Synopsis of Research

Conducted under the 2010–2011 Northern Contaminants Program

Aboriginal Affairs and Northern Development Canada
Affaires autochtones et Développement du Nord Canada

Canada

Synopsis of Research Conducted under the 2010–2011 Northern Contaminants Program

Published under the authority
of the Minister of Aboriginal Affairs
and Northern Development and
Federal Interlocutor for Métis
and Non-Status Indians
Ottawa, 2011

www.aandc-aadnc.gc.ca
1-800-567-9604
TTY only 1-866-553-0554

QS-8602-100-BB-A1
Catalogue No. R71-64/2010E
ISBN 978-1-100-16962-0

Publié avec l'autorisation du
ministre des Affaires autochtones
et du développement du Nord canadien
et interlocuteur fédéral auprès
des Métis et des Indiens non inscrits
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QS-8602-100-BB-A1
N° de catalogue R71-64/2010E
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Dedication

This Northern Contaminants Program synopsis report is dedicated to our friend and colleague, Marty Bergman. Marty was a pillar in the Canadian Arctic science world whose life was tragically lost as a result of an airplane crash, which took place on August 20, 2011 near Resolute Bay in Nunavut, Canada and killed 12 people. Marty was on his way to Resolute Bay to greet the Prime Minister and Governor General and to show them the newly expanded operations at Polar Continental Shelf Program.

Marty Bergmann was the Director of the Polar Continental Shelf Program (PCSP), Natural Resources Canada, for the past 4 years and also spent a large part of his career as an Arctic Science Manager at the Department of Fisheries and Oceans, Freshwater Institute, in Winnipeg. He was a close friend and colleague to many Arctic researchers and touched so many people's lives throughout his career. He will be deeply missed by all.

Marty's work was internationally recognized and respected. He was the Chair of the Forum of Arctic Research Operators (FARO) and a past chair of the Pacific Arctic Group (PAG). Marty was a true champion of promoting Arctic collaborations and developing the next generation of scientists. His dedication, energy, humour and enthusiasm were only several hallmark characteristics that drew so many people to him.

Marty's enthusiasm for the Arctic was infectious and he inspired us all to do more for the Arctic and its people. He was a warm, passionate person which makes his passing that much more difficult. He always had time to talk to people and share his vision of the Arctic. He was an outstanding individual in all facets of life. Despite living a full life, he still had so much more to give when his life ended so abruptly. He was at least alive to see part of his vision in place with so much interest

Hommage

Ce sommaire du Programme de lutte contre les contaminants dans le Nord est dédié à notre ami et collègue Marty Bergmann. Marty est un ambassadeur de la science dans l'Arctique canadien ayant perdu la vie de façon tragique lors de l'écrasement d'avion le 20 août 2011 proche de Resolute Bay au Nunavut et coûtant alors la vie à 12 personnes. Marty se rendait à Resolute Bay pour rencontrer le premier ministre et le gouverneur général et leur montrer le tout récemment agrandit centre d'opération du Programme du plateau continental polaire.

Marty Bergmann était au cour des quatres dernières années, le directeur du Programme du plateau continental polaire (PPCP) de Ressources naturelles Canada et a passé la majorité de sa carrière en tant que Gestionnaire des sciences Arctiques au sein de l'Institut des eaux douces du ministère des Pêches et Océans à Winnipeg. Il était un ami proche et un collègue pour plusieurs chercheurs Arctiques et a influencé les vies de plusieurs durant sa carrière. Il sera infiniment manqué par tous.

Les accomplissements de Marty sont reconnus et rayonnent internationalement. Il était le président du Forum des opérateurs en recherche Arctique et précédemment le président du groupe Arctique Pacifique. Marty excellait dans la promotion de la collaboration Arctique et développait la prochaine génération de chercheurs. Son dévouement, son énergie, son humour et son enthousiasmes étaient quelques une de ses qualités exceptionnelles amenant les gens vers lui.

Son enthousiasme pour l'Arctique était contagieux et nous inspirait tous à en faire plus pour l'Arctique et sa population. Il était chaleureux et passionné rendant sa perte si difficile. Il avait toujours un instant pour jaser avec les gens et partager sa vision de l'Arctique. Il était un homme remarquable. En dépit d'une vie remplie, il avait encore beaucoup à partager lorsqu'il s'est subitement éteint.

and attention being paid to the Arctic region from all walks of life over the past several years. Marty will live on in our memories and in the significant legacy he has left behind. We will now do our very best to further realize his overall vision for the Arctic.

