavut with ongoing and new research. The NCR assisted with open houses, disseminating results of research projects to the communities, collection of samples for analysis as well as the distribution of research related books, posters and pamphlets to Nunatsiavummiut. The NCR was able to work with youth and harvesters from the Youth Outreach Program to help collect and process samples for a variety of contaminate-related research projects, building capacity and educating individuals on the research process and overall goal of the projects.

Nunatsiavut Health and Environment Research Committee

The Nunatsiavut Health and Environment Research Committee continued to tour the Nunatsiavut communities of Nain, Hopedale, Postville, Makkovik and Rigolet to disseminate research and contaminated related information as well as get concerns and feedback from local residents. This diverse committee consists of:

- Katie Winters, (NG) Northern Contaminants Researcher, committee co-chair
- Ed Tuttauk, (NG), Ordinary Member (Upper Lake Melville), committee co-chair.
- Tom Sheldon, (NG) Director of Environment
- Carla Pamak, (NG) Inuit Research Advisor
- Michele Wood (NG) Research/Evaluator
- Rodd Laing (NG) Environmental Assessment Manager
- Eric Loring (ITK) Senior Environmental Researcher

Members of the committee travelled the coast in March to present information about research projects, hear and listen to community members concerns about any environmental and health concerns and to discuss the benefits of eating country food. The committee also visited the high school grades in each community to involve youth in research, to inform them about the benefits of country food and to talk about contaminants, including Persistent Organic Pollutants, mercury and the difference between long range and local contaminant sources.

Inuit Health Survey Contaminant Assessment in Nunatsiavut – Results Release

In November 2012, the Northern Contaminants Researcher, together with the Director of Environment for the Nunatsiavut Government, travelled to all Nunatsiavut communities to publically release the results of the contaminants assessment within the Inuit Health Survey (after a lot of work through the Steering Committee). During this tour, public meetings were held along with meetings with town councils as well as health workers (both Nunatsiavut Government and Provincial). Radio interviews were also conducted on the local radio station. In the overall context of public health, there were several key messages delivered as a result of this research and the guidance of the Steering Committee. These included (but are not limited to) the following:

- Country foods are great sources of nutrients that are vitally important to Inuit health;
- Contaminant exposure levels for Inuit in Nunatsiavut are generally below guideline levels of concern;
- Inuit in Nunatsiavut (especially young people) should continue eating country foods because the health benefits are greater than the risks.

The overall release of the contaminants assessment portion of the Inuit Health Survey in November 2012 was an extremely positive event within Nunatsiavut. It re-affirmed the benefits of country foods while placing contaminants within an overall public health context.

Nasivvik Center for Inuit Health and Changing Environments

The Nasivvik Center is a multi-disciplinary research and training center that is funded by the Canadian Institutes of Health Research-Institute for Aboriginal Peoples Health. The Northern Contaminants Researcher is a Board member for the Nunatsiavut Region. The focus for this program involves building capacity in Inuit health research through training support and initiatives in key environmental health areas that are very important to the Inuit regions in the Canadian Arctic/sub Arctic. The NCR has taken part in decision making by teleconference and face-to-face meetings regarding funds that are allocated to enhance training opportunities for the Inuit.

Nunatsiavut Government Research Advisory Committee

The NCR continues to participate on the Nunatsiavut Government Research Advisory Committee to review research proposals that are relevant to the Nunatsiavut Region. This is a chance to voice concerns as a committee to ensure that all proposals are culturally appropriate, valuable and that other researchers are not already completing similar research projects. This committee provides an opportunity to represent Nunatsiavut priorities in research.

ArcticNet Integrated Regional Impact Study for Nunavik and Nunatsiavut

The NCR traveled to Kuujjuaq with staff and executive council members of the Nunatsiavut Government to meet with members of the Kativik Regional Government, Makivik, ArcticNet and a variety of other partners for the launch of the ArcticNet Integrated Regional Impact Study Report in January 2013. This provided an opportunity to have discussions regarding contaminants and research processes with researchers and members of government from other regions.

Expected Project Completion Date

Projects are ongoing in the Nunatsiavut Region

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Chan, L. Inuit Health Survey. (August 2011), Department of Indian and Northern Affairs Ottawa, ON. ISBN: 0-320-7. PP:271-280

Coordination, participation and communication: evolving Inuit Research Advisor responsibilities in Nunatsiavut for the benefit of Inuit and their communities

Coordination, participation et communication : évolution des responsabilités du conseiller en recherche inuite du Nunatsiavut, au bénéfice des Inuits et de leurs collectivités

- **Project Leader:**
  Carla Pamak, Nunatsiavut Inuit Research Advisor, Nunatsiavut Government
- **Project Team Members and their Affiliations:**
  Tom Sheldon, Director of Environment, Nunatsiavut Government, Nain, NL.
  Katie Winters, Northern Contaminants Researcher, Nunatsiavut Government Nain, NL

Abstract

The Inuit Research Advisor for Nunatsiavut continues to serve as the first step in a more coordinated approach to community involvement and coordination of Arctic science and represents a new way of knowledge sharing and engagement of Inuit in Arctic science. The Nunatsiavut Government (NG) encourages researchers to consult with Inuit Community Governments in the five Nunatsiavut communities (Rigolet, Makkovik, Postville, Hopedale and Nain) as well as NG departments in developing more community based research proposals. Comprehensive reviews of proposals are initiated involving appropriate NG departments and Inuit Community

Résumé

Le conseiller en recherche inuite du Nunatsiavut poursuit son mandat, constituant la première étape d'une approche coordonnée en matière de participation et de coordination communautaires dans le domaine des sciences de l'Arctique. Il propose un nouveau moyen de diffuser les connaissances et de mobiliser les Inuits en ce qui concerne les sciences de l'Arctique. Le gouvernement du Nunatsiavut incite les chercheurs à consulter les gouvernements des cinq collectivités inuites du Nunatsiavut (Rigolet, Makkovik, Postville, Hopedale et Nain) ainsi que ses ministères en vue d'élaborer de nouvelles propositions de recherche communautaire. L'examen complet

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.

des propositions est effectué par les ministères concernés, les administrations des collectivités inuites et les sociétés communautaires inuites. De concert avec ses homologues des autres régions inuites du Canada, le conseiller en recherche inuite du Nunatsiavut s'efforce de promouvoir une nouvelle façon de diffuser les connaissances et de mobiliser les Inuits 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 Inuits et les changements environnementaux.

Key Messages

- The IRA co-manages the 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 over 30 researchers this fiscal year. This year the IRA has chaired 8 NGRAC meetings
- The IRA, along with other members of the Nunatsiavut Health and Environment Review committee, traveled to the five Nunatsiavut communities to meet with high school students and community members to inform them of research projects relating to contaminants, environment and health. The NHERC also reviewed NCP funded proposals for the region.
- 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.

Messages clés

- Le conseiller en recherche inuite est cogestionnaire du Centre de recherche de Nain, faisant office de premier point de contact pour tous les chercheurs qui mènent des travaux au Nunatsiavut et qui doivent communiquer avec le gouvernement du Nunatsiavut ou obtenir son aide.
- Le conseiller est le président et l'administrateur du Comité consultatif de la recherche du Nunatsiavut. Il a échangé avec plus de 30 chercheurs durant le présent exercice. Cette année, il a également présidé huit réunions du Comité consultatif.
- Le conseiller et d'autres membres du Comité d'examen de la santé et de l'environnement du Nunatsiavut se sont rendus dans cinq collectivités du Nunatsiavut afin de rencontrer des élèves du secondaire et des membres des collectivités pour les informer des projets de recherche concernant les contaminants, l'environnement et la santé. Le Comité d'examen a aussi passé en revue les propositions financées par le PLCN pour la région.
- Le conseiller a joué le rôle d'agent de liaison, de contact et d'assistance pour ce qui est des projets de recherche menés au Nunatsiavut. Entre autres, il a mis les chercheurs en rapport avec les personnes ou organisations pertinentes, par exemple les

- The IRA has also served as 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.

ministères du gouvernement du Nunatsiavut et les administrations des collectivités inuites du Nunatsiavut, et il a fait des suggestions quant aux propositions et aux plans de recherche.

- Le conseiller assure également la liaison avec des partenaires comme l'Inuit Tapirit Kanatami, le Conseil circumpolaire inuit (Canada), les administrations des collectivités inuites et les sociétés communautaires inuites du Nunatsiavut, l'Année polaire internationale, les chercheurs, les étudiants et divers organismes.

Objectives

- Improving the coordination and operation of the Nain Research Center
- Continued development and management of the Nunatsiavut Government research consultation process.
- Direct engagement (through implementation) in several specific regionally-led research programs, rather than solely focusing on overall research coordination and facilitation. This includes evaluation of the community freezer program in Nain as well as its expansion to other Nunatsiavut communities.
- Improve the delivery of health messaging in the region by working directly with the Northern Contaminants Researcher, the Nunatsiavut Department of Health and Social Development and Labrador Grenfell Health to ensure appropriate health messaging related to the environment, especially messages related to valued country foods.
- Place NCP activities within the larger scope of research in the Canadian North, through formalizing links with other research initiatives. The IRA will also serve as a link between NCP, ArcticNet, Nasivvik, and the Nunatsiavut Government, in addition to Inuit Tapirit Kanatami (ITK) and Inuit Circumpolar Council (ICC) Canada.
- Together with the IRA coordinators, and ITK and ICC Canada, ensure that projects funded by the Northern Contaminants Program (NCP), ArcticNet and Nasivvik Centre have addressed local realities and concerns, integrated Inuit knowledge and undergone sufficient and meaningful consultation with Inuit.
- Support for the Nunatsiavut Health and Environment Research Committee (NHERC), of which the IRA is a member, as well as ongoing support for key NCP communicators.

Introduction

The Inuit Research Advisor provides guidance and recommendations related to Inuit needs, priorities, policy development, and research to NCP, ArcticNet and Nasivvik. The newly developed Nain Research Centre is quickly becoming a hub for community and regionally-owned research in Nunatsiavut, including contaminants related research, and requires operational coordination. Efficient coordination is resulting in enhanced benefits for community members with respect to research. The Inuit Research Advisor also focused on internal capacity building by participating more directly and actively in regionally-led research initiatives. Finally, research in the region (including research related to contaminants) has increased. To help with communication, we are in the final stages of developing a Nain Research Centre website that will result in greater awareness of research and a better understanding of research results generally, and contaminants related issues, specifically.

Activities for 2012-2013

- Managed the Nain Research Center and served as chair of the Nunatsiavut Government Research Advisory Committee, making contact with all researchers, students and organizations visiting or wanting to conduct research in the Labrador Inuit Land Claims Area.
- Along with the IRAs in the other regions participated in numerous teleconferences and attended a training/workshop in Iqaluit.
- Attended Arcticnet's Inuit Advisory Committee teleconferences.
- Participated in the social-cultural review of NCP proposals, along with members of NHERC for Nunatsiavut.
- Reviewed proposals under Health Canada's, Climate Change and Health Adaptation program.
- Actively participated in several specific regionally led research programs, including evaluation of a pilot community freezer program in Nain, with associated NCP contaminants research.
- Attended ArcticNet's, Annual Scientific Meeting in Vancouver where the IRA co-authored 3 presentations (two oral and one poster)
- Numerous local presentations to a variety of audiences including community public meetings, meetings with organizations such as Nutrition North Canada and the Labrador Institute of Memorial University.

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.

Expected Project Completion Date

This is an on going project.

Ensuring capacity building, synthesized contaminants messaging and communications of research in the Inuvialuit Settlement Region

Renforcement des capacités, diffusion de messages synthétisée sur les contaminants et communication des recherches dans la région désignée des Inuvialuit

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Abstract

The Inuit Research Advisor (IRA) completed two projects and all mandatory activities as proposed for the 2012-13. These projects included the development and distribution of two bilingual Inuvialuit Research Newsletter (IRN) and one community visit to each of the six Inuvialuit communities. Mandatory activities include continued presence and participation in the NWT Regional Contaminants Committee and scheduled attendance at the NCP Annual Results Workshop (ARW), which was cancelled this year due to low registration numbers. In addition to these NCP related duties; the IRA maintained involvement in community based research and training through the

Résumé

Le conseiller en recherche inuite a mené à bien deux projets ainsi que toutes les activités obligatoires proposées pour 2012-2013. Les projets consistaient à préparer et à distribuer deux numéros bilingues du bulletin d'information sur la recherche inuvialuit (Inuvialuit Research Newsletter), ainsi qu'à se rendre dans chacune des six collectivités inuvialuit. Les activités obligatoires étaient quant à elles les suivantes : assurer une présence et une participation continues au Comité régional des contaminants des Territoires du Nord-Ouest, et prendre part comme prévu à l'atelier annuel sur les résultats du Programme de lutte contre les contaminants dans le Nord (PLCN), lequel a été

Health Canada Climate Change and Health Adaptation Program for First Nations and Inuit Communities.

The two editions of the IRN were completed in January and March of 2013 and distributed as a package of two in May 2013 to all six Inuvialuit communities and to those who live outside of the region with a valid mailing address. Inuvialuit translations for this year's editions were done by Emily Kudlak of Ulukhaktok for the Uummarmiutun dialect and Fred Wolki of Tuktoyaktuk for the Siglitun dialect. Contributors to the Newsletter included researchers Nikolaus Gantner, Chris Burn, Zoe Todd, and Lisa Loseto. Organization updates were submitted by ICC-Canada, Inuit Tapiriit Kanatami and Nasivvik.

The community tour took place from September-December of 2012, with meetings held in Ulukhaktok from (September 12-14), Paulatuk (September 18-21), Sachs Harbour (October 9-11), Aklavik (October 22-24), Tuktoyaktuk (October 29-31) and Inuvik on (November 9). Each community visits featured a lunch or dinner, a presentation from the IRA, breakout sessions and door prizes. Topics highlighted in each event included contaminants concerns, community based research, training needs and research processes (licensing reviews, current projects in communities, ethics, and participation).

The NWT RCC met in Yellowknife from February 20-21, 2013 at the Waldron Building. This meeting was attended by regional representatives from Inuvialuit, Gwich'in Métis Nation, Tlicho, and Dene Nation. Government and national representatives included Stanton Territorial Health Authority, Northern Contaminants Program, Aurora College and Inuit Tapiriit Kanatami. In the two days, 21 proposals were reviewed by the Committee and social and cultural recommendations made to each one.

annulé cette année en raison du petit nombre d'inscriptions. Outre ces fonctions liées au PLCN, le conseiller a poursuivi sa participation à la recherche et à la formation communautaires par l'intermédiaire du Programme de Santé Canada sur le changement climatique et l'adaptation du secteur de la santé pour les communautés du Nord, des Inuits et des Premières Nations.

Les deux numéros du bulletin ont été produits en janvier et en mars 2013, puis distribués ensemble en mai 2013 dans les six collectivités inuvialuit ainsi qu'aux personnes de l'extérieur de la région qui avaient une adresse postale valide. Cette année, la traduction en dialecte uummarmiutun a été faite par Emily Kudlak, de Ulukhaktok, et celle en dialecte siglitun par Fred Wolki, de Tuktoyaktuk. Les chercheurs Nikolaus Gantner, Chris Burn, Zoe Todd et Lisa Loseto ont collaboré au bulletin, tandis que le Conseil circumpolaire inuit (Canada), l'Inuit Tapiriit Kanatami et Nasivvik ont soumis des mises à jour concernant leur organisation.

Les visites dans les collectivités se sont déroulées de septembre à décembre 2012. Des réunions ont été tenues à Ulukhaktok (12 au 14 septembre), Paulatuk (18 au 21 septembre), Sachs Harbour (9 au 11 octobre), Aklavik (22 au 24 octobre), Tuktoyaktuk (29 au 31 octobre) et Inuvik (9 novembre). À chacun des endroits, on a organisé un dîner ou un souper, le conseiller en recherche inuite a fait une présentation, on a tenu des séances en petits groupes et des prix de présence ont été offerts. Parmi les sujets abordés, notons les préoccupations entourant les contaminants, la recherche communautaire, les besoins de formation et les processus de recherche (examens des permis, projets en cours dans les collectivités, éthique et participation).