Néanmoins, il a tout de même eu le privilège de voir la mise en œuvre, au cour de plusieurs années, d'une partie de sa vision de l'Arctique grâce à l'intérêt d'une multitude de personne dans plusieurs domaines d'activités. Marty restera vivant dans nos mémoires et par ses réalisations qu'il laisse aux générations futures. Nous allons maintenant faire de notre mieux pour honorer sa vision de l'Arctique.

Russel Shearer

Chair, Northern Contaminants Program Management Committee,

Chair of the Arctic Council's Arctic Monitoring and Assessment Programme, and

Chair, Research Management Committee, ArcticNet

Russel Shearer

Président, Comité de gestion du Programme de lutte contre les contaminants dans le Nord

Président du Conseil Arctique du Programme de surveillance et d'évaluation de l'Arctique, et

Président, Comité de gestion de recherche, ArcticNet

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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 2010–2011 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 http://www.aadnc-aandc.gc.ca/ncp.

Official Languages Disclaimer
These synopsis reports are published in the language chosen by the researchers. The full reports, which are available on CD-Rom, 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@aandc-aadnc.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 2009–2010 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 http://www.aadnc-aandc.gc.ca/plcn.

Avertissement lié aux langues officielles
Les chercheurs ont rédigé leurs rapports dans la langue de leur choix. Les rapports qui sont disponibles sur CD-Rom 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

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.

Canada's North. As a result, priorities for current and future research are based on an understanding of the species that are most relevant for human exposure to contaminants in the North, and geographic locations and populations that are most at risk.

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

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

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

Dans le deuxième Rapport de l'évaluation des contaminants dans l'Arctique canadien, on trouve une synthèse des résultats du second volet du Programme (PLCN-II), mis en oeuvre de 1998–1999 à 2002–2003. Les recherches menées au cours de ce volet visaient à déterminer les risques et conséquences pour la santé humaine associés au degré actuel de contamination d'aliments clés dans l'Arctique. Pour que l'évaluation des risques soit juste, on a aussi défini et quantifié les avantages des régimes traditionnels. On a aussi mis l'accent sur les activités de communication dans le cadre du PLCN-II. Sous la conduite des organisations autochtones du Nord, le dialogue entre les habitants de la région et la communauté scientifique, amorcé lors du PLCN-I, a continué d'accroître la sensibilisation aux questions liées aux contaminants et la compréhension de celles-ci et a permis d'améliorer la prise en charge de certains problèmes associés aux contaminants à l'échelle locale. En outre, les efforts déployés dans le cadre du PLCN afin d'assurer l'établissement de mécanismes internationaux de contrôle des contaminants sont demeurés un objectif privilégié du second volet. À l'occasion de la Conférence ministérielle de la Commission économique des Nations Unies pour l'Europe, ayant eu lieu à Aarhus, au Danemark, en juin 1998, trente-quatre pays (dont le Canada) ont signé le protocole sur les POP, ayant force obligatoire, dans le cadre de la Convention sur la pollution atmosphérique transfrontalière à longue distance. Le Canada a ratifié l'entente en décembre 1998. Les négociations visant la conclusion d'un accord global sur les POP, ayant force obligatoire, dans le cadre du Programme des Nations Unies pour l'environnement, ont abouti à la signature de la Convention sur les polluants organiques persistants, à Stockholm, en Suède, le 23 mai 2001, par plus de cent soixante pays. Le Canada a

The NCP is directed by a management committee that is chaired by Aboriginal Affairs and Northern Development Canada, 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 Canada). 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 $4.8 million annual research budget comes from INAC and Health Canada.

The NCP Operational Management Guide, available on the NCP website (www.ainc-inac.gc.ca/ncp), 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.

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 indiennes et du Nord Canada (AINC), 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 indiennes et 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 4,8 millions de dollars du PLCN-II proviennent d'AINC et de Santé Canada.

Le Guide de gestion des opérations du Programme de lutte contre les contaminants dans le Nord, que l'on peut consulter sur le site Web du Programme (www.ainc-inac.gc.ca/ncp), 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 généraux sur tous les comités et équipes d'examen du PLCN.

This report provides a summary of the progress to date of research and activities funded by the Northern Contaminants Program in 2010–2011. It is a compilation of reports submitted by project teams, emphasizing the results of research and related activities that took place during the 2010-2011 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 Research; and Communication, Capacity and Research.

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 trois sous-programmes principaux : i) santé humaine; ii) surveillance de la santé des habitants et des écosystèmes de l'Arctique et de l'efficacité des mécanismes internationaux de contrôle; iii) 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.

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 2010–2011. 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 2010–2011. Les chapitres du rapport rendent compte de la portée étendue du programme: Recherche sur la santé humaine, Surveillance et recherche environnementales, Recherche et surveillance au sein des communauté, Communication, sensibilisation et consultation.

Human Health

Disruption of Thyroxine Transport by Persistent Organic Pollutants in Inuit Women of Childbearing Age from Nunavik

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Abstract

Contaminants that are present in the Arctic aquatic food chain may alter brain development in Inuit infants. One possible mechanism involves interference with the thyroid system during the developmental stage by metabolites of persistent organic pollutants that resemble the endogenous hormone L-thyroxine (T4). The disruption of T4 transport has received special attention since some hydroxylated metabolites of polychlorinated biphenyls and polybrominated diphenyl ethers have been shown to bind to transthyretin (TTR), a transport protein involved in supplying the foetus with T4 and transporting T4 across the blood brain barrier to the developing brain. Recently, several other compounds have been identified as binders of TTR and thyroid binding globulin (TBG), another T4 transport that may

Résumé

Les contaminants présents dans la chaîne alimentaire aquatique de l'Arctique peuvent influer sur le développement du cerveau des nourrissons inuits. Un des mécanismes possibles est l'action perturbatrice exercée par des métabolites de polluants organiques persistants ressemblant à l'hormone endogène L thyroxine (T4) sur le système thyroïdien durant le développement. La perturbation du transport de la T4 a particulièrement retenu l'attention depuis qu'on a montré que certains métabolites hydroxylés des polychlorobiphényles et des éthers diphényliques polybromés se liaient à la transthyrétine (TTR), une protéine de transport chargée d'alimenter le fœtus en T4 et de transporter la T4 à travers la barrière hémato encéphalique jusqu'au cerveau en développement. On a identifié récemment plusieurs autres composés qui sont des agents de liaison de la TTR et de la

be involved in supplying the placenta with T4. The objective of this study is to examine whether plasma levels of these compounds are linked to a decrease in the proportion of circulating T4 bound to TTR and/or TBG in Inuit women of childbearing age. Such a relation would strengthen the biological plausibility of a link between exposure to food chain contaminants and adverse effects on brain development in this population.

globuline liant la thyroxine (TBG), une autre molécule de transport de la T4 qui peut approvisionner le placenta en T4. La présente étude visait à examiner si les concentrations plasmatiques de ces composés sont associées à une diminution de la proportion de T4 circulante liée à la TTR et/ou à la TBG chez les femmes inuites en âge de procréer. Une telle relation renforcerait la plausibilité biologique d'un lien entre l'exposition à des contaminants de la chaîne alimentaire et les effets indésirables sur le développement du cerveau dans cette population.

Keys messages

- Contaminants in the marine food chain bind to thyroid hormone transport proteins
- Analysis are underway to verify if this binding alters thyroid hormone status in Inuit women

Messages clés

- Les contaminants se retrouvant dans la chaîne alimentaire marine se lient aux protéines hormonales thyroïdiennes.
- Des analyses sont en cours pour vérifier s'il existe une altération de l'hormone thyroïdienne chez les femmes inuites.

Objectives

The main objective of this study is to investigate relations between plasma concentrations of persistent organic pollutants (and their metabolites) and the amount of thyroid hormones bound to their transport proteins in Inuit women of childbearing age. The secondary objective is to identify the major chemicals other than thyroid hormones that are bound to these proteins.

The specific objectives are:

- To determine the amount of thyroid hormones (L-thyroxine and triiodothyronine) bound to the two major thyroid hormone transport proteins (thyroid-binding globulin and transthyretin) in plasma samples of Inuit women of childbearing age who participated in the Nunavik Health Survey;
- To examine relations between plasma concentrations of possible thyroid transport disrupting chemicals and the amounts of thyroid hormones bound to transport proteins;
- To verify the identity of major xenobiotics bound to each transport protein;
- To complete the panel of thyroid hormone parameters measured in the Inuit Health Survey by measuring TTR and total T4 concentrations in plasma samples from participants.