Le Comité régional des contaminants des Territoires du Nord-Ouest a tenu une rencontre les 20 et 21 février 2013 à l'immeuble Waldron, à Yellowknife. L'événement a réuni des représentants régionaux des Inuvialuit, des Gwich'in, de la Nation métisse, des Tlicho et des Dénés. Les représentants gouvernementaux et nationaux provenaient quant à eux de la Stanton Territorial Health Authority, du PLCN, du Collège Aurora et de l'Inuit Tapiriit Kanatami. Pendant ces deux jours, le Comité a passé en revue 21 propositions et formulé des recommandations sociales et culturelles sur chacune.

Key Messages

- Inuvialuit communities appreciate having the Newsletter to keep them up to date on current contaminants and other related research happening in the region. Many people say without the IRA position, none of this information would likely be available to communities.
- The Community tour is the best way to hear about contaminants information or research in general as it provides the opportunity for forum and discussion amongst many segments of the community, from elders to youth to frontline workers.
- Working with regional translators is time consuming and thus the Newsletter is not able to come out as quickly as before, but adds great value to the publication as Inuvialuit fluent in Inuvialuktun can practice and teach youth using the Newsletter as a resource.
- Contributions to the Newsletter are gaining momentum, with researchers and national organizations keen to utilize the publication as a means to communicate with northerners and allowing their work to be published and featured to a regional audience.

Messages clés

- Les collectivités inuvialuit aiment recevoir le bulletin parce qu'il les tient au courant des recherches sur les contaminants et d'autres sujets connexes qui sont réalisées dans la région. Beaucoup de gens affirment que, sans le bulletin, les collectivités n'auraient probablement pas accès à ces renseignements.
- Les visites dans les collectivités constituent le meilleur moyen pour les habitants de se renseigner sur les contaminants ou la recherche en général. En effet, elles permettent à de nombreux segments de la population (aînés, jeunes, travailleurs de première ligne) de prendre part à des discussions sur ces sujets.
- La collaboration avec des traducteurs de la région prend du temps. Cela retarde la publication du bulletin, mais ajoute une grande valeur au produit, puisqu'il offre ainsi aux Inuvialuit qui connaissent l'inuvialuktun l'occasion de pratiquer ce dialecte et de l'enseigner aux jeunes.
- Le bulletin suscite un intérêt croissant chez les chercheurs et les organisations nationales, qui s'en servent pour communiquer avec les habitants du Nord et faire connaître leurs travaux dans la région.

Objectives

- Keep Inuvialuit engaged and informed of current research happening in the ISR.
- To engage Inuvialuit in discussions about research and training via community visits.
- To engage researchers, local people and organizations in research happening in the ISR through contribution to the Newsletters.
- Continue with participation in NCP related committees and events.

Introduction

Inuvialuit have been working with the Northern Contaminants Program (NCP) since the organization was first established the late1980's and early 1990's. From the mid to late nineteen nineties, Billy Archie of Aklavik was the Regional Contaminants Coordinator. Then in the mid to late 2000's IRC hired researcher Barbara Armstrong in maintaining the level of activity with the Program through her project "Monitoring our Mothers Study" with a position then called Health and Environment Research Coordinator (HERC). In 2004, Barbara approached Aurora College Natural Resources Technology Program (NRTP) seeking an Inuvialuk beneficiary interested in working with environmental issues in the region. Of the students in the class, Shannon O'Hara showed interest and took advantage of the opportunity to become involved with Inuvialuit Regional Corporation's mentoring program. Soon after, Shannon began attending the NWT ECC (now RCC) monthly teleconferences and ArcticNet's first annual meetings. In 2005, IRC then hired Catherine Cockney to take over the position, while continuing to mentor Shannon for the year.

In 2006, Shannon graduated from the NRTP and was offered the HERC now called the IRA position Shannon worked as the HERC/IRA in 2006-07 until 2007-08 then Shannon took a year off for maternity leave. During this year off, Shannon's position was filled by Jonathon Michel. Then in 2008-09 and 2009-10 once Shannon was back in the role, the HERC position name was dropped and the title was known solely as the IRA across all Inuit regions in Canada. In 2010-11 Shannon went on maternity leave for the second time and was briefly replaced by Tamara Hansen and Jennifer Johnston. Shannon came back to the position for the 2011-2012 and has been resumed work for the 2012-13 and 2013-14.

Context

The purpose of the Inuit Research Advisor (IRA) position is to be the link between researchers and communities. The IRA in the Inuvialuit Settlement Region (ISR) conducts ongoing communication and outreach projects that inform Inuvialuit of current research, contaminants messaging and help to build capacity in the region. Another responsibility that IRA remains active in is assisting researchers in the region through consultation and planning meetings. As part of the IRA role in NCP, the IRA produces the Inuvialuit Research Newsletter and other communication products and also keeps people informed. The IRA also conducts a yearly community tour to each Inuvialuit community to hold workshops and special meetings to engage Inuvialuit and front line workers. In addition to all this, the IRA has been an active member of the NWT Regional Contaminants Committee to take part in the Social and Cultural Review and the development or review of key contaminants findings and messaging.

Scope

Over the years, the positions funded through the Northern Contaminants Program have evolved as was outlined in the Introduction section. As the IRA position has evolved so has the scope of the NCP mandate and the work the Organization funds. Some of the changes that have occurred include the main audience, the messages and the methods of communicating these messages. When the IRA position was first established, NCP was focused on delivering these messages to women of child bearing age and health care professionals about the basics of contaminants (sources, food chains, food webs, etc). Today, the main audience is frontline workers so that they can keep Inuvialuit people informed about the key findings of the various contaminants work that the NCP has done on human health and environmental monitoring. The contaminants messaging in the Inuvialuit region has always remained "country foods, still healthy, safe and strong" and "the benefits of country foods outweigh the risks of contaminants". Today with new results from studies such as the Inuit Health Survey have shown that there are some health advisories but that is mainly for marine mammals such as beluga, and large older fish. IRC and the IRA still promote the consumption of country food and suggest that people eat a balanced diet of good country food and healthy store bought food.

Rationale

Inuvialuit people have always been concerned with and feel it is important to monitor the health of our animals and human population against new and emerging contaminants. Initial work with the NCP focused on learning about contaminants and how to communicate about them to Aboriginal populations in the North. The next step was to develop materials to inform Northerners of contaminants sources and pathways and teach Northerners how to live with contaminants in everyday life and to make informed choices in their diet.

Relationship to prior work related to;

The regional contaminants coordinator position has steadily evolved in the Inuit Research Advisor position. As of 2006, there were four IRA's across Canada located in each Inuit region, Inuvialuit Settlement Region, Nunavut, Nunavik (Northern Quebec) and Nunatsiavut (Northern Labrador). The focus of the position has changed from strictly contaminants communication to also be a resource for researchers and communities. The position now entails communications about research ethics, licensing, research approvals, capacity building, and community based research and monitoring.

IRA's

Since the IRA position was established, steadily the landscape of research and community involvement in Inuit regions has improved. As more researchers and community members are aware of the position, the more relationships and partnerships are built that benefit Inuit communities. The emergence of the position has also created opportunities for community members from each region to get involved in research projects at all levels. The continued presence of IRA's in each region helps to keep Northerners informed of research from various organizations while also ensuring appropriate level of consultation, benefit and involvement of Inuit communities in leading or shaping scientific studies either through the integration of traditional knowledge or the training of new northern-based scientists.

Communities

Inuvialuit communities are much more aware their place in research, especially in their home region. The IRA has worked hard to inform them of their rights in research, how to best approve project that are of benefit to them and how to apply for and receive funding from various government programs to do their own research.

Researchers

With the promotion of the IRA position at ArcticNet, IPY and NCP meetings, more researchers are aware that they can come to IRA's for guidance and consultation when doing communication exercises in Inuit communities. The numbers of researchers now send IRA's draft proposals to review, progress updates and invitations to get involved in their research. Researchers are finding that they are able to build relationships with community members much more meaningfully now that they have a point of contact in the region of study to help them through the lines of regulation, licensing and approvals needed to conduct research within Inuit regions.

Other

In addition to the Programs that fund the IRA position, IRA's are now being approached by many other researchers that need assistance when planning a project in the North. IRA's are now also being utilized by Industry, Independent researchers and Inuit researchers from the South to help guide them in starting up projects or get reviews underway.

Past NCP projects

- **Dietary Survey** (2005)
- **Cook books series** (2006-2007)
- **Newsletters** (2008-2013) First newsletters in 2008 (4 editions), 2009 (4 editions), 2010 (4 editions), 2011 (2 English/Inuvialuktun translated editions), 2012 (2 English/Inuvialuktun translated editions) and 2013 (2 English/Inuvialuktun editions)
- **Tours + Cook show** (2004-2007)

Current NCP projects

- Inuvialuit Research Newsletter (2011-2013)

  Research updates from ISR, NWT, and National, organizational updates, project updates from Community Based Monitoring, contaminants information, IRA updates, country food recipes, what's it contest, cross word puzzles.

- Community Tours (2006-2013)

  Each community visit includes information and discussions on IRA position, funders, education and training, contaminants, research concerns, and features prizes and a meal. The IRA also holds separate organizational side meetings to inform community corporations, schools, hamlet office and HTC's of current work.

Past priorities were focused on contaminants messaging and dietary advice. Present priorities are now more focused on HQIP and HQP as well as other. Now of IRA training, capacity building, making the IRA a first point of contact, IRA guide, other work involvement (sub-committees, networks etc)

Activities in 2012-13 A description of NCP funded (and related) activities.

Capacity Building

- IRA training in Iqaluit (May 2012)

The Inuvialuit region's Inuit Research Advisor assisting in conducting a training workshop for all IRA's in Iqaluit, NU in May 2012. The workshop was held at Nunavut Tunngavik Incorporated from May 29-30. This workshop was lead by ITK and ICC- Canada IRA Coordinators, Kendra Tagoona and Pitsey Moss-Davies, Nasivvik Coordinators, Kristeen McTavish and Shirin Nuesslein, with the training and mentoring done by IRA Shannon O'Hara. The workshop featured a presentation of best practices, a review of the newly developed IRA Guide and an opportunity to share information on how to communicate with the scientific community and northern Inuit communities. Another workshop is planned for June 2013.

Community based monitoring projects (CBM workshop, December 2012)

The Inuvialuit IRA first became involved with Community-based Monitoring Programs in 2010. The IRA first became involved in the Health Canada Climate Change and Health Adaptation Program as a reviewer of Inuit regional proposals. While a member of this committee the IRA learned of other programs offered such as CIMP-NWT and the NCP CBM Program. Since then, the IRA has promoted all of these Programs in all Inuvialuit communities through community visits and the distribution of funding guides. In 2011, the IRA took a more hands on approach and assisted the community's of Inuvik and Paulatuk submit to all three programs.
In this year, both communities, through their Hunters and Trappers Committees were successful in receiving funding for projects led

by each organization. Inuvik HTC received funding from Health Canada in 2012 for a traditional knowledge project on beluga whales and fish, while Paulatuk received funding from both NCP and Health Canada for a beluga study.

Both these project led to a final workshop held in Inuvik called the Community Based Monitoring Knowledge Sharing Workshop. This workshop was hosted by the Inuvik Hunters and Trappers Committee in partnership with Inuvialuit Regional Corporation held a Community Based Knowledge Sharing Workshop in Inuvik, NT from December 5-7, 2012 NT at the Midnight Sun Recreation Complex in the second floor Curling Club Lounge. The workshop had 3 main purposes including;

- Informing Inuvialuit of research funding opportunities via presentation from the funders themselves.
- Allowing existing community based monitoring and research projects to share results from last year with other communities.
- Inform community members about to how to undertake community based projects (seeking concern from the community level, finding funding, securing partners, planning activities, writing proposals, and reporting results).

Invited guests included representatives from 3 of the major northern research funding organizations and 5 of the 6 Inuvialuit communities (Aklavik, Inuvik, Sachs Harbour, Ulukhaktok and Tuktoyaktuk). Paulatuk representatives were not able to make it. From the funding programs in person attendees included, Scott Tomlinson of the Northern Contaminants Program and Claire Marchildon from CIMP NWT. We also had Megan Duncan of the Health Canada Climate Change and Health Adaptation program call in from Ottawa. Inuvialuit attendees included, Lisa Rogers, Michelle Gruben, Charles Gruben, Laverna Klengenberg, Richard Notaina, Lawrence Rogers, Ryan Lucas, Mary Ruth Meyook, and Sharon Green. We also had a guest researcher, Shirley Roburn come and share her academic perspective.

The workshop was held in three days;
Day 1 included an introduction and opening remarks by Nellie J. Cournoyea. The first day was the day of presentations made my funders and community members.

Day 2 included more presentations and information sharing. Following this exercise community (s) broke out into groups and began brain storming ideas and concerns from the community level that could lead to projects.

Day 3 was learning about research licensing, ethics, proposal templates, and how to communicate back results of research.

- Health Canada Training proposal (June 2012-May 2013)

This year in addition to receiving NCP, ArcticNet and Nasivvik funding, the IRA applied to and was successful in receiving Health Canada funding for a project called "Inuvialuit Capacity Building and Training Year". This project, worth $60,000 was intended to support Inuvialuit to gain essential training that they need to become involved in community based research or employment through research. This was accomplished through direct partnership with Aurora College in Inuvik through a sub-agreement where to College would implement the funding and deliver the courses to each of the six Inuvialuit communities free of charge to Inuvialuit beneficiaries.

This project has six phases:

Phase 1: January-March 2012
During this phase, the IRA worked on amending the proposal to better fit the Health Canada Program.

Phase 2: March-June 2012
The IRA began consulting with Aurora College staff regarding a possible partnership. Meetings went well and planning commenced. Met with

Doug Robertson, Anne Church (Tara Gilmore) and Marja Van Nuyenheizen.

Phase 3: June-August 2012

At this point, the IRA now had to communicate the project with regional communities. This was done via e-mail and teleconferences. Then, the IRA developed a training signup sheet and short registration form so that Inuvialuit community organizations could begin intake of names of interested individuals.

Phase 4: August-October

Names of interested individuals begin to come into IRC. The IRA then consulted with IRC Human Resources for possible partnership. An agreement was made to share information of trained individuals to be inputted into the HR Database for future reference.

Phase 5 October 2012-December 2012

During this final phase, the IRA compiled all names and presented that to Aurora College for planning. The IRA then did some community consultation to secure venue, and book Instructors time.

Phase 6: January 2012-March 2013

During this phase, IRC and Aurora College have signed a contribution agreement and begin booking travel for the Instructors to the communities. Next, training takes place on a rotational basis. The Instructor will visit one community for 1 week periods depending on how many times the course has to be offered to fill the need. Once one community is complete the Instructor moves on the next and the next Instructor comes in. Communities were serviced with coastal communities first and Delta communities second. Courses ran until April 2013.

Results of First Aid and Firearms courses:

Safety Training Beaufort-Delta via Health Canada funding	
Paulatuk-First Aid	**Paulatuk-FAC**
Illasiak, Stephanie	Ruben, Sharon
Ruben, Ruby	Ruben, Christopher
Ruben, Robert	Ruben, Arnold
Ruben, Susan	Ruben, Jason
Ruben, Angela	Esagok, Douglas
Thrasher, Frida	Ruben, Peter
	Wolki, Frank
	Ruben, Marcus Jr.
	Kudlak, Norman Jr.
	Ruben, Richard Sr.
	Ruben, Albert
	Ruben, Arnold Jr.
	Ruben, Corey
	Ruben, Francis
Sachs Harbour-First Aid	**Sachs Harbour-FAC**
Keogak, Andrea	Keogak, John Sr.
Gully, Kevin	Esau, Warren
Kaslak, Albert	Lucas, Samantha
Elias, Yvonne	Lucas, Steven
Esau, Corey	Carpenter, Richard
Wolki, Kyle	Amos, Vernon
Ulukhaktok-First Aid	**Ulukhaktok-FAC**
Malgokak, Tammy	Akoaksion, Jerry Sr.
Ogina, Joanne	Alanak, Lily
Kudlak, Zakkery	Kuptana, Joseph
Memogana, Chad	Alikamik, Diane
Kataoyak, Florence	Joss, Stephen
Inuktalik, Matthew	Ovilok, Lori
Kagyut, Phylicia	Kagyut,Adrian
Illasiak, Dana	Olifie, Larry
Kagyut, Adrian	Inuktalik, Annie
Okheena, Byron	Pollock, Stephanie
Martin, Marlene	Koreman, Margaret
Banksland, Marlene	

Inuvik – First Aid & CPR – March 18-19, 2013

All courses listed here are with co-funding from ECE.	
1	Aviugana, Clara
2	Cockney, Jennifer
3	Greenland, Greenland
4	Greenland, Dustin
5	Sharpe, Mabel
Aklavik - First Aid & CPR - March 20-21, 2013	
1	Capot-Blanc, Travis
2	Dillon, Frank
3	Elanik, Jeanette
4	Elanik, Kelvin
5	Greenland, Cecilia
6	Greenland, Millie
7	Gruben, Frank
8	Gruben, Vikki
9	Illisiak, Curtis
10	Joe, Gerald
11	Koe, Vivian
12	Meyook, Jimmy
13	Pascal, Janelle
Tuk - First Aid & CPR - March 22-23, 2013	
1	Cockney, Flora
2	Gruben, Chukita
3	Nasogaluak, Diane
4	Nuyariak, Jody
5	Ovayuak, Susie
6	Payne, Michael
7	Pingo, Nadine
8	Pokiak, Noah
9	Taylor, Ida
10	Teddy, Victoria

Communications

- School and College visits (September-December 2012)
- IPY 2012 Conference (April 2012)
- ArcticNet Annual Scientific Meeting (December 2012)
- Regional Community Tour (September-December 2012)
- NWT RCC Social and Cultural Review meeting (February 2012 and 2013)
- Inuit Knowledge Centre meeting (March 2012)
- Assisted NCP researchers in proposal reviews and consultation in the region; Lisa Loseto, Nikolaus Gantner, Laurie Chan and Hailey Hung.

Traditional Knowledge Integration

- Inuvik Hunters and Trappers Committee Health Canada project
- Paulatuk Hunters and Trappers Committee Health Canada/NCP Project

Through the assistance of the IRA in both of the Hunters and Trappers Committee projects in Inuvik and Paulatuk, the IRA is having a greater role in the dissemination and promotion of traditional knowledge integration in research in the ISR.

Related IRA Duties

- Promoted two Nasivvik call for proposals in the region
- Assisted other researchers in the region (Laura Eerkes-Medrano and David Atkinson, University of Victoria as one example)
- Reviewed Aurora Research Institute research applications
- Reviewed IRIS 1 report for ArcticNet and provided comments in May.
- Attended Arctic Observing Summit (for 2013-14 year)

- Attended (by phone) Health Canada Inuit Selection Committee Review

Results

- Inuvialuit are more knowledgeable about contaminants through general discussions during community breakout sessions held during community visits.
- Inuvialuit are becoming trained in key areas that they have identified as needing, such as basic courses like First aid and CPR. The next step is to build on this baseline of training and get people into more specialized courses such as Wilderness First Aid, Small Vessel tickets, Food preparation certificate and monitoring certificates.
- Communities are applying for funding to conduct community based projects.
- Newsletter is becoming more engaging as more researchers and community members are contributing to it.
- Community Tours offer more interactive activities to get elders, youth and community members involved through breakout sessions, round table discussions and opportunities to win prizes based on knowledge of contaminants.
- IRA would like to move into new direction of developing more communication materials and informing Inuvialuit of current contaminants information.

Discussion and Conclusion

Now that the IRA position is much more established with positions filled in all Inuit regions, the position is now ready to be fully functional. In addition, with the completion of the IRA Guide in 2012 and finalization of it this year (2013), IRA's now have the tools and knowledge they need to undertake the work. With continued training planned for this coming year, IRA's will have all the expertise needed to undertake mandatory communications duties such as oral and poster presentations, consultations, community visits and guidance. As each region is unique in what it does, it is now up to each IRA to plan projects that would not only fit well with regional priorities but that benefit Inuit from across each region, build capacity, increase training and overall increase involvement and benefit from research. The Inuvialuit region IRA has plans to begin developing new communication materials for communities that focuses on contaminants results, climate change knowledge and community based research. These areas of focus are a good basis in helping communities not only become involve in specific studies but to also lead them based on regional priorities, for each community.

Expected Project Completion Date:

March 2013

Acknowledgements

ArcticNet and Nasivvik for their support of the IRA position salary dollars, training and activities. Special thanks to the Northern Contaminants Program for continued salary and project support.

Nunavik Inuit Research Advisor

Conseillère en recherche inuite du Nunavik

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Note: Louisa Thomasie worked as the Nunavik IRA for a number of years and resigned in August 2012 in order to return to her teaching career. Betsy Palliser entered the IRA position in September 2012. The IRA works closely with various research bodies and Inuit organisations of the region, from meetings to workshops and working groups.

Abstract

A concise summary of what was done, found, and concluded to date. This will be translated into French and posted on the NCP website. Suggested length: 250-300 words

The IRA position is housed within the Renewable Resources, Environment, lands and Parks Department of the Kativik Regional Government (KRG) and works closely with the Nunavik Board of Health and Social Services NNHC and the Makivik Research Centre. In addition to the Northern Contaminants Program support, the Nunavik IRA position is also co-funded by ArcticNet and the Nasivvik

Résumé

Employée par le Service des ressources renouvelables, de l'environnement, du territoire et des parcs de l'Administration régionale Kativik (ARK), la conseillère en recherche inuite collabore étroitement avec la Régie régionale de la santé et des services sociaux du Nunavik (RRSSSN) et le Centre de recherche Makivik. En plus d'être financé par le Programme de lutte contre les contaminants du Nord (PLCN), le poste de la conseillère en recherche inuite (CRI) du Nunavik est aussi cofinancé par ArcticNet et par le Centre Nasivvik pour la santé des Inuit et les changements environnementaux.

Centre for Inuit Health and Changing Environments.

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 objectives of the IRA position in Nunavik are to help facilitate research at the program level as well as to act as a liaison between northern communities and researchers to facilitate research and the development of effective partnerships. This includes offering guidance to researchers about the northern concerns and priorities as well as assisting in the development of local research capacity, and preparing communities in advance of research.

The IRA reviews national and international research proposals and provides comments. She attends the meetings of the Northern Contaminants Program, attends international scientific conferences like the IPY or the ArcticNet ASM and works closely with the ITK on research reviews. The Nunavik IRA collaborates with the other regional IRAs in training session, producing and distributing a brochure on the role of the Nunavik Inuit Research Advisors. She also participates in meetings and workshops with the Nunavik Nutrition and Health Committee.

Au Nunavik, la conseillère en recherche inuite demeure la première personneressource lorsqu'il s'agit de mieux coordonner les efforts de la collectivité et les travaux scientifiques liés à l'Arctique.

La conseillère en recherche inuite cherche à faciliter les activités de recherche à l'échelle du programme ainsi qu'à établir les communications entre les collectivités du Nord et les chercheurs afin de faciliter la recherche ainsi que l'établissement de partenariats efficaces. Pour ce faire, elle doit notamment orienter les chercheurs en fonction des préoccupations et des priorités des collectivités du Nord, contribuer au développement des capacités de recherche locales, et préparer les collectivités en vue des travaux de recherche.

La conseillère en recherche inuite examine les projets de recherche nationaux et internationaux et formule des commentaires à ce sujet. Elle participe aux réunions du Programme de lutte contre les contaminants du Nord, assiste à des conférences scientifiques internationales comme celles de l'API et de l'association étudiante d'ArcticNet, et elle collabore étroitement avec Inuit Tapiriik Kanatami lors de l'examen des projets de recherche. En collaboration avec les conseillers en recherche inuite des autres régions, la conseillère en recherche inuite du Nunavik prépare des séances de formation et se charge de la production et de la distribution de dépliants sur le rôle des conseillers en recherche inuite du Nunavik. Elle participe également à des réunions et à des ateliers en collaboration avec le Comité de la nutrition et de la santé du Nunavik.

Key messages

Concise, plain language summary of key take-home messages of work to-date, findings and conclusions. This will be translated into French and posted on the NCP website. Preferably 2-4 points, in bullet form

- Shifting the way research is seen and done in the Arctic and in Inuit communities for the benefit of Nunavik.
- Developing for the IRA to be the first point of contact for all researchers conducting work in Nunavik. Helping researchers and communities to coordinate and communicate information using various strategies that would attract future participation from the region in collaboration with research teams.
- Providing input and direction to three major Arctic Research Programs (NCP, Nasivvik and ArcticNet), to related research centers and partners (NNHC, Makivik Research Center, Centre d'études nordiques, Centre interuniversitaire d'études et de recherches autochtones, CNRS Institue of Ecology and Environment in Montpellier, HTO, NICCC, NICHO, NICER, KEAC, KSB, NRBHSS, Inuit Knowledge Center, ITK, ICC, Nunavik communities).
    - 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 undertakes a number of diverse tasks for KRG ranging from attending workshops/meetings and focus groups to collaborating and networking with researchers.
    - The IRA also undertakes a number of tasks for both ArcticNet and Nasivvik, helping in liaison and avoid overlap in research activities.

Messages clés

- Changer, dans l'intérêt du Nunavik, la façon dont les travaux de recherche sont perçus et menés dans l'Arctique et dans les collectivités inuites.
- Faire en sorte que la conseillère en recherche inuite soit la première personneressource pour l'ensemble des chercheurs travaillant au Nunavik. Aider les chercheurs et les collectivités à coordonner et à communiquer les renseignements en mettant en œuvre diverses stratégies afin d'amener les intervenants régionaux à participer aux prochains travaux des équipes de recherche.
- Formuler des commentaires et des lignes directrices pour trois grands programmes de recherche sur l'Arctique (PLCN, Nasivvik et ArcticNet) ainsi que les centres de recherche et les partenaires participants (CNSN, Centre de recherche Makivik, Centre d'études nordiques, Centre interuniversitaire d'études et de recherches autochtones, Institut écologie et environnement du CNRS à Montpellier, OCT, CNICC, CINS, NICER, CCEK, CSK, RRSSSN, Centre du savoir inuit, ITK, CCI, collectivités du Nunavik).
    - La conseillère en recherche inuite est membre du Comité de la nutrition et de la santé du Nunavik, auquel elle donne son avis sur le processus de propositions du PLCN et sur les renseignements en matière de santé qui sont communiqués aux collectivités du Nunavik dans le cadre du PLCN.
    - Au nom de l'ARK, la conseillère en recherche inuite effectue diverses tâches (p. ex. : participation à des ateliers et à des réunions; collaboration et réseautage avec des chercheurs).
    - De plus, la conseillère en recherche inuite réalise certaines tâches pour ArcticNet et Nasivvik, veillant notamment à établir les communications et à éviter le chevauchement des activités de recherche.

Objectives

In relation to the Northern Contaminants Program, the role or the IRA is to provide guidance and assistance to the research program and its researchers, and engage Inuit, northern communities, and regional organizations in research. The objectives are multiple:

- Training of the IRA;
- Be an active member of the NNHC;
- Liaise with national and international organizations and other Inuit regional organizations in matters related to Arctic science and research;
- Act as a liaison between researchers and communities to facilitate research and the development of effective partnerships;
- Collaborate with Makivik Research Center on developing a research licensing tool for the Nunavik region; ensuring that the researchers communicate with the appropriate community representatives (and vice-versa);
- Develop long term capacity for research needs in Nunavik;
- Develop a research mentorship program for KRG and Nunavik;
- Facilitate and foster more community-based research;
- Assist in the development of local research capacity;
- Identify concerns and priorities of northerners, communities, and regional organizations in order to promote these to the NCP and other researchers;
- Identify potential community or regional partnerships to be made with existing and future projects;
- Identify opportunities for youth to become engaged in research and science;
- Identify northern students and youth interested in participating in research activities and connecting them with appropriate research projects and training initiatives;
- Identify Inuit-led project proposals that could apply for funding;
- Provide information on other research activities occurring in the region;
- Provide support and advice to communities on research from the Northern Contaminants Program;
- Offer guidance in the production of promotion and communication materials and the distribution of these materials in each region for the research programs and individual projects;
- Offer guidance and, where appropriate, assist with communicating research results of individual projects to relevant communities and regional organizations;
- Gather and locate accurate and relevant contaminant materials to distribute;
- 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;
- Provide information regarding research in Nunavik and opportunities for local involvement
- Inform and communicate with the Nunavik population about contaminants research and the results of research studies. (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. If 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);

- Provide information to the ITK Research Team, the Inuit Nipingit: the National Inuit Committee on Ethics and Research (NICER); the Inuit Qaujisarvingat: The Inuit Knowledge Centre;

Introduction

The past decade has seen a reinvestment in Arctic Science in Canada and an increased level of research activity in the Arctic. Currently a series of multidisciplinary science programs, like the Northern Contaminants Program (NCP), the Northern Ecosystem Initiative, ArcticNet and Nasivvik) are looking to work closer with Nunavik communities in order to better integrate Inuit concerns and needs into science and policy and to improve cooperation at community, regional and international levels.

In 2003, Nasivvik identified the need for coordination of research being undertaken in the North, utilizing NCP's successful partnership model Nasivvik, in collaboration with ITK and ICC, and began the development of the regional Inuit Research Advisor (IRA) positions. These positions were established to better coordinate research, build capacity, and encourage greater Inuit engagement and foster researcher and community interaction of these Arctic research programs.

The ArcticNet Network of Centers of Excellence, Nasivvik and the Northern Contaminants Program provide funding for an Inuit Research Advisor (IRA) in each of the four Inuit land claim regions of the Canadian Arctic to guide Arctic research and to engage Inuit in undertaking research activities of importance to their communities. Inuit participation at the regional level is mandatory to ensure appropriate community consultation and liaison and effective communication between researchers, regions, coordinators, and liaison officers. The IRAs receive support and training to assist university and government researchers in making the appropriate connections with communities and regional organizations, to develop Inuit-led research projects, and to facilitate research in Inuit regions on contaminants, climate change and environmental health. The IRA position is a step towards a more coordinated approach to community involvement and coordination of Arctic science and represents a new way of knowledge sharing and engagement of Inuit in Arctic science.

These regionally based IRA positions receive support and coordination both nationally and internationally from Kendra Togoona, Eric Loring from ITK and Dr Scot Nickels and Carrie Grable from the Inuit Knowledge Center and from Pitsey Moss- Davies, the ICC ArcticNet Coordinator. Additional support in Nunavik, for the IRA position, will come with mentorship from Michael Barrett as well as other members in the environmental and renewable resources fields of the Kativik Regional Government and the from the NCP funded Nunavik Nutrition and Health Committee.

Activities in 2012-2013

Louisa Thomasie worked as the Nunavik IRA for a number of years and resigned in August 2012 in order to return to her teaching career. Betsy Palliser entered the IRA position in September 2012. The IRA works closely with various research bodies and Inuit organisations of the region, from meetings, workshops to international conferences.