Introduction

Thyroid hormones, namely L-thyroxine (T4) and its biologically active metabolite, triiodothyronine (T3), are involved in the regulation of the cellular metabolic rate and are essential for the development and differentiation of several tissues, specially the brain (Yen, 2001; Bernal et al., 2003). A small proportion of T4 circulates in the blood as the free form, but most T4 is bound to transport proteins. Thyroxine binding globulin (TBG) is the major T4 transport protein in human plasma and carries about 75% of T4, transthyretin (TTR); the second transport protein, transports about 20% of T4 and finally, human serum albumin, the third transport protein, carries about 5% of T4. The affinity of the three transport proteins for T4 varies greatly, as well as their plasmatic concentration, providing a redundant buffer system for free T4 (Schreiber, 2002). TTR is especially important for maternal to foetal transport of thyroid hormones and for delivery of T4 across the blood brain barrier (Schreiber, 2002). TBG also appears to facilitate iodine supply to the fetus which initially has no iodine reserve (Schussler, 2000). Several chemical contaminants whose structure is similar to that of T4 have been shown to interfere at different levels with the thyroid signalling pathway [see Boas et al. (2006) for review]. Disruption of the T4 transport has been the focus of researchers since several hydroxylated metabolites of polyhalogenated aromatic hydrocarbons (PHAHs) have been shown to interact with TTR (Lans et al., 1993; Hallgren et al., 2002). Some of them, albeit with much lower affinity, also interact with TBG (Cheek et al., 1993; Lans et al., 1994).

The displacement of T4 from its transport proteins during the developmental stage could adversely affect brain development with repercussions in adulthood (Porterfield, 2000; Fritsche et al., 2005). Therefore, exposure of pregnant women and their foetuses to thyroxine transport disruptive chemicals is a cause of concern. This is especially the case for the Inuit population of Nunavik that was shown to be highly exposed to several PHAHs through its traditional diet (Dewailly et al., 1993; Muckle et al., 2001). Dallaire et al. (2009) previously reported a negative relationship between maternal levels of pentachlorophenol (PCP), a strong TTR binder (Marchesini et al., 2008), and umbilical cord fT4 concentrations in neonates (Dallaire et al., 2009). HO-PCBs, HO-PBDEs, bromophenols, halogenated bisphenol A and genestein are other compounds of interest since they exhibit moderate to high affinity for TTR (Marchesini et al., 2008; Hamers et al., 2008). In addition, HO-PBDEs were recently shown to possess moderate to strong binding activity for TBG (Marchesini et al., 2008). Hence there is a need to investigate the potential influence of several groups of chemicals on binding of T4 to both TTR and TBG. The present study aims at measuring thyroid hormones bound to TTR and TBG in plasma samples of 300 Inuit women of childbearing age (18-39 years) who were recruited in the course of the Nunavik Health Survey in 2004. We hypothesised that plasma concentrations of thyroxine-transport-disrupting chemicals would be negatively related to TTR- or TBG-bound T4. Such a relationship would increase the biological plausibility of food-chain contaminants altering neurodevelopment in this population.

Activities in 2010–2011

- We further refined the experimental conditions for the isolation of the transport proteins by immunoprecipitation, which was a key step in our initial protocol. However, we could not reach the desired purity for the protein fractions. We noted a substantial contamination of the TTR fraction by albumin, and of the TBG fraction by TTR and albumin. Therefore, we had to modify our experimental approach to achieve the objectives of the project.
- Using internal funds at INSPQ, we have acquired a nanospray source for our Quadrupole-Time-of-flight mass spectrometer (QToF-MS). With this instrumental setup, we can analyse intact protein complexes; the TTR tetramer without any ligand (apoprotein), or bound to one or two T4 molecules can be observed (McCammon et al., 2002). Other ligands were also tested including T3 and a hydroxylated polychlorinated biphenyl metabolite, 4-OH PCB-72, which displays a greater affinity for TTR than the natural ligand T4.
- A new approach was designed to determine the concentration of plasma T4 bound to TTR and TBG. To determine the concentration of T4 bound to TTR, an excess of 4-OH PCB-72 is added to the plasma sample to displace T4 from TTR binding sites. Following ultrafiltration, the resulting free T4 concentration is mesured by LC-MS. To detrmine the concentration of T4 bound to TBG, an excess of tetraiodothyroacetic acid (Tetrac) is added to the plasma sample to displace T4 from TBG binding site and the resulting free T4 concentration is measured by LC-MS.
- We completed the measurement of TTR concentration in 300 plasma samples from Inuit women of reproductive age.

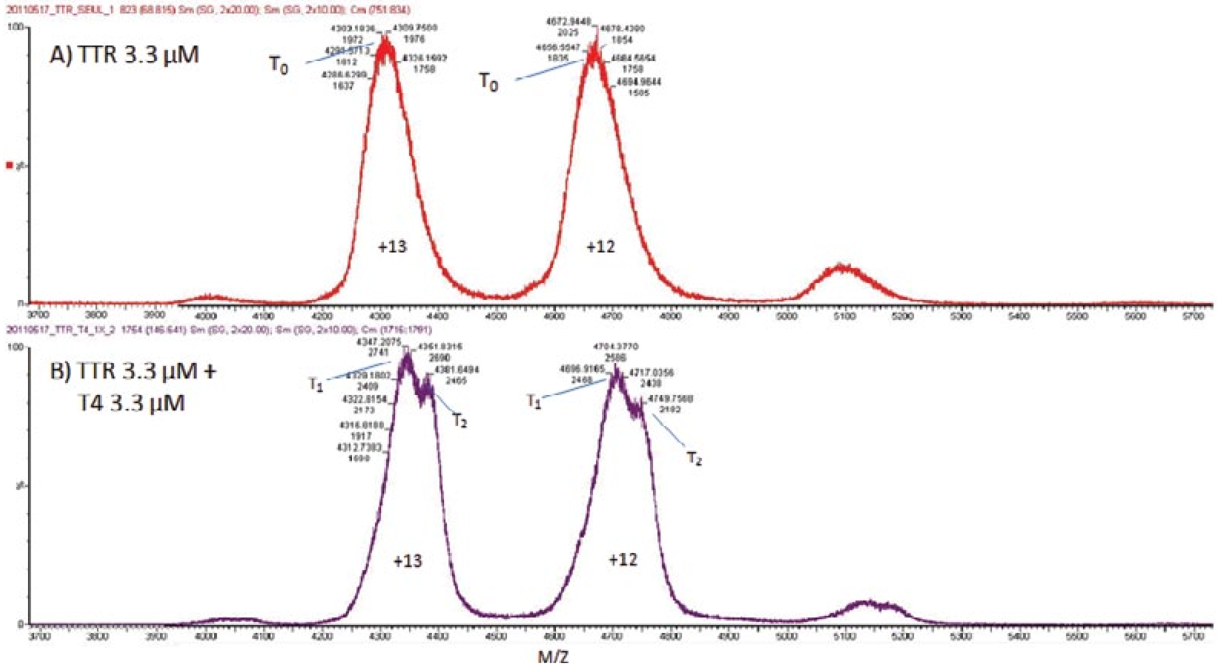

Figure 1: Mass spectrum of TTR in the absence (A) and presence of 3.3 μM T4 (B). Spectrum was acquired by mass spectrometry equipped with a nanosource (Nanospray-G2-QToF from Waters). Capillary voltage: 1 kV; cone voltage: 15 V; source temperature: 100°C; pH 7.4 in 100 mM ammonium acetate buffer. Thyroxine was dissolved in DMSO. Final concentration of DMSO : 0.25%.