Louisa Thomassie's main work conducted in 2012 on this project was the following:

The Nunavik IRA attended the International Polar Year Conference held in Montreal in April 2012. Louisa met with the researchers from different fields to follow up on their research projects, analysis and results. Through critical thinking and questions asked, she assisted them in giving advice on how to go about the research projects carried out in Nunavik.

With the Nunavik Nutrition and Health Committee (NNHC) Louisa edited and updated evaluation criteria.

During the NNHC committee-meeting in Kuujjuaq, she reviewed research proposals, results, and updates.

Louisa also traveled to Montpellier (France) to assist the CNRS Institute of Ecology and Environment with the drafting and editing of OHM.I mining impact research proposal. This international science project will study the socio-economic effects of mining activities on a local Inuit community as well as the related environmental impacts in the region.

Later in the year, Louisa attended the mining exploration information session held in Kangirsuk, Nunavik.

Together with project leader Gina Muckle from the Child Cohort study working group (Québec city), Louis drafted and edited the related research proposal.

With Kendra Tagoona, she attended the Inuit Research Advisor's workshop held in Iqaluit. With the other four regional IRAs she was reviewing science and policy, the role of research advisors, as well as discussing the related challenges and successes.

The main activities of Betsy under the current project were

Betsy Palliser, following a job posting, was named to the position of Nunavik Inuit Research Advisor in September of 2012.

Betsy joined the Nunavik Nutrition and Health Committee (NNHC) and was introduced to the committee face-to face during the meeting in Kuujjuaq on November ß

Betsy attended a NNHC meeting in Quebec City on February 11th-15th, where she had appointments with researchers, reviewed proposals and provided advice.

The week of February 18th-24th, Betsy attended an Inuit Tapirit Kanatami round table discussion in Iqaluit to discuss research on Inuit education in Canada.

In March 2013, she attended in Québec-city an international working-group meeting to follow-up on the OHM.I research proposal.

Results

As can be seen from the above detailed activities, both IRAs were very productive in international and regional networking and collaborations by providing guidance and advice to scientists and regional authorities in regard to strategic planning, research needs and gaps, community questions and input on traditional knowledge. The IRAs have been attending many meetings and conferences, which allowed them to consolidate collaborations and further the interactions between scientists and Northerners.

The IRAs commitment contributed valuable input on the concerns and needs of Inuit when reviewing and editing research in the region ensuring liaison and helping the communication of research results in a way that is appropriate and meaningful to Nunavimmiut. As active members of the NNHC, the Nunavik IRAs advised Nunavik Public Health Director about educating the public on food and health issues, including benefits and risks associated with contaminants and country food.

Within the Northern Contaminants Program the IRA identified issues specifically related to the research affecting Inuit, provided guidance and advice on policy issues, research and made recommendations. This is ongoing work. The Early Childhood research project conducted in the Eastern Hudson Bay area is one of the major projects that benefited directly from these contributions. Another projects that benefits directly from the IRA, is the OHM.I, the International Man-Environment Observatory Project in Nunavik, which is designed around the needs addressed by the Inuit and their environment.

After some delays in the past, the Nunavik Research Licencing project is moving well ahead now. Nunavik with its two land claim agreements (one onshore and one offshore) has a rather complex situation when it comes to which authorities should be contacted and informed before doing research in the region. An interactive website with a map- and text-based application showing pertinent information was developed by Makivik in collaboration with the IRA and is about to be launched. With this, an important tool facilitating interactions between potential partners on research projects in the region is to be created.

The ArcticNet Integrated Regional Impact Study (IRIS4) report was launched during the past winter, and the IRA will contribute in the future on decimating those results to the Nunavik communities.

The IRA is also to participate in the coordination on a new permafrost education and outreach project within Nunavik communities. She will facilitate community involvement, participation, training and education. Local decision and policy makers as well as the students (the next generation of leaders) will work together with scientists in workshops to address current challenges related to permafrost and land use planning. This project also connects with two other educational and outreach projects, one on sea-ice and one on the little berries, which are currently ongoing in Nunavik's Secondary schools.

Discussion and Conclusions

There is a strong need to use both traditional and western knowledge to address Arctic research and science. The role of the IRA is to liaise with scientist and to facilitate developing links with local people and traditional knowledge holders. In some cases this link may be sufficient enough if the researcher and community develop a relationship for long term work. In other cases, it may require the use of KRG's contacts to traditional knowledge groups to place research into a broader context of Inuit needs and values.

The IRA plays a critical role in helping the research communication process by advising, and producing products that are appropriate for community consultations or discussions. Working with communities and communicating information back to the communities is a key communication deliverable. Therefore the IRA needs to meet regularly with the NCP, ArcticNet, Nasivvik and other researchers to learn about the nature of their research and to assist them in developing regional and community oriented communication plans. This also furthers development of appropriate research capacity within the Inuit and the scientific community.

Speaking about communication, if the media is to be used for communications on human health research result, the specific NNHC communication protocol has to be respected. It 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 first, and the KRG communication department has to give a consent form before the results for the region are published or announced by the IRA. Given the sensitivity of human health and country food diet research and, to avoid any misunderstandings about the research results, the regional population is to receive the information before it is released by the media.

The IRA has ongoing communications with the region. She will continue to identify interests from Nunavik to conduct Inuit led research projects and to identify opportunities to involve students in research programs, education and development opportunities. She is available to provide assistance to researchers in their work in the region and in communicating their results back to communities.

The IRA will continue to attend NCP result workshop, to sit on NNHC meetings and to inform all communities of research activities that are being conducted via the NCP. She will further participate on the National Inuit Climate Change Committee, the ArcticNet Inuit Advisory Committee, the ArcticNet Students Assocations meetings, the National Inuit Committee on

Health meetings, the Nasivvik BOD meetings and participate in the Nasivvik proposal reviews.

To conclude, the IRA is a valuable key-person in the relationship and cooperation between scientists and northern communities, who facilitates and supports research design and planning, collaboration and education and outreach projects to be appropriate and meaningful to Nunavimmiut.

Expected Project Completion Date

As the above discussion has shown, there is a strong long term need for an IRA in Nunavik, therefore project should be reconducted in the future.

Acknowledgments

Please note that the NCP must be acknowledged in a formal way in all presentations and other communications products (including papers) related to activities funded by the NCP and their results.

The Research Advisor - Increasing Nunavut Tunngavik Incorporated's Social and Cultural Research Coordination

Conseiller en recherche : accroître la coordination de la recherche socioculturelle menée par la Nunavut Tunngavik Incorporated

Project Leader:

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Niqiit Avatittinni Committee, Health and Social Services, Government of Nunavut, Department of Environment, Government of Nunavut, Aboriginal Affairs and Northern Development Canada, Environment Canada, Nunavut Research Institute, Inuit Tapiriit Kanatami

Abstract

Each Inuit region has an Inuit Research Advisor (IRA) co-funded by NCP, ArcticNet, the Nasivvik Center for Inuit Health and Changing Environments as well as a host institution. In Nunavut, the Research Advisor is hosted by Nunavut Tunngavik Incorporated. Although this synopsis report will highlight NCP related activities, it is important to note that many of the funding organization responsibilities for the research advisor position overlap.

The Research Advisor joined NTI's research team and the inter-regional Inuit Research

Résumé

Dans chaque région inuite se trouve un conseiller en recherche inuite (CRI) dont le poste est cofinancé par le Programme de lutte contre les contaminants dans le Nord (PLCN), ArcticNet, le Centre Nasivvik pour la santé des Inuit et les changements environnementaux ainsi qu'un établissement hôte. Au Nunavut, l'établissement hôte est la Nunavut Tunngavik Incorporated (NTI). Bien que le présent résumé porte sur des activités liées au PLCN, il est à noter que les organisations qui financent le poste de conseiller en recherche ont de nombreuses responsabilités en commun.

Advisor (IRA) team in March 2012. NCP related activities include participating in regular IRA team teleconferences, attending regional contaminants committee (Niqiit Avatittinni Committee) meetings as well as communicating with the NAC and NCP researchers.

Additional activities include working on NCP-funded Inuit Health Survey Risk Perception and Messaging Evaluation project, developing "Research in Nunavut" Fact Sheets, assisting in the development of the IRA training handbook, co-facilitating workshops at ArcticNet's ASM Student Day as well as presenting on an APECS online webinar series regarding working with northern communities.

As part of NTI's Social and Cultural Development department research team, the research advisor's activities are wide ranging. NTI's research team is now at full capacity and is on its way to playing an even greater role in the realm of research occurring in Nunavut.

La conseillère en recherche s'est jointe à l'équipe de recherche de la NTI et à l'équipe interrégionale des conseillers en recherche inuite en mars 2012. Dans le cadre du PLCN, l'équipe de la CRI organise des téléconférences périodiques, assiste aux réunions du Comité régional des contaminants (Comité Niqiit Avatittinni) et communique avec les chercheurs du Comité Niqiit Avatittinni (CNA) et du PLCN.

L'équipe participe également au projet d'évaluation de la perception des risques et des communications concernant l'Enquête sur la santé des Inuits, un projet financé par le PLCN. De plus, l'équipe crée des fiches d'information sur les travaux de recherche effectués au Nunavut, contribue à l'élaboration du manuel de formation des CRI, coanime des ateliers lors de la journée des étudiants organisée par l'association étudiante d'ArcticNet et donne des présentations sur la collaboration avec les collectivités du Nord dans le cadre d'une série de webinaires offerts par l'APECS.

La conseillère en recherche participe à une foule d'activités au sein de l'équipe de recherche des Services de développement social et culturel de la NTI. Désormais complète, l'équipe de recherche de la NTI est en voie de jouer un rôle encore plus important dans le milieu de la recherche au Nunavut.

Key messages

In 2012-2013, the Research Advisor's involvement in NCP research included:

- Established relationships and regular communications with NCP researchers working in Nunavut.
- Active participant on the Niqiit Avatittinni Committee. This includes promoting Inuit interests in the social-cultural review of NCP proposals.
- Reviewing NCP blueprints.
- Regularly reviewing communication materials and providing feedback from a social-cultural perspective. This includes

Messages clés

En 2012-2013, dans le cadre des travaux de recherche du PLCN, la conseillère en recherche :

- a établi des relations et activités de communication périodiques avec les chercheurs du PLCN travaillant au Nunavut;
- a pris part aux travaux du Comité Niqiit Avatittinni, notamment en faisant la promotion des intérêts des Inuits lors de l'examen des aspects socioculturels associés aux projets du PLCN;
- a examiné les plans directeurs du PLCN;

promoting incorporation of traditional knowledge in research projects as well as greater involvement of Inuit at all levels of research, including project development.

- Advancements in IRA funding arrangements – i.e. NCP funding dollars for Nunavut IRA position to now flow through ITK.

- a procédé à l'examen périodique des documents de communication et fourni de la rétroaction sur les aspects socioculturels, notamment afin d'encourager la prise en compte des connaissances traditionnelles dans le cadre des projets de recherche ainsi qu'une participation accrue des Inuits à toutes les étapes de la recherche, y compris l'élaboration de projets;

- a contribué à améliorer l'entente de financement du poste de conseiller en recherche inuite (c'est désormais Inuit Tapiriik Kanatami qui versera les fonds du PLCN affectés au poste de conseiller en recherche inuite du Nunavut).

Objectives

In relation to the NCP program, the role of the Research Advisor and IRAs is to provide guidance and assistance to the research programs and their researchers and engage Inuit, northern communities and regional organizations in NCP research. More specifically, in Nunavut the Research Advisor:

- Acts as a liaison between NCP researchers and communities to facilitate research and the development of meaningful partnerships.
- Offers guidance and, where appropriate, assists with communicating research results of individual projects to relevant communities and regional organizations.
- Identifies interests, needs, concerns and priorities of northerners, communities and regional organizations and promotes these to NCP researchers and into the NCP blueprint review.
- Identifies where potential community or regional partnerships could be made with an existing project as well as Inuit-led project proposals that could apply for NCP funding.
- Works with the Niqiit Avatittinni Committee to offer guidance to NCP researchers. This includes connecting researchers with community members and organizations, reviewing communications documents as well as attending presentations and meeting with NCP researchers when possible.

Introduction

The Research Advisor works as part of a research team within NTI's Social and Cultural Development department. This report highlights NCP related activities but does not capture the entire scope of work the Research Advisor is involved in.

Activities in 2012-2013

- Participated in IRA Training in Iqaluit, May 2012.
- Provided feedback on the development of the IRA Training Handbook, May 2012.
- Participated in regular Inuit Research Advisor teleconferences.
- Participated in ArcticNet Inuit Advisory Committee (IAC) meetings.

- Attended Nunavut's Niqiit Avatittinni Committee (NAC) face-to-face meetings in Iqaluit, October 2012. Filled in as co-chair for Gayle Kabloona (NTI).

- Reviewed NCP 2013-2014 proposals and provided feedback to NAC and PIs on select proposals.

- Attended NAC Social-Cultural Review of 2013-2014 NCP proposals in Iqaluit, February 2013.

- Developed Research in Nunavut Fact Sheets for NCP researchers, circulated to NAC and IRAs for feedback, March 2013. Fact sheet series focuses on: 1) What researchers should know when engaging schools in research, 2) Expectations when collecting traditional knowledge and 3) Expectations when submitting a NCP proposal for review to the Niqiit Avatittinni Committee. Fact sheet series is currently in finalization process.

- Attended NCP researchers Hayley Hung (M-01) and Sandy Steffen's (M-02) presentation to Nunavut Arctic College's Environmental Technology Program – "Air Monitoring Research at Alert, NU", January 2013. Met with the two PIs afterwards to discuss outreach activities as well as ways to incorporate traditional knowledge in their work.

- Co-facilitated ArcticNet ASM Student Day Presentations on: 1) Inuit and Northern Culture and 2) Community-Based Research and Knowledge Exchange – December 2012.

- Developed Nunavut IRA "Research in Nunavut" poster for NCP Results Workshop and ArcticNet ASM.

- Presented on APECS webinar, "Working with Northern Communities". Presentation focused on, "Working in the North: The Importance of Building Relationships and the Value of Building Capacity with Northern Partners" – March 2013.

- Completed NCP's "Niqiit: The Story of Contaminants in the North" online course and promoted course among networks.

- NCP Project H-01, Project Leader Laurie Chan. NCP-NTI Inuit Health Survey Risk Perception and Messaging Evaluation project:
  - Worked with NTI research team, IHS research team and GN HSS throughout the development of this project.
  - Connected research team with appropriate community contacts and organizations in the three Nunavut communities project took place in – Arviat, Cambridge Bay and Iqaluit.
  - Facilitated community-researcher teleconferences and communications, assisted with the organization of community feasts, assisted with the review of project materials and aided in the advertisement of project.
  - Travelled to Cambridge Bay to assist research team with evaluation project on the ground, March 2013. This trip included assisting in the training of community interviewers.

- Communicated with various NCP researchers to discuss community outreach activities and communications as well as incorporation of traditional knowledge into research.

- Facilitated communication between researchers/research community and Nunavut communities.

- Provided feedback to NAC and NCP researchers to assist in the development and review of community communications materials.

- Received and regularly reviewed NRI research license applications.

- Reviewed Nasivvik research scholarship applications.

- Attended the International Polar Year Conference in Montreal, March 2012. NTI participated on a research panel and did a joint presentation as a partner of the Inuit Health Survey.

Note: Did not attend NCP Results Workshop in 2012 as the event was postponed.

Communications

Other specific examples of research advisor communications with NCP researchers include, but are not limited to:

- M-07 led by Gary Stern; Team member Lisa Loseto - Research advisor has been in contact with Lisa Loseto regarding the Pangnirtung portion of this project and her future work in Nunavut communities. The Research Advisor will continue to communicate with Lisa prior to her visit with the HTO in Pangnirtung.

- M-04 led by Derek Muir – Helped researcher in the review and development of their communication material for HTO's. A main recommendation of this review was that the Inuit Health Survey report and ringed seal advisory be included in reporting back to the Resolute HTO.