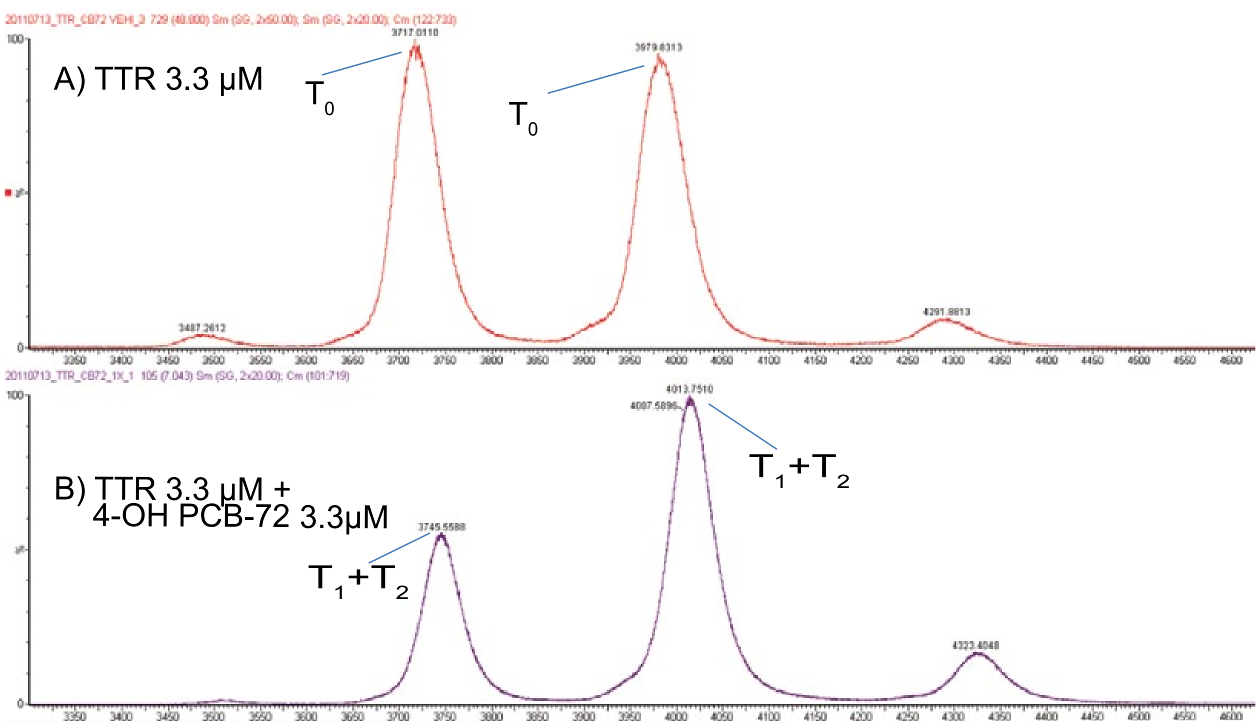

Figure 2: Mass spectrum of TTR in the absence (A) and presence of 3.3 μM 4-OH PCB-72 (B). Spectrum was acquired by mass spectrometry equipped with a nanosource (Nanospray-G2-QToF from Waters). Capillary voltage: 1 kV; cone voltage: 15 V; source temperature: 100°C; pH 7.4 in 100 mM ammonium acetate buffer. 4-OH PCB-72 was dissolved in 7:5, acetonitrile:water. Final concentration of organic solvent was 0.7%.

Results

Figure 1 shows the mass spectrum of human recombinant TTR either alone (panel A) or together with an equimolar concentration of thyroxine (panel B). In each case the major peaks are those of the TTR tetramer with 12 and 13 charges. Although, for each charge species, only one peak can be observed in the absence of T4, two peaks are noted in the presence of an equimolar concentration of T4 (panel B). These peaks correspond to TTR with one (T_1) and two T4 molecules (T_2).

The mass spectrum of human recombinant TTR either alone (panel A) or together with an equimolar concentration of 4-OH PCB-72 (panel B) is shown in Figure 2. Here T_1 and T_2 correspond to TTR with one and two molecules of 4-OH PCB-72, respectively. In contrast to the spectrum obtained with T4 as the ligand, we were not able to observe separate peaks for T_1 and T_2. However, the shift of m/z values for peaks between panel A and B clearly indicates the binding of 4-OH PCB-72 to TTR.

Discussion and Conclusions

Our results using the nanospray QToF-MS instrument indicate that 4-OH PCB-72 can bind to TTR, as was reported previously by Marchesini et al. (2008) using a surface plasmon resonance biosensor assay. Hence it is possible to displace T4 from its TTR binding sites by adding excess concentrations of 4-OH PCB-72 to plasma samples. This approach will be used to determine the concentration of T4 bound to TTR in plasma samples of Inuit women. After displacing T4 from TTR, free T4 can be separated from proteins by ultrafiltration and its concentration determined by LC-MS. Similarly, adding Tetrac to plasma samples can displace T4 from TBG, which can allow for the determination of TBG-bound T4.

The following work will be performed until the completion of the project in December 2011:

- Complete the study of various compounds that may bind to thyroid hormone transport proteins by nanospray QToF-MS.
- Measure thyroid hormones (T4, T3) in ultrafiltrate following their displacement from transport proteins, using isotope dilution LC-MS (Thienpont et al., 1999; Van Uytfanghe et al., 2004).
- Statistical analyses of the data, including correlation analyses between the dependent variables (T4 bound to TTR or TBG expressed as molar ratio) and independent variables (plasma concentrations of the various thyroid transport disrupting chemicals). Subsequently, predictive multiple linear models will be constructed to explain the variance in transport protein-bound T4 in relation to plasma concentrations of total T4, total T3, TTR and TBG as well as those of thyroid transport disrupting xenobiotics.
- Conduct additional exploratory analyses to identify new compounds interfering with T4 binding to TTR and TBG in this population.

NCP Performance Indicators:

Number of northerners engaged in the project: none

Number of meeting/workshops held in the North: none

Number of students involved in the NCP work: 1

Number of publication: none

Expected Project Completion Date

This project will be completed in December 2011.