- M-08 led by Birgit Braune – Researcher has been in touch with NTI and NAC. The research advisor had the opportunity to review the researcher's 2012-2013 proposal, specifically the community engagement aspect, prior to submission. This was beneficial and sets a good example of NCP proposal development.

- M-09 led by Marlene Evans and Derek Muir - Provided information on translation services to Marlene Evans.

- M-23 led by Paul Drevnick – Provided comments on communication materials that will go to the Resolute Bay HTA.

- M-14 led by Mary Gamberg – Provided comments on brochure regarding work specific to the Qamanirjuaq Caribou Herd.

- H-01 led by Laurie Chan – NTI's research team worked very closely with the researcher and his team in the development and implementation of the Inuit Health Survey Risk Perception and Messaging Evaluation study. This included project material development and review, facilitating communication between research team, partners and communities, advertising the project, organizing community logistics and feasts as well as providing training to community research assistants. A significant in-kind contribution of NTI staff time went into this project.

Traditional Knowledge:

- The Research Advisor and NTI research team is committed to providing advice and assisting researchers in learning about and incorporating traditional knowledge into their research projects and into the NCP program.

- An example of this is the development of Fact Sheet #2 of the Research in Nunavut fact sheet series which focuses on "Expectations when collecting traditional knowledge". This includes general information for NCP researchers to consider in order to incorporate traditional knowledge in their work to a greater degree.

Results

The research advisor's activities are ongoing and coincide with the activities of NTI's Social and Cultural Development department's research team. Specific to NCP activities, the research advisor and NTI's research team continue to work closely with the Niqiit Avatittinni Committee and NCP researchers. NTI's research team continues to represent Inuit interests in NCP-funded projects, including promoting community engagement, Inuit participation and incorporation of traditional knowledge. NTI's involvement in the social-cultural review of NCP project proposals offers guidance to researchers to ensure that Inuit are engaged in meaningful ways.

The research advisor was contacted by and communicated with representatives from approximately half of the research teams that were granted funding from NCP in 2012-2013. Communications with researchers focussed on reviewing communication materials that were being prepared for communities as well as input on community engagement and outreach activities. This also included requests for assistance with Inuktitut and Inuinnaqtun translation sources as well as approval of content included in communication materials.

The research advisor worked with NTI's research team and the NAC to develop a "Research in Nunavut" fact sheet series. Representatives from various organizations in Nunavut had the opportunity to review these fact sheets. After finalization, they will remain living documents that can be amended on an as-needed basis. The fact sheets will be distributed to NCP researchers to help them prepare for working in Nunavut communities.

NTI's research team played a significant role in the NCP-funded Inuit Health Survey Risk Perception and Messaging Evaluation Project (H-01). NTI's research team worked closely with the Principal Investigator and partner organizations throughout the entire timeframe of project development. This included connecting the IHS research team with appropriate communities and organizations, preparing written documentation, advertising the project as well as organizing community feasts and community logistics. The research advisor travelled to one community to facilitate communication and aid in the on-the-ground implementation of the project. NTI's research team was an essential link between the IHS research team and the communities involved in the project. NTI contributed a significant amount of in-kind staff time into this research project.

NTI's research advisor and research team are committed to continuing to work with the Niqiit Avatittinni Committee and NCP researchers.

Discussion and Conclusions

With the Research Advisor position filled, NTI's Social and Cultural Development department research team is now at full capacity. The NTI research team communicates regularly with researchers from a variety of organizations and institutions and continues to ensure that the interests of Inuit are addressed. NTI's next steps in the realm of research include developing strategies for an even greater coordinated approach to working with research in Nunavut.

Expected Project Completion Date:

Ongoing

National/Regional Coordination and Aboriginal Partnerships

Coordination nationale et régionale et partenariats autochtones

Council of Yukon First Nations – Northern Contaminants Program Meetings

Conseil des Premières Nations du Yukon – réunions à propos du Programme de lutte contre les contaminants dans le Nord

Project Leader:
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Project Team Members and their Affiliations:
Yukon First Nations, Yukon Contaminants Committee

Abstract

Over the past year the Council of Yukon First Nations has continued to be active as a member of the NCP management committee as well as responding to requests for information, participating in regional contaminants committee activity, informing Yukon First Nations about the annual call for proposals, maintaining and updating the Yukon NCP website and working with NCP researchers active in the Yukon

Résumé

Au cours de la dernière année, le Conseil des Premières Nations du Yukon (CPNY) a continué d'être un membre actif du comité de gestion du Programme de lutte contre les contaminants dans le Nord (PLCN). À ce titre, le CPNY a effectué les tâches suivantes : répondre à des demandes d'information, participer aux activités du comité régional des contaminants, mettre les Premières Nations du Yukon au courant des appels annuels de propositions, tenir et mettre à jour le site Web du PLCN (Yukon) et collaborer avec les chercheurs du PLCN travaillant au Yukon.

Key Messages

- Our Traditional Foods are safe to eat.
- Levels of contaminants are generally low in the Yukon.
- We need to continue monitoring as new contaminants are being released into the atmosphere and water which may cause problems in the future.

Messages clés

- Les aliments traditionnels peuvent être consommés en toute sécurité.
- Au Yukon, les concentrations de contaminants sont généralement faibles.
- Il est nécessaire de poursuivre la surveillance, car de nouveaux contaminants sont rejetés dans l'atmosphère et l'eau, ce qui peut avoir des conséquences dans l'avenir.

Objectives

To enhance the confidence of Yukon First Nations in making informed decisions about traditional food consumption and other health related factors.

Ensure that Yukon First Nations are aware of the latest research regarding the transportation of long range contaminants to the Yukon and their effects on the environment and human health.

Ensure that the programs offered by and the research done for the Northern Contaminants Program meets the needs of Yukon First Nations.

Ensure that Yukon First Nations are aware of the funding envelopes and calls for proposals available under the Northern Contaminants Program and that these envelopes are relevant for and accessible to Yukon First Nations.

Introduction

The Council of Yukon First Nations has been a member of the Yukon Contaminants Committee and participated in the Northern Contaminants Program as a member of the Management Committee since the program became active in the Yukon. The current Northern Contaminants Program focus is addressing northern community concerns as people are being exposed to higher levels of long-range contaminants than the rest of Canada. The Yukon is not a high priority area, but still it is important that Yukon First Nations have the information necessary to make informed decisions on the risks and benefits of consuming traditionally harvested foods.

Activities in 2012-2013

Over the past year the Council of Yukon First Nations participated in Northern Contaminants Program management committee activities. A CYFN representative attended the Management Committee meetings held in Ottawa in April 2012 to review proposals and funding recommendations made for the various envelopes and advise the Program on the Committee's recommendations. We also attended the Management Committee meeting held in Whitehorse in October.

Information on the Northern Contaminants Program was shared at the Council of Yukon First Nations General Assembly held in Burwash in June. The Circumpolar Relations Department had a display set up, talked to individuals regarding contaminants concerns and made information packages and literature available to the delegates attending the assembly. We also attend First Nations General Assemblies if invited and provide information and answer questions about contaminants issues. When the annual call for proposals was issued, we provide

First Nations with information regarding the call and work with any First Nation interested in submitting a proposal.

CYFN also participates in the work of the Yukon Contaminants Committee, meeting with researchers, discussing communications on contaminants issues and doing a review of proposals submitted to NCP to conduct research in the Yukon. We also work with researchers to disseminate information on their research and ensure they engage with communities in all aspects of their work.

CYFN maintains and updates the website www.northerncontaminants.ca. The site documents activity carried out by researchers active on contaminants issues in the Yukon and provides information on contaminants of concern.

This year the NCP management committee struck a subcommittee to examine the issue of traditional knowledge in the context of NCP research. The committee was also charged with exploring options for holding rotating regional contaminants workshops. The CYFN representative participated as a member of this subcommittee.

The Environment Canada air quality researchers operating the Little Fox Lake site in the Yukon (Hayley Hung and Sandy Steffen) travelled to the Yukon to do outreach over the winter. We helped to link the researchers with the Yukon Science Institute for a public lecture on their work with airborne contaminants.

In conjunction with the NCP fall management committee meetings held in Whitehorse the Yukon Research Centre organized a Partners in Science event on October 18th. CYFN participated in planning and discussions related to this event which was originally envisioned as being a regional NCP 20th anniversary celebration but morphed into something different. We participated with a CYFN circumpolar relations display which included literature and information about the Northern Contaminants program.

Results

- Attended management committee meeting to recommend funding for research envelopes
- Communicated information on contaminants and the NCP to Yukon First Nations at the CYFN General Assembly
- Attended Yukon Contaminants Committee meetings and reviewed projects proposing to do work in the Yukon
- Attended NCP midyear management meeting
- Participated in NCP subcommittee on traditional knowledge
- Maintained and updated website
- Helped arrange contact between researchers and the Yukon Science Institute facilitating a public lecture on airborne contaminants

Discussion and Conclusions

The NCP plays a vital role in monitoring the health of Yukon ecosystems and assuring Yukon residents that traditionally harvested foods are safe to eat. In general, levels of contaminants transported to the Yukon through the atmosphere and aquatic sources remains low, however levels of mercury may be a concern for older, larger fish in some areas. We continue to generate new chemicals on a continuous basis; some of these are now showing up in the Arctic and accumulating in animals and fish as well as in water and on the land. Long term data sets are critical to understand background levels, track changes and understand their relationship with climate change, industrial activity and other factors.

Expected Completion Date:

Ongoing

Year-End Activity Report By Inuit Tapiriit Kanatami (ITK)

Rapport d'activités de fin d'exercice Réalisé par l'Inuit Tapiriit Kanatami (ITK)

- **Project Leader:**
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- **Project Team Members and their Affiliations:**
  Yukon First Nations, Yukon Contaminants Committee

Abstract

This report will provide details on the funding and deliverables required for the Inuit Tapiriit Kanatami (ITK) to participate with federal departments and territorial agencies in the Northern Contaminants Program (NCP). Funding to ITK allows us to assess information and research generated by the program and to play an informed role in influencing present and future NCP management priorities, and to set national and international priorities. ITK involvement ensures that Inuit understand Canadian positions in international negotiations to reduce and eliminate chemicals contaminating our environment and country food, threatening Inuit health. ITK participation in the NCP also helps Inuit to persuade federal agencies of the perspectives of Inuit in domestic

Résumé

Le présent rapport fournit des renseignements à propos du financement accordé à l'Inuit Tapiriit Kanatami (ITK) et des réalisations attendues de sa part pour que l'organisme puisse participer, en collaboration avec des ministères fédéraux et des organismes territoriaux, au Programme de lutte contre les contaminants dans le Nord (PLCN). Le financement accordé à l'ITK nous permet d'évaluer les recherches produites dans le cadre du Programme ainsi que les renseignements obtenus, en plus de jouer un rôle d'influence dans l'établissement des priorités présentes et futures relativement à la gestion du PLCN, et d'établir des priorités à l'échelle nationale et internationale. Grâce à la participation de l'ITK, les Inuits comprennent les positions du Canada dans les négociations

and international policy development. It provides a grassroots perspective to the NCP management team by providing an establish network to communicate findings and results and answer priorities at the community level.

internationales visant à réduire et à éliminer les produits chimiques qui contaminent notre environnement et nos aliments traditionnels et qui menacent ainsi la santé des collectivités inuites. La participation de l'ITK au PLCN aide également les Inuits à faire valoir aux organismes fédéraux leur point de vue sur l'élaboration des politiques nationales et internationales. L'ITK offre une perspective locale à l'équipe de gestion du PLCN grâce à son réseau permettant de communiquer les conclusions et les résultats et de répondre aux priorités à l'échelle communautaire.

Background

The story of contaminants in the arctic can be one of fear of the unknown; research carried out under NCP has shown that the contaminants of most concern for Inuit are persistent organic pollutants (POPs) and Heavy Metals like mercury.   The concern of these contaminants comes from the fat-rich country marine foods diet that Inuit depended upon both for nutritious food and sustaining a lively culture. The fear portion comes from reports derived from NCP data that shows that up to 73 percent of Inuit women have PCB blood levels above (and up to five times higher than) the guideline value set by Health Canada as a "level of concern". For other POPs, up to half of the Inuit in the studies have intakes exceeding Health Canada intake guidelines. Not only do many Inuit exceed the blood level and intake guideline levels, they are also exposed to mixtures of chemicals which recent Health Canada studies show may magnify the effects (e.g. child growth and hormone disruption) of individual chemicals. The mercury story is equally scary, High levels of mercury are found in some of Inuit preferred and most consumed country foods. As a result there are places in the Canadian Arctic where some of the Inuit population are at risk because their dietary intake of mercury is greater than the levels that are known to be safe (NCP 2012). As well, NCP health projects out of Nunavik show that Inuit children have subtle negative effects because of prenatal exposure to PCBs and mercury. Inuit want to know and have the right to know what is happening to the health of Inuit, and to the

Contexte

L'histoire des contaminants dans l'Arctique peut être synonyme de peur de l'inconnu. Les recherches réalisées dans le cadre du PLCN ont montré que les contaminants les plus préoccupants pour les Inuits sont les polluants organiques persistants (POP) et les métaux lourds, comme le mercure. L'aspect préoccupant de ces contaminants est lié à la consommation d'aliments traditionnels provenant de la mer, riches en gras, dont les Inuits dépendaient autrefois pour obtenir des éléments nutritifs et maintenir une culture dynamique. La peur est inspirée par des rapports élaborés à partir de données du PLCN montrant que jusqu'à 73 % des Inuites ont des concentrations sanguines de PCB supérieures au seuil recommandé de Santé Canada, considéré comme niveau préoccupant (les concentrations atteignent jusqu'à cinq fois cette valeur). Dans le cas d'autres POP, jusqu'à la moitié des Inuits ayant fait partie des études absorbent des quantités excédant celles recommandées par Santé Canada. Non seulement de nombreux Inuits dépassent les concentrations sanguines et les seuils d'absorption, mais ils sont également exposés à des mélanges de produits chimiques. De récentes études de Santé Canada montrent que ces mélanges pourraient amplifier les effets (p. ex. croissance des enfants et perturbation hormonale) des produits chimiques individuels. Le mercure raconte également une histoire inquiétante. En effet, des concentrations élevées de mercure sont trouvées dans les aliments traditionnels préférés et les plus consommés des Inuits. Par conséquent, il existe des health of the arctic environment. With these alarming reports and data it is critical that Inuit involvement within the program to what advice, direction and information should be provided in context with regional priorities and concerns in the delivery of this sensitive information.

Since the beginning of the Northern Contaminants Program (NCP) in 1991, Inuit Tapiriit of Kanatami (ITK) has participated in the program as managing partners. This partnership continues to be fruitful and effective both for Canadian Inuit and to the Northern Contaminants Program (NCP). As the national political voice for Canadian Inuit, ITK continues to play multiple roles within the NCP. First, ITK provides guidance and direction to AANDC and the other NCP partner's (HC, DFO, EC, etc) - bringing Inuit interests to the NCP management and liaison committees of which we are a member. As a result, the NCP can better respond to the needs and concerns of Inuit. Secondly, ITK is dedicated to facilitating appropriate, timely communications about contaminants in the North. Thirdly, ITK are working diligently with their Inuit partners at the Inuit Circumpolar Council (ICC)-Canada on the international stage to persuade nations to reduce their generation and use of persistent organic pollutants (POPs) and Heavy Metals (Mercury) that end-up in the Inuit diet. We are confident that Inuit organizations and communities in each of the four Inuit land claim regions are making good use of NCP information and funding. Lastly, ITK is now working with other research programs like ArcticNet, Nasivvik, Health Canada Climate change program, CINE, CEC and the Chemicals Management Plan to make sure that research on contaminants is conducted in a coordinated approach. One of the mechanisms to ensure this is the coordination of and engagement with the Inuit Research Advisors for all the programs. ITK has developed training and mentoring for these IRA's to help with this process (online courses located on www.inuitknowledge.ca). The other is through the regional contaminants committee in each of the four Inuit regions of which ITK helps assist and guide. ITK involvement in NWTRCC, NAC, NNHC, and NHERC contaminant committee is critical in

endroits dans le Canada arctique où certaines populations inuites courent un risque parce que leur apport alimentaire de mercure est plus élevé que le niveau jugé sécuritaire (PLCN, 2012). De plus, les projets du PLCN liés à la santé réalisés à l'extérieur du Nunavik montrent que les enfants inuits subissent des effets négatifs subtils à cause de leur exposition prénatale aux PCB et au mercure. Les Inuits veulent savoir, et ont le droit de savoir, ce qui se passe avec leur santé et celle de l'environnement arctique. Vu les données et les rapports alarmants, il est essentiel que les Inuits qui participent au PLCN soient conseillés, orientés et renseignés, dans le contexte des priorités et des préoccupations régionales, sur la façon de communiquer ces renseignements de nature délicate.

Depuis la création du PLCN en 1991, l'ITK y a participé à titre de partenaire de gestion. Ce partenariat continue d'être fructueux et efficace pour les deux parties. En tant que voix politique nationale des Inuits canadiens, l'ITK continue de jouer de multiples rôles au sein du PLCN. Tout d'abord, l'ITK fournit conseils et directives à Affaires autochtones et Développement du Nord Canada (AADNC) et à d'autres partenaires du PLCN (p. ex. Santé Canada, Pêches et Océans Canada et Environnement Canada), faisant ainsi valoir les intérêts des Inuits aux comités de gestion et de liaison du PLCN, dont l'ITK est membre. Ainsi, le PLCN répond mieux aux besoins et aux préoccupations des Inuits. Ensuite, l'ITK cherche à faciliter des communications appropriées et opportunes à propos des contaminants dans le Nord. De plus, l'ITK, sur la scène internationale, collabore assidûment, avec ses partenaires inuits, au Conseil circumpolaire inuit (CCI) Canada à persuader les pays de réduire leur production et leur utilisation de POP et de métaux lourds (mercure), qui s'accumulent dans les aliments consommés par les Inuits. Nous sommes certains que les organismes et les collectivités inuits de chacune des quatre régions faisant l'objet d'une revendication territoriale font bon usage des renseignements et des fonds fournis par le PLCN. Pour terminer, l'ITK travaille maintenant avec d'autres programmes de recherche (p. ex. ArcticNet, Nasivvik, le programme de changements climatiques de Santé Canada, le order to deliver a consistent message to Inuit regarding the NCP and contaminants.

ITK enjoys a productive relationship with the NCP, and look forward to continuing this relationship in the future. We are pleased to present the following year-end report of our activities for the fiscal year 2012/13.

Centre for Indigenous Peoples' Nutrition and Environnement [CINE], le CEC et le Plan de gestion des produits chimiques) afin de vérifier que les recherches sur les contaminants sont menées selon une approche coordonnée. Pour ce faire, on favorise la coordination avec les conseillers en recherche inuite de tous les programmes et on veille à leur engagement. L'ITK a mis au point une formation et un programme de mentorat pour ces conseillers en recherche inuite pour les aider dans ce processus (cours en ligne à l'adresse suivante [en anglais seulement] : www.inuitknowledge.ca). Une autre façon d'assurer une approche coordonnée est d'aider et de guider le comité régional des contaminants de chacune des quatre régions inuites. La participation de l'ITK au Comité régional des contaminants des Territoires du NordOuest (CRCTNO), au Comité consultatif autochtone, au Comité de la nutrition et de la santé du Nunavik et au Comité d'examen de la santé et de l'environnement du Nunatsiavut (comité sur les contaminants) est essentielle pour transmettre le même message aux Inuits sur le PLCN et les contaminants.

L'ITK entretient une relation fructueuse avec le PLCN et se réjouit à la perspective de poursuivre la collaboration. Nous sommes heureux de vous présenter le rapport de fin d'exercice sur les activités de l'année 20122013.

Activities for 2012-2013

Funding from the NCP to ITK comes from three funding envelops. 1. National Coordination Capacity "A" dollars which allows ITK to assess information and research generated by the program and to play an informed role in influencing present and future NCP management priorities through the established committees that are in place. Objectives of this folder include

Short Term

- To participate in the NCP Management Committee
- To participate NWT-RCC meetings
- To participate NNHC meetings
- To participate the Niqiit Avatittinni Committee (NAC) meetings
- To participate Nunatsiavut Health and Environment Research Committee
- Participate on NCP review Team Committees
- Participation with Inuit Research Advisors teleconference and in person meetings
- Participate and guide the 2013 release of the mercury and POP assessments.
- Participate in and Nasivvik meetings
- Participate at the ArcticNet general meeting/RMC and BOD

Long Term

- Provide a voice for Inuit of Canada during discussions
- To develop priorities and issues within the NCP framework and incorporation of NCP concerns in the Inuit Knowledge Centre
- Develop the confidence for Inuit in making informed decisions about Country food use.
- To continue to be an active and constructive member of the NCP Management Structure ensuring that contaminants issue and NCP research and results are communicated to Inuit and that Inuit are represented at key regional, circumpolar and international meetings and initiatives.
- Coordinate Contaminants activities in Nasivvik, ArcticNet and IPY programs
- To contextualize contaminant information in a broader communication process using the Inuit Knowledge Centre and the National Inuit Ethic and Research Committee

The focus of this year's activities is around the various NCP research committees such as the Regional Contaminant Committees (RCC's) with active participation on the NWT Regional Environment Committee (NWTRCC), Niqiit Avatittinni Committee (NAC), Nunivak Nutrition and Health Committee (NNHC), and the Nunatsiavut Health and Environment Review Committee (NHERC). Also, ITK is now able to bring information forward to the National Inuit Committee on Health (NICoH) and the new Inuit Knowledge Center Committee. Last year with close working ties developed with ITK Health and Social Economic Development Department we were able to bring forward NCP concerns to Inuit Public Health Task Group. This year with the new formation of the Wildlife and Environment department we are developing stronger regional wildlife contacts with Wildlife workers to vent NCP environment information through. Some of the NCP information and data was used in our Polar Bear efforts and fact sheet development to go to United Nations in Bangkok.

ITK also participated in all of the NCP management meetings, as well as various review committees like the Human Health review team, the Environment Trends, Community Base

Monitoring and Research and Communication and Capacity Outreach teams. Participation on these committees provide a voice for the Inuit of Canada, developed priorities and issues within NCP framework, developed confidence for Inuit in making informed decisions on their food and coordinated contaminant activities with other research programs like ArcticNet and Nasivvik to ensure that the message of contaminants are placed in a wider context and the research is conducted in a responsible manner throughout the arctic. This is also done with the Inuit Research Advisors (IRA's) that are partially funded by the NCP and are assisted by ITK. The main objective here is to provide a coordinated approach towards research and communication, to provide and Inuit "voice" and direction at the NCP management table to ultimately allow Inuit to have confidence in making good informed decisions about their food use.

ITK was also able to participate in CEC meetings and the discussion of vulnerable communities due to environment contaminants. ITK was able to bring to the table in Mexico NCP research and modes of operations that allows for community and regional involvement and engagement. ITK was also able to participate in the National Chemical Management Plan again bringing forward NCP voice and data. Alaska health planners and environment organizations via the North Pacific Research Board invited ITK to come to Anchorage to discuss Inuit involvement in the research world of contaminant communication. Other presentations included discussions at the Inuit Studies Conference in Washington DC, a general contaminants primer for the Nunavut Sivuniksavut students, updates at the ITK annual BOD meetings and AGMs. Discussion at these meetings focus on ITK and ICC mercury efforts within beluga whales in the ISR.

In June of 2012 ITK took part in the Inuit Health in Transition Study, organized and run by members from the NNHC in Kuujjuaq. From this meeting the vision for the future was pretty clear, Nunavik' s goal is to undertake Qanuippita but with and update d specific set of goals. The new survey should be designed to address psychosocial dimensions of community health, and issues anticipated to be associated with development projects in Nunavik

IRIS meetings

ITK also work with Environment Canada and ICC on mercury related issues, must of the efforts this year went towards ICC international efforts at the global Mercury Meetings. ITK also took part in the Arctic Wildlife Conservation Meeting, bringing forward NCP information when requested.

Also funding also enable us to help guide and provide comments to the ArcticNet IRIS 1 and 2. Meetings were held in Iqaluit, Cambridge Bay and Inuvik.

The second funding envelop which ITK access is also under the National Coordination Envelop, "Capacity B" funding. Capacity Building B funding is a prescribe proposal which reflects where research will be conducted and to address ITK need to review and take part in these NCP projects and consult with the principal investigators and communities as necessary.

Activities for the Capacity B envelop: This is there are over 21 projects that are taken place in the Inuit regions. ITK involvement in these projects can range from minimum advisory role to very intensive project control as in the Inuit Health Survey. A list of the research that ITK is assisting on this year is as follows:

Health Projects (9 projects involving Inuit):

- Nunavik Child Cohort Study (NCCS): communication of study results from the 11-year follow-up and pilot study for follow-up with adolescents. Gina Muckle.
- Assessment of contaminant and dietary nutrient interactions in the Inuit Health Survey: Nunavut, Nunatsiavut and Inuvialuit. Laurie Chan
- Nunavik Child Cohort Study (NCCS): pilot study for follow-up with teenage children – hormonal and behavioral outcomes Pierrich Plusquellec

- Contaminant Nutrient Interaction Issues as part of a Public Health Intervention Study of Inuit Children in Nunavik: Data Analysis and Communication. Huguette Turgeon O'Brien
- Monitoring spatial and temporal trends of environmental pollutants in maternal blood in Nunavik. Eric Dewailly
- Mercury exposure and emergence of cardio-vascular diseases in Inuit Eric Dewailly (CHUQ)
- Selenium status and related health effects in the Inuit population from Nunavik Pierre Ayotte

Environment Projects: 24 projects involving Inuit regions) they included but not limited to the following

- Northern Contaminants Air Monitoring: Organic pollutant measurement Hayley Hung
- Air Measurements of Mercury at Alert and Little Fox Lake. Alexandra Steffen
- Temporal Trends of Persistent Organic Pollutants and Metals in Ringed Seals from the Canadian Arctic Derek Muir, Michael Kwan & Marlene Evans
- Temporal and Spatial Trends of Legacy and Emerging Organic and Metal Contaminants in Canadian Polar Bears Robert Letcher
- Time-trend studies on new and emerging persistent halogenated compounds in beluga whales from Hendrickson Island and Pangnirtung Gregg Tomy.
- Temporal Trends of Heavy Metals and Halogenated Organic Compounds in Arctic Marine Mammals (beluga, narwhal and Walrus) Gary Stern (DFO)
- Temporal Trends of Contaminants in Arctic Seabirds Eggs Birgit Braune
- Temporal Trends and Spatial Variations in Persistent Organic Pollutants and Metals in Sea-run Char from the Canadian Arctic
- Temporal Trends of Persistent Organic Pollutants and Mercury in Landlocked Char in the High Arctic Derek Muir, Günter Köck & Marlene Evans
- Arctic Caribou and Moose Contaminant Monitoring Program Mary Gamberg

Communication Projects (8 Inuit projects)

So far this year ITK has guided researcher in various environmental monitoring programs on how to communicate to communities, translating scientific information, making links to other research programs, encouraging capacity building and funding from Nasivvik. ITK will continue to assist both the researchers and the Inuit regions and communities with the conclusion of these projects.

- Member of both the blood monitoring committees to provide feedback on communication material. Face to face meetings and teleconference calls.
- Work with Derek Muir and Marlene Evans on developing community hand out sheets
- Worked with Gary Stern and Lisa Loseto on presenting findings back to Inuvialuit communities
- Air Measurement in Alert: Involved with NCP researchers in developing communication and capacity building.
- The Inuit Health Survey
- Nunavik Cohort Study
- Environmental monitoring proposal, seals, belugas, narwhal, polar bears and char.
- Nunatsiavut Ringed Seal Program
- IRA coordination
- Nunatsiavut communication material
- Contaminant communication in ISR

Community Based Monitoring (2 Inuit lead projects)

Nasivvik Projects include:

- Cindy Hague – Muskox Herd Health Surveillance in the Kitikmeot Region
- Randi Anderson – Chronic stress in ringed seals of the Hudson Bay: Implications on a subsistence hunting staple
- Rebecca Mearns – Exploring Land Camps as an Educational and Research Tool – A Case Study in Gjoa Haven, NU
- Sonja Ostertag – Mercury Accumulation in Beluga Whales (Delphinaterus leucas):
  - Potential impacts on neurochemistry, behaviour and human health
- Melanie Lemire – The muktuk dilemma: Benefits and risks of high selenium intake in Nunavik Inuit population

Other Nasivvik funded projects include

- Nunavik Child Development Study
- Nunavik Musk ox zoonosis disease and contaminants monitoring
- Inuvialuit Ethnobotony Project
- Healthy Lands, Healthy Ice, Healthy Life
- Integration of scientific knowledge into Inuit Knowledge
- Food Security project
- Drinking Water Quality in Nunavik: Health impacts in a climate change context
- Development of illustrated Inuit food guide and Canadian Arctic food database
- Contaminants in Hopedale Labrador
- Assessing second hand smoke exposure in Aklavik home

The third funding for ITK comes from the National Coordination blueprint where ITK was committed to providing a coordination role for Inuit to attend the both the IPY workshop in April 2012 and the ArcticNet AGM in Vancouver December 2012. Led by the Department of Environment and Wildlife, an internal coordination committee was formed with representatives from the Inuit Qaujisarvingat: Inuit Knowledge Centre (IQ), Health and Social Development, Communications and Finance. All activities led by ITK were a joint effort between these departments.

Over 120 Inuit were in attendance at IPY. With coordination efforts from ITK staff and AANDC, Inuit were involved in many areas of the conference. From oral presentations and posters, to booths, crafts, and performances, the Inuit presence was noticeable and appreciated.

i. Indigenous Knowledge Exchange

The Indigenous Knowledge Exchange (IKE) was an Indigenous specific program which highlighted presentations from various Circumpolar Arctic regions. The IKE program was selected by a steering committee made up of representatives from Indigenous organizations across the globe. The IKE Steering committee met several times during the months leading up to the conference to ensure the planning and selection of presentations was appropriate and diverse to represent an equal balance of the various arctic regions involved in IPY research.

The ITK representative on this committee was the Director of Environment and Wildlife, John Cheechoo. John also facilitated the session on Wildlife Management: Co-Management and Decision Making.

The Indigenous Knowledge Exchange had 9 session theme areas as follows:

- Wildlife Management: Co-management Processes and Decision Making
- Wildlife and Land Use Management
- Arctic Lavvu Dialogue: Indigenous Leaders Roundtable on Climate Change

- Indigenous Youth Leaders on Climate Change
- Youth and Capacity Building
- Tools for Knowledge Transfer
- Indigenous Knowledge: From Understanding Other Ways of Knowing to Indigenous Participation in Research in the Arctic, including an IQ hosted Panel: Research to Action in Inuit Nunangat: Inuit Perspectives and Legacy Post-IPY (please see Appendix A for more details)
- Food Security and Health
- Policy and Governance

ITK Coordination of Inuit Participants at IPY

Out of the many Inuit who attended the conference, ITK played a role in coordinating some of these participants. Through funding from ArcticNet and the Northern Contaminants Program, ITK led the selection process (through land claim regions) and coordination of full travel and accommodations for 9 regional representatives. We were also able to fund students from the Ottawa based school Nunavut Sivuniksavut, in offering them free accommodations for the duration of the conference.