Acknowledgments:

The financial support of the Northern Contaminants Program (Indian and Northern Affairs Canada) is gratefully acknowledged. The Nunavik Health Survey was conducted in 2004 thanks to funding from the Quebec Ministry of Health and Social Services, Indian and Northern Affairs Canada, CIHR and ArcticNet Network of Centres of Excellence of Canada.

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Assessment of Contaminant and Dietary Nutrient Interactions in Inuit Health Survey: Nunatsiavut

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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 obtained from Nunatsiavut in 2008. A total of 265 adults between 18 to over 60 years old from 5 communities participated in the contaminant study. Concentrations of cadmium, lead, mercury, organochlorines and polybrominated diphenyl ethers in the blood samples of the participants were measured. The risks and benefits associated with the traditional food diet and the relationship between contaminants and health outcomes of the participants are being analyzed. Results of the study are being discussed with the health professionals and policy makers at the territorial, national and international levels in developing environmental health policies and aid Inuit in making informed dietary choices.

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. Nous présentons ici les principaux résultats obtenus au Nunatsiavut en 2008. En tout, 265 adultes âgés entre 18 ans et plus de 60 ans et provenant de cinq collectivités ont participé à l'étude sur les contaminants. Les concentrations de cadmium, de plomb, de mercure, d’organochlorés et d’éthers diphényliques polybromés ont été mesurées dans les échantillons de sang des participants. Les risques et les avantages associés à l’alimentation traditionnelle et la relation entre les contaminants et les effets sur la santé des participants ont été analysés. Nous discutons des résultats de l’étude avec les professionnels de la santé et les responsables des politiques à l’échelle territoriale, nationale et internationale en vue d’élaborer des politiques d’hygiène du milieu et d’aider les Inuits à faire des choix alimentaires éclairés.

Key Messages:

- Country food is essential to the health and wellbeing of Inuit People.
- Inuit Health Survey Adult contaminant data is similar to previous studies showing that the levels in Nunatsiavut are the lowest among all Inuit regions.
- Continue close collaboration with Inuit partners for results delivery and public health message development and implementation, and knowledge translation.
- Champion for stop smoking.
- Consider pan-regional, coordinated Public Health Messaging related to contaminants and country food safety and security.

Messages clés :

- Les aliments traditionnels sont essentiels à la santé et au bien-être des Inuits.
- Les données de l'Enquête sur la santé des Inuits montrent que les taux de contaminants chez les adultes du Nunatsiavut sont parmi les plus faibles dans l'ensemble des régions inuites.
- Il faut continuer à collaborer étroitement avec les partenaires inuits pour assurer la prestation de résultats, l'élaboration et la mise en œuvre des messages ainsi que l'application des connaissances.
- Cette population compte le plus grand nombre de personnes qui ont cessé de fumer.
- Il faudrait évaluer la possibilité de diffuser des messages de santé publique sur les contaminants et le caractère sain et sécuritaire des aliments traditionnels.

Short-term Objectives

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

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

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

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

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

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

Long-term Objectives

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

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

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

Introduction

While the NCP and Arctic Monitoring and Assessment (AMAP) programs are very successful in monitoring the levels of body burden and exposures in the northern populations, there is an increasing demand from the Inuit and health professionals alike to collect more information to interpret the contaminant data in the context of the health status of the populations. The Inuit Health Survey provides an excellent opportunity to conduct a comprehensive study that will include the measurement of dietary intake of contaminants, contaminant body burden, as well as other determinants of health and their relationship with health outcomes of the participants. It is the first time that such a complete set of data has been collected from Inuit in Nunavut, Inuvialuit, 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. We will be building on the experience of the very successful study conducted in Nunavik in 2004 (Dewailly et al 2006), and will expand the effort to compare data/results with other concurrent studies of Inuit Health in other Circumpolar countries including Alaska and Greenland.

Risk communication is a very important component of the NCP program. Results of this project are being released at stages under the guidance of the Steering Committee of the Inuit Health Survey and in partnership with the relevant public health departments and committees in the regions.

Activities

In October of 2008, the IHS travelled to five Inuit communities in the Nunatsiavut Region aboard the CCGS Amundsen. There were a total of 265 participants in Nunatsiavut with 263 samples collected for OCs, 264 samples collected for metals. Analyses of cadmium, lead, mercury and selenium, 3 toxaphene congeners, 4 brominated flame retardants, 10 organochlorine and 14 PCB congeners were conducted at the Centre de Toxicologie, Institute National de Santé Publique.