Led by Kendra Tagoona (Dep't of Environment and Wildlife), we ensured their experience at IPY was a success. ITK acted as a main point of contact for these participants and assisted them in choosing sessions, meeting other Inuit, and participating fully in the conference. Several of these participants were selected based on their involvement with IPY research and to assist with poster and oral presentations.

Inuit Qaujisarvingat: The Inuit Knowledge Centre (IQ) at IPY

The Inuit Qaujisarvingat: Inuit Knowledge Centre, the research centre at ITK, played a large role at the conference. IQ activities included oral and poster presentations, hosting a panel as part of the IKE, and curated a photo exhibit entitled Unikkaavut Ajjitiqut (Our Stories Through Pictures)

Polar Lines: The Inuit Editorial Cartoon Exhibition ITK had the opportunity to display this popular exhibit, which was located in the Indigenous Knowledge Exchange presentation area. In celebration of ITK's 40th anniversary, this humorous exhibit was developed. The exhibit displays 100 cartoons which are organized in 10 thematic panels, and span 50 years of Canadian history. It was a hit at IPY as passers-by stopped to laugh and enjoy the political satire, while teaching viewers a bit about Inuit-government relations.

Inuit Tapiriit Kanatami Booth: The ITK newly upgraded booth, made its premier at the IPY Conference. The booth provided ITK staff as well as other Inuit, a meeting spot within the busy atmosphere of the conference space. ITK staff rotated shifts to sit at the booth and represent ITK, hand out resources and network.

Inuit Tapiriit Kanatami- Private Rest/Meeting Room

ITK requested an Inuit-only meeting room for the duration of the week. Many Inuit participants stopped at the room to relax, meet with friends, and hold side meetings. One of the highlights of this meeting space was a youth gathering with ITK President (at the time) Mary Simon. The room became very useful in providing a space for planned or spontaneous meetings throughout the conference

The level of Inuit participation and attendance at IPY was much higher than anticipated, and ITK was happy to assist those travelling to Montreal and ensure Inuit got the most out of the conference. It was a busy week for all and in the end it was well worth it. ITK would like to thank all of our funders and partners - Aboriginal Affairs and Northern Development Canada the Northern Contaminants Program for making it possible for ITK Staff and Inuit from Canada's northern regions to attend and experience the International Polar Year Conference 2012.

Also ITK received funding to attend the ArcticNet ASM. ITK has been hearing from the communities and regions that information that is given to the communities need to be placed in a greater overall research context. Inuit involvement at this ArcticNet ASM 2012 meeting will allow Inuit to understand other research ongoing in their land to better help place the NCP contaminant message. Climate change, food security, animal health will all be important information for Inuit to learn and the NCP recognizing this important capacity building event to provide funds for Inuit to attend this meeting. Inuit will be in a better position to help administer and facilitate delivering difficult information, making it understandable, providing Inuit with the ability to make informed proper choices, and to continue practicing traditional methods of hunting, and in effect preserving our culture.

This meeting will also provide the chance for the IRA to play a critical role in the development and training of the other Inuit so they can help in the delivery of results and preparing communities for NCP researchers. Also critical is ITK's involvement with Nasivvik in ensuring that essential capacity that can be built with the communities and regions are developed and to one day shape Arctic research to that which is done by Inuit for Inuit. NCP is considered a major contributor to this vision

ArcticNet annual science meeting is an excellent opportunity for Inuit to come and learn about research that is being conducted both from the ArcticNet program as well as overlap research with the Northern Contaminants Program. This funding provided financial support for ITK to organize the participation of approximately 10 Inuit to ArcticNet ASM 2012. Increasing the engagement and visibility of Inuit at ArcticNet greatly enhanced the Annual Science Meeting (ASM) and allowed for an Inuit specific session such as the topical session on community-based research. Having a large Inuit Delegation present at ArcticNet also increased opportunities for Inuit-Science knowledge exchanges.

General NCP Activities

General meetings

- Chan proposal meeting
- IKC meetings
- NICOH
- Food Security Working Group
- Gina Muckle Results group
- CINE BOD meeting
- Indoor Air Quality Study
- Health Canada Environment health guides
- ICC conference
- Chemical Management plan
- CEC program
- Alaska health forum
- ITK public Health meetings

ITK's internal Research Team met to share information and discuss research topics of interest to Inuit. The Team works collaboratively, consisting of members from the five departments within ITK (Health Socio-Economic Development, Wildlife and Environment- The Inuit Knowledge Center, Communications, and Executive), and focuses on improving the practice, process, networking, and communication of Arctic and Inuit research. The Team develops training for and works collaboratively with the Inuit Research Advisors (IRAs), Regional Contaminants and Health Committees (RCHCs), and other research groups in the Inuit regions in order to further Inuit engagement in research. With this network, the ITK research team can support and promote community based research activities and advocate for the work at a national level. The research team reports to the respective directors and through them to the ITK Management and Board of Directors.

Examples of the projects the Team is currently engaged in include:

- Advising researchers and wildlife programs of the recent ITK BOD resolution towards the ethical treatment of polar bears. Over the next few months the Team will be informing research programs partnering with Inuit of this resolution and working with them to identify alternative methods of conducting research;
- Working with researchers, the ISR and Rebecca Pokiak in the community of Tuktoyaktuk to assemble and communicate beluga research information;
- Developing training modules for Inuit Research Advisors;
- Developing partners and providing direction for the IPY project Arctic Culture, Resilience, and Caribou.

One of the main duties of the ITK research team this year was the development of the Inuit Research Advisors (IRA's) manual. This purpose of this manual is to provides information to assist and support the IRAs in providing high quality research support to Inuit regions and communities. It is ITK's hope that the IRAs, will find this manual a useful tool to support and enhance what they are already doing. The goal of this manual is to provide information and tools that the IRAs can refer to on a day-to-day basis. In particular, it is a place where IRAs can easily look for information about the following:

- day-to-day tasks and responsibilities
- Documents and resources
- Descriptions of Funding Organizations
- IRAs support and guidance mentors
- organizations involved in research in Inuit regions and communities
- What is research and how is research conducted in Inuit regions and communities

The information found in this handbook was compiled by Inuit Tapiriit Kanatami (ITK) with input from the IRAs, their host organizations in each of the four Inuit land claim regions, the programs that fund the IRA positions and from other Inuit organizations involved in northern research.   An interactive guide such as this, benefits greatly from any additional feedback.

IRA's are certainly one of the key success of the NCP but in order for the IRA's to be successful they need good mentoring and support this comes from the very heart of NCP program with its development and operation of the Regional Contaminants Committees. Every year ITK actively participates on these committees to ensure Inuit needs and concerns are met. This year's efforts began with the continued development of the Regional Contaminant Committee in the region of Nunatsiavut.

Developing Partnerships with Northerners

The ITK has been and will continue to act as liaison between communities/regions and NCP government partners and researchers and to advocate and advise on securing and strengthening these relationships.

Activities include:

- Working closely with each RCC
- Building contacts with Nasivvik
- Building networks with Nunavut Sivuniksavut and NCP researchers
- Building networks in Alaska
- Building new Networks with the new government in Nunatsiavut

Capacity-building, Employment and Training Opportunities

ITK has continued to work with the NCP partners and Inuit in the regions to enhance the level of involvement and employment of community members in all NCP activities. Extensive use is made of local capabilities, and a mix of small and large projects has been useful in capacity-building and skills bases at the community level as well, local people gain training and employment through working with researchers.

Capacity building at the regional level has also been successful, primarily through involvement in policy and research activities with ITK and the other regional organizations. Development of co-management and wildlife policy has been particularly useful under the general rubric of the NCP.

Inuit Circumpolar Council – Canada Activities in Support of Circumpolar and Global Contaminant Instruments and Activities

Conseil circumpolaire inuit – Activités du Canada en appui aux activités et aux outils visant les contaminants circumpolaires et mondiaux

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Abstract

This report outlines ICC Canada's activities funded by Northern Contaminants Program (NCP) in the fiscal year of 2012/2013. ICC Canada is working nationally and internationally to address the issue of contaminants in the Arctic. National activities include support to the NCP in the Management Committee, blueprint and proposal reviews, Results Workshop participation, and work on contributions for the Canadian Arctic Contaminants Assessment Highlights Report III. Internationally, ICC Canada was very engaged in work related to

Résumé

Ce rapport fait état des activités du Conseil circumpolaire inuit (CCI) Canada financées par l'intermédiaire du Programme de lutte contre les contaminants dans le Nord (PLCN) pendant l'exercice 20122013. Le CCI Canada travaille à l'échelle nationale et internationale à régler les questions relatives aux contaminants dans l'Arctique. Les activités nationales comprennent le soutien du PLCN au sein du comité de gestion, un plan et l'examen des propositions, la participation à des ateliers sur les résultats, et des travaux sur les contributions à la phase III du

the United Nations Environment Programme (UNEP), and was part of the Canadian delegation to the 4th and 5th Intergovernmental Negotiation Committee (INC) meeting on a legally-binding agreement for mercury in Uruguay (June/July 2012) and Geneva (January 2013), respectively. ICC (Greenland) also attended the meetings independently, and made interventions in this capacity. Work on persistent organic pollutants (POPs) is ongoing, with ICC Canada attending the 8th POP Review Committee (POPRC) in October 2012. ICC Canada continued to support Arctic Council activities, such as providing input for the changes to the Adaptation Actions for a Changing Arctic (AACA) proposal during and after the AMAP WG meeting in Stockholm (Oct 2013). ICC Canada continues to be active on the Sustaining the Arctic Observing Networks (SAON) Board and is now also a member of the SAON Executive Committee. ICC Canada worked with Health Canada on an ICC Chapter for the AMAP Health Expert Group risk communication report, and hopes to continue working on the circumpolar Inuit perspective on risk communication soon.

Rapport de l'évaluation des contaminants dans l'Arctique canadien (RECAC III). À l'échelle internationale, le CCI Canada a beaucoup investi dans des travaux liés au Programme des Nations Unies pour l'environnement (PNUE), et il a fait partie de la délégation canadienne présente à la 4e et à la 5e réunion du Comité de négociation intergouvernementale (CNI-4 et CNI-5) portant sur l'établissement d'accords juridiquement contraignants sur le mercure, qui ont respectivement eu lieu en Uruguay (juin-juillet 2012) et à Genève, en Suisse (janvier 2013). Le CCI Groenland, qui a également participé aux réunions en tant qu'organisme indépendant, est intervenu à ce titre. Les travaux sur les polluants organiques persistants (POP) sont en cours, et le CCI Canada a participé au 8e Comité d'étude des polluants organiques persistants (CEPOP) en octobre 2012. Le CCI Canada a continué de soutenir les activités du Conseil de l'Arctique, par exemple en commentant les modifications à la proposition de l'initiative axée sur les mesures d'adaptation pour un Arctique en évolution (Adaptation Actions for a Changing Arctique [AACA]) pendant et après la réunion du groupe de travail du Programme de surveillance et d'évaluation de l'Arctique (PSEA), à Stockholm (octobre 2013). Le CCI Canada continue d'être actif au sein du conseil des réseaux d'observation de longue durée de l'Arctique (SAON), et il est maintenant membre du comité exécutif des SAON. Le CCI Canada a collaboré avec Santé Canada à la rédaction d'un chapitre du rapport de communication des risques du Groupe d'experts sur la santé humaine (GESH) du PSEA, et il espère continuer de travailler au point de vue circumpolaire inuit sur la communication des risques sous peu.

Key Messages

- ICC Canada worked actively to support NCP by working on the Management Committee, Environmental Trends and Monitoring Subcommittee, and supported work on the CACAR III Highlights report.
- ICC Canada was part of the Canadian delegation to the Intergovernmental Negotiation Committees (INC 4 and 5) meetings on a legally-binding agreement for mercury.
- ICC Canada attended the 8th POP Review Committee meeting and provided input in POPRC working group documents.
- ICC Canada actively contributed to Arctic Council related work, attended the AMAP Working Group meeting and the SAON Board meeting, and is now also represented in the SAON Executive Committee.
- Work on mercury isotopes in ice cores and snow samples to identify mercury pathways and sources to the Arctic has been continued with separate funds from NCP's Environmental Trends Envelope. A separate report will be prepared for this work.

Messages clés

Le CCI Canada a travaillé activement à soutenir le PLCN en siégeant au comité de gestion et au sous-comité sur les tendances et la surveillance environnementales, et a appuyé les travaux sur le RECAC III.

Le CCI Canada a fait partie de la délégation canadienne présente à la CNI-4 et à la CNI-5, qui portaient sur l'établissement d'accords juridiquement contraignants sur le mercure.

Le CCI Canada a pris part à la 8^{e} réunion du CEPOP et fournit une rétroaction sur les documents du groupe de travail du CEPOP.

Le CCI Canada a participé activement aux travaux du Conseil de l'Arctique, à la réunion du groupe de travail du PSEA et à la réunion du conseil des SAON. Il est maintenant représenté au sein du comité exécutif des SAON.

Les travaux sur les isotopes du mercure dans les carottes de glace et les échantillons de neige visant à définir les tendances et les sources du mercure vers l'Arctique se poursuivent grâce aux fonds distincts de l'enveloppe budgétaire accordée aux tendances environnementales du PLCN. Un rapport sur ces travaux distinct sera rédigé.

Objectives

Short-term objectives of ICC's activities are:

- to ensure that Inuit are aware of global, circumpolar and national activities and initiatives on contaminants
- that Inuit viewpoints and interests are represented in contaminant-related matters, and are considered and included in relevant research, reports, assessments and meetings pertinent to policy development
- to ensure that scientific research in the Arctic is addressing Inuit needs and is done with proper Inuit support and involvement

Long-term goals are:

- to ensure Inuit have the capacities, resources and knowledge necessary to support their participation and involvement in national and international policy development on contaminant issues,
- to assist in the development of a framework that allows for sustained and integrated community-based research and includes the use of traditional and scientific knowledge, and, ultimately,

- to reduce, and if feasible eliminate, contaminants in the Arctic environment

Introduction

Inuit are Arctic Indigenous peoples living in Russia (Chuktoka), the U.S.A. (Alaska), northern Canada and Greenland. The Inuit Circumpolar Council (ICC) was founded in 1977, when Inuit across the circumpolar Arctic recognized that they need to have a united voice to represent them internationally, and to represent circumpolar Inuit in the respective countries. Since then, ICC has been growing into an internationally renowned organization with offices in each of the four countries. ICC is working successfully to address Inuit concerns on matters and overarching issues such as health, the environment, and culture. Among ICC's principle goals are the promotion of Inuit rights and interests on an international level and the development and encouragement of long-term policies that safeguard the Arctic environment.

A very important issue for Inuit is contaminants which undergo long-range transport, bioaccumulate in the Arctic ecosystem and lead to very high concentrations in some Inuit populations, potentially impacting their health and well-being. Funding by the Canadian government, and in particular the Northern Contaminants Program (NCP) of the Department of Indian and Northern Affairs (INAC), has enabled ICC Canada to work effectively on addressing the issue of contaminants in the Arctic. ICC Canada is part of the NCP Management Committee, is directly involved with contaminant research in the Arctic, works within the Arctic Monitoring and Assessment Programme (AMAP) of Arctic Council, and represents Inuit at the United Nations Environment Programme (UNEP) and related meetings.

This is the year-end report on activities undertaken by ICC from April 1, 2012 - March 30, 2013, which is a delivery requirement detailed under the 2012/13 NCP contribution agreement.

Eva Kruemmel is the Senior Policy Advisor on Environment and Health for ICC Canada and is the lead on NCP and related files. Duane Smith continues to support and speak to the findings and model of the NCP in international meetings. Further assistance has been provided by Leanna Ellsworth and Pitseololaq (Pitsey) Moss-Davis, as appropriate and necessary. Yvonne Moorhouse provides administrative support. Stephanie Meakin as Science Advisor continues to support Eva Krümmel when needed.

Detailed Activities in 2012-2013

1. NCP

Proposed activities:

a. General NCP work:

- attendance of Results Workshop, Management Meetings and related work, as covered in Capacity A and B proposals

Work undertaken:

- Eva Kruemmel attended the NCP Research Management Meeting April 11 – 13, 2012 in Ottawa, reviewed proposals and documents as required and provided input and comments. ICC Canada was very engaged in preparations for the NCP Results Workshop, which was scheduled to take place in September 2012 in Inuvik. ICC Canada participated in the planning committee teleconferences and related work, and Duane Smith and Eva Kruemmel planned to attend the meeting. However, this Result Workshop was first postponed, and later cancelled. ICC Canada is planning to attend the next Results Workshop, planned for Sep 24 – 26, 2013 in Yellowknife.

ICC Canada reviewed the documents in preparation of the Research Management Meeting October 16 – 17, 2012 in Whitehorse, which was attended by Leanna Ellsworth.

Proposed activities:

b. CACAR III: Reports on POPs, mercury and the highlights report

   – Input into the highlights report preparation, work on advisory committee
   – Reviewing of reports/chapters as applicable
   – Participation of related meetings and teleconferences

Work undertaken:

- Eva Kruemmel reviewed chapters of the POPs report and provided comments. She also participated in teleconferences of the advisory committee for the highlights report, reviewed the documents and provided comments.

Proposed activities:

c. Participation in Risk Communication sub-committee:

   – ICC Canada will participate in meetings, teleconferences and/or related work as required and possible.

Work undertaken:

- At the last Manager Meeting it was decided that the committee would be newly established, but the membership and when it would begin its work has not yet been established.

Proposed activities:

d. Continued participation in NCP Evaluation Working Group:

   – Participation in meetings/ teleconferences and reviewing of documents as required and possible.

Work undertaken:

- The NCP Evaluation Group had no further activities in this fiscal year.

2. AMAP

Proposed activities:

e. General:

   – Participation at WG and HoD meetings, pending resource availabilities
   – Contributions to reviews and other documents, as applicable, including work for the development of the Arctic Change Assessment (funding for this was not included in the proposal, as the level of effort was going to be determined after approval of the project.).

Work undertaken:

- Duane Smith attended the last AMAP HoD meeting (January 31st – February 3rd, 2012 in Victoria, B.C.), and Eva Kruemmel attended the AMAP WG meeting October 3 – 5, 2012 in Stockholm, Sweden.

ICC Canada was part of the organization group of the AACA workshop last fiscal year, and participated at both the Arctic Resilience Report (ARR) and AACA meetings. Eva Kruemmel contributed to the drafting of the AMAP AACA response proposal at and following the AMAP WG meeting. ICC Canada also provided input into the AACA – Part B report that Canada prepared, had a teleconference with Environment Canada about the report and sent ICC Canada reports with related information to Environment Canada. ICC Canada remains very interested in contributing to the AACA throughout the Canadian Chairmanship of Arctic Council and beyond.

Proposed activities:

f. SAON:

   – Attendance of relevant meetings of the SAON Board (pending funding) and Canadian group, teleconferences
   – General work on SAON Board, such as reviewing of documents
   – Work within the CBM group, participation in workshops (pending funding) and further work on SAON tasks

- Coordination for CBM review (task proposal with SAON), progress reports, etc.

Work undertaken:

- Eva Kruemmel attended the first Sustaining the Arctic Observing Network (SAON) Board meeting held in January 2012 in Tromsø, and the second meeting, October 1 – 2 in Potsdam, Germany. She was in frequent email contact and has held several teleconferences and meetings with partners on the ICC-led SAON community-based monitoring (CBM) task proposal, including Exchange for Local Observations and Knowledge of the Arctic – ELOKA/Inuit Knowledge Center - IKC (Peter Pulsifer), Conservation of Arctic Flora and Fauna – CAFF WG (Michael Svoboda, Tom Barry) and Aleut International Association – AIA (Jim Gamble). Eva Kruemmel (with Peter Pulsifer), Tom Barry and Jim Gamble produced a progress report on their CBM work in preparation of the first SAON Board meeting (available at http://www.arcticobserving.org/tasks/108).

- ICC Canada was able to engage Noor Johnson as a task lead for the ICC-led SAON proposal, she is conducting this work as part of her post-doctoral studies at Brown University in Boston, Massachusetts. The Department of Fisheries and Oceans (DFO) provided funding to assist with Dr. Johnson's travel to the SAON Board meeting, and Eva Kruemmel and Noor Johnson gave an update on ICC's work on CBM and the task proposal at the Board meeting (the presentation is available at http://www.arcticobserving.org/board/board-meetings/125). Eva and Noor also contributed to a breakout group on CBM, where Noor acted as rapporteur and upon reconvening of the plenary discussions, presented the outcomes to the whole group. The SAON meeting report is available at http://www.arcticobserving.org/index.php?option=com_content&view=article&id=95&Itemid=100024. At the SAON Board meeting, the terms of reference (ToR) was adopted, which called for the establishment of a SAON Executive Committee, consisting of the SAON Chairs, a Permanent Participant (PP) and Arctic country representative, and the SAON secretariat (consisting of AMAP and IASC). ICC nominated Eva Kruemmel as their representative for the SAON Executive Committee, which was supported by other PP organizations. Starting in December 2012, Eva Kruemmel has therefore been a member of the SAON Executive Committee, participated in all teleconferences which are held on a regular basis, and provided input into relevant documents. She also is currently leading the development of a strategic white paper on community-based monitoring (CBM), which will be used for directional discussions at the upcoming SAON Board meeting (to take place April 29th in Vancouver, B.C.).

Further SAON-related activities:

- Eva Kruemmel and Noor Johnson attended a workshop on data coordination that was held on April 27th 2012, after the IPY Conference in Montreal (http://www.arcticobserving.org/index.php?option=com_content&view=article&id=92:workshop-on-arctic-data-coordination-at-ipy-2012-montreal&catid=28:old-news&Itemid=73).

- Both Eva Kruemmel and Noor Johnson were invited by the European Environment Agency (EEA) to attend the Eye on Earth 1st User Conference in Dublin, Ireland, March 4-6, 2013. Eva Kruemmel's participation was funded by the EEA, and Noor Johnsons' travel was supported by the ArcticNet Science to Policy project, which ICC has been contributing to. At the conference, Eva presented on ICC's activities related to CBM, and Noor presented on the progress of ICC's SAON task. The presentations are available at:

- http://www.eyeonearth.org/en-us/Documents/Eva.Krummel.arctic_session.5.3.13.pdf http://www.eyeonearth.org/en-us/Documents/Noor.Johnson.Arctic_session.5.3.13.pdf

Proposed activities:

g. AMAP Health Expert Group:

- Participation at relevant meetings (where possible, for example the meeting in Montreal, April 2012) and consultations with the group.
- Reviewing and contributing to papers produced by the group.

Work undertaken:

- Leanna Ellsworth and Eva Kruemmel participated at the AMAP Health Expert Group (HHEG) meeting that took place during the IPY Conference April 23 - 25 2012 in Montreal. ICC Canada also participated at the AMAP HHEG teleconference October 24th, 2012. Eva Kruemmel provided information about the outcomes of the 8th POPRC meeting at the teleconference, and sent a summary of the POPRC information to the HHEG secretariat for inclusion in the meeting minutes.
- ICC Canada produced two reports on risk communication during the last fiscal year, which were funded by Health Canada. The report on ICC Canada's experience on international risk communication will be included as a chapter in the risk communication report of the AMAP Human Health Assessment Group. Eva Kruemmel sent a draft of the chapter to Jason Stow from the NCP secretariat and Eric Loring from ITK for comments and revised the chapter accordingly. The risk communication report is being compiled and edited by Tara Leech.
- Eva Kruemmel and Leanna Ellsworth also had several discussions with Shawn Donaldson and Tara Leech of Health Canada about the continuation of the communication work, which will hopefully be done with support from the risk communication group of the NCP.

3. UN related

Proposed activities:

h. Global mercury agreement:

- Attendance of INC-4 in Punta del Este, Uruguay, from 25 – 29 June, 2012 and INC-5 in February 2013
- Consultations with the government, UNEP, scientists and partner organizations, attending of teleconferences and meetings
- Reviewing of documents, researching papers and general mercury related research
- Development of position papers and assistance in policy development

Work undertaken:

- Eva Kruemmel participated in consultations held by Environment Canada and submitted detailed ICC Canada stakeholder comments in preparation for INC-4 and INC-5 (Attachments 1 and 2, respectively). She attended INC-4 and INC-5 as part of the Canadian delegation, and participated in related teleconferences. During INC-4, she particularly assisted the Canadian delegation during contact groups on section J of the proposed treaty text (Awareness raising, research and monitoring, and communication of information). During INC-5, Eva Kruemmel especially assisted the Canadian delegation during the contact group meetings on mercury emissions and releases. Eva Kruemmel also worked with ICC Greenland (Parnuna Egede), who attended the meetings as an independent observer, and made interventions on the implications of atmospheric mercury emissions for Inuit (Attachments 3 and 4). After the meetings, as part of the agreement to be on delegation, Eva Kruemmel prepared meeting reports to Environment Canada which summarized the meetings from the view of ICC Canada and provided recommendations for further consultation. The report from INC-5 highlighted the importance of the NCP for monitoring mercury levels in the Arctic. The meeting reports are attached to this report (Attachments 5 and 6).

- ICC Canada also prepared press releases that were distributed widely, and after INC-4, ICC Canada sent additional information to CBC upon request. Kirt Ejesiak (ICC's Vice President) gave an interview in Iqaluit that was aired as part of a report about the mercury negotiations and ICC's activities at INC-4 on CBC's news show "Northbeat". The press releases are attached to this report (Attachments 7 and 8).

Proposed activities:

i. POPRC:

- Attendance of POPRC -8, in Geneva, Switzerland, October 15 – 19, 2012
- Contribution to POPRC working groups as required and possible
- Reviewing of documents and scientific papers
- Consultations with government, partner organizations, scientists
- Writing of reports, position papers etc.

Work undertaken:

- Eva Kruemmel attended the 8th POPRC meeting, which took place in Geneva, October 14 – 19, 2012, and gave an intervention on short-chained chlorinated paraffins (SCCPs), which mentioned NCP's work (Attachment 9). She also continuously contributes to intersessional POPRC work, for example by reviewing and commenting on POPRC documents (for example on draft Risk Profiles and Risk Management Evaluations for several POP candidates, such as chlorinated naphthalenes (CN) and pentachlorophenol (PCP) / pentachloroanisole (PCA)), and sends applicable scientific information to the POPRC secretariat. Eva Kruemmel has been in contact with NCP and AMAP scientists and other partner organizations to gather information on new POP candidates and the state of the science and notified them about POPRC outcomes. Any new information she receives from the scientists on POP candidates is incorporated into POPRC documents and/or send on to the POPRC secretariat. This enables a very direct flow of scientific information from the NCP to the POPRC and vice versa. Eva Kruemmel sent the NCP secretariat information about the status of the POP candidates after POPRC-8 (Attachment 10), which was included in the NCP call for proposals and appropriate blueprints.

Proposed activities:

j. LRTAP:

- Providing stakeholder comments to government when possible
- Consultations with government, partner organizations, researchers
- Reviewing documents

Work undertaken:

- There have been no opportunities for input this year with regards to LRTAP.

Other UN-related activities:

ICC Canada participated in a webinar to prepare for COP 6 of the Stockholm Convention on POPs organized by Environment Canada and Health Canada on February 13th, 2013, and submitted detailed stakeholder comments to Environment Canada on "Key Issues of the 6th Meeting of the Conference of the Parties (COP6) of the Stockholm Convention on Persistent Organic Pollutants (POPs), April 28 – May 10, 2013". The comments also highlight the importance of the NCP to assess the effectiveness of the Stockholm Convention, and are attached to this report (Attachment 11).

4. IPY Conference

- Attending of conference in Montreal, April 22 – 27, 2012
- Preparatory work
- Presentation of talk , co-chairing of mercury session, judging of posters for contaminant session

- Preparation of post-conference meeting report and other material as required

Work undertaken:

- Stephanie Meakin was a member of the IPY International Steering Committee and the Indigenous Knowledge Exchange Steering Committee.

- ICC Canada staff and political leadership attended the conference, maintained a booth with documents to disseminate and participated in several panels and sessions:

  – Duane Smith spoke on panels in sessions on "*Adaptation and Change", and "The future of monitoring networks, research and prediction systems to provide services in Polar Regions"*.
  – Stephanie Meakin co-convened sessions on "*Indigenous and Local Knowledge (Research Methods/Technological Innovations*", "*Ways of Knowing and Being: Cultural, Social, and Political Considerations*" and "*Indigenous Knowledge Exchange Food Security and health"*.
  – *Eva Kruemmel presented preliminary results about ICC Canada's mercury study ("Mercury in Ice and Water from Penny Ice Cap in Auyuittuq National Park, Baffin Island, Nunavut")* and co-convened a session on Contaminants in Polar Environments.

5. Other mercury and POPs related work

Proposed activities:

- meetings, teleconferences and consultations with researchers and partner organizations about contaminant research

- reviewing scientific papers, reports, assessments, data and other documents to develop briefing notes, brochures and other information material

Work undertaken:

- ICC Canada and its partners from the University of Ottawa and Trent University received NCP funding for the continuation of the study on mercury pathways in the Canadian Arctic (M-20: Spatial and temporal variations of Hg isotope ratios in ice cores across the Canadian Arctic). As part of this and earlier work, a paper co-authored by Eva Kruemmel was recently published in a peer-reviewed journal (see References). A year-end report on this study will be prepared separately.

- As part of the general mercury work, Eva Kruemmel reviewed two technical mercury reports co-produced by AMAP and UNEP and provided comments. Eva Kruemmel further undertook literature searches, contacted scientists for information as needed and reviewed publications for input into work on UNEP meetings, briefing notes, and other relevant items.

6. Communication

Proposed activities:

- development/revision of communication strategy with ITK, Inuit Tuttarvingat and other partners as appropriate

- development of communication materials such as brochures, fact sheets, YouTube clips or others

Work undertaken:

- Unfortunately, funding for Inuit Tuttarvingat (as part of the National Aboriginal Health Organization) was cut by Health Canada in this fiscal year, and work with them was discontinued as of their closure in June. Nevertheless, ICC Canada's efforts to work on a communication strategy are ongoing, particularly with regards to mercury. Work on this will likely be tied to risk communication efforts with ITK and the Inuit Regions, as well as within the NCP and the AMAP HHAG.

- ICC Canada continues to communicate its work to Inuit partner organizations and -regions through regular meetings and briefing notes (e.g. ICC Canada Board meetings, meetings of the National Inuit Committee on Health (NICoH), the

National Inuit Committee on Climate Change (NICCC), the Inuit Knowledge Centre National Committee, etc.). ICC Canada further sends out press releases on the various topics, as well as provides newsletter contributions (for example to Shannon O'Hara at the ISR, and/or ICC Alaska's newsletter).

Expected Project Completion Date:

Work is ongoing

Acknowledgments

NCP was acknowledged in all presentations prepared as part of the funded work.

References

Zdanowicz, C., Krümmel, E. M., Lean, D., Poulain, A. J., Yumvihoze, E., Chen, J., and Hintelmann, H. 2013. Accumulation, storage and release of atmospheric mercury in a glaciated catchment, Baffin Island, Canada. *Geochim.Cosmochim. Acta. 107:316-335*.

Attachments available from NCP Secretariat upon request

- INC-4 stakeholder comments to EC
- INC-5 stakeholder comments to EC
- INC-4 intervention
- INC-5 intervention
- INC-4 meeting report
- INC-5 meeting report
- INC-4 Press release
- INC-5 Press release
- POPRC-8 intervention
- POPRC-8 information for NCP
- Stockholm Convention COP6 comments to EC

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