In March 2011 preliminary Inuit Health Survey and contaminant results based on the 2008 Nunatsiavut data were delivered to the Inuit Health Survey Research Committees in Nain. Consultation and planning for results delivery continued throughout 2011 with members of the Inuit Health Survey Research Committee from Nunatsiavut.

Results

The characteristics of the participants in Nunatsiavut are presented in Table 1. There were more women than men participated (65% vs 35%). The percentage of young adults was less at 9.3% compared to the other two age groups. There were very few non-smokers at only 10.7%.

Concentrations of cadmium (Cd), lead (Pb), mercury (Hg), organochlorines including PCBs and total PBDE are represented in Table 2 and 3. None of the geometric means of contaminant exceeded the guideline levels established by Health Canada (5.0 ug/L for Cd, 100 ug/L for Pb, 20 ug/L for Hg and 20 ug/L for PCBs).

Comparing the results collected from Nunavik showed that Hg, Cd and Pb found in Nunatsiavut were significant lower (Table 4). Blood Cd concentrations were significantly higher among smokers than ex- and non-smokers (Figure 1).

Hg intake from traditional food was estimated using data collected from the food frequency and chemical analysis of food samples collected. There was a strong correlation between blood Hg concentrations and the estimated Hg intake for both the general public and women of child-bearing age (Figure 2).

Table 1. Gender, age and smoking status of participants of the Inuit Health Survey conducted in Nunatsivut, 2008 (N=310).

		N	%
Gender			
	Men	108	34.9
	Women	202	65.1
Age groups			
	18-24	29	9.3
	25-44	125	40.3
	45-	156	50.4
Smoking habits			
	Non smokers	28	10.7
	Ex-smokers	90	34.5
	Smokers	143	54.8

Table 2 . Metal concentrations in the participants of the Inuit Health Survey conducted in Nunatsiavut, 2008 (µg/L whole blood).

Metal	N	Geometric mean	95% Confidence Interval		Range		95th percentile
			Lower	Upper	Min	Max	
Mercury	264	3.2	2.9	3.6	0.1	50	14
Cadmium	264	1.1	1.0	1.4	0.1	10	6
Lead	264	28	25	31	5.6	170	97

Table 3. Organochlorine concentrations in the participants of the Inuit Health Survey conducted in Nunatsiavut, 2008 (µg/L).

Organochlorine	N	Geometric mean	95% Confidence Interval		Range		95th percentile
			Lower	Upper	Min	Max	
Chlordane	264	0.19	0.15	0.22	0.01	5.74	1.81
pp'-DDE+pp'-DDT	264	1.06	0.92	1.22	0.03	20.1	7.22
Total Toxaphene	264	0.03	0.03	0.04	0.01	2.27	0.28
Total PBDE	264	0.08	0.08	0.09	0.04	5.61	0.42
∑PCBs	264	1.93	1.68	2.23	0.26	39.9	11.8

Table 4. Comparison of blood mercury, lead and cadmium concentrations in Nunavik (1992, 2004) and Nunatsiavut (2008)

Metal	Region	Year	N	Geometric Mean(µg/l)	95% Confidence Interval	
					Lower	Upper
Mercury	Nunavik	1992	492	15.0	13.9	16.2
	Nunavik	2004	917	10.3	9.6	11.0
	Nunatsiavut	2008	264	3.2	2.9	**3.6**
Cadmium	Nunavik	1992	493	3.7	3.5	4.0
	Nunavik	2004	917	2.9	2.7	3.1
	Nunatsiavut	2008	264	1.2	1.0	**1.4**
Lead	Nunavik	1992	493	90	83	91
	Nunavik	2004	917	40	37	41
	Nunatsiavut	2008	264	27.8	25.3	**30.5**

Discussions and Conclusions

The average concentrations of contaminants were below the guideline levels established by Health Canada suggesting that most of the people in Nunatsiavut do not have a concern for contaminant related adverse health effects. A small percentage of high-end traditional consumers can still be exposed to elevated levels of contaminants; 1.5% of adults and 12.2 % of women of child bearing age for Hg, 1.4% for Cd, 3.8 % for Pb and 1.9% for PCBs. Blood concentrations of all contaminants were lower than those reported in Nunavik (Dewailly et al., 2006). These results are in consistent with the trend that contaminants exposure is lowest in Nuanatsivut in comparison with other Inuit regions in the Canadian Arctic (Van Oostdam et al. 1999, 2005; Donaldson et al., 2010).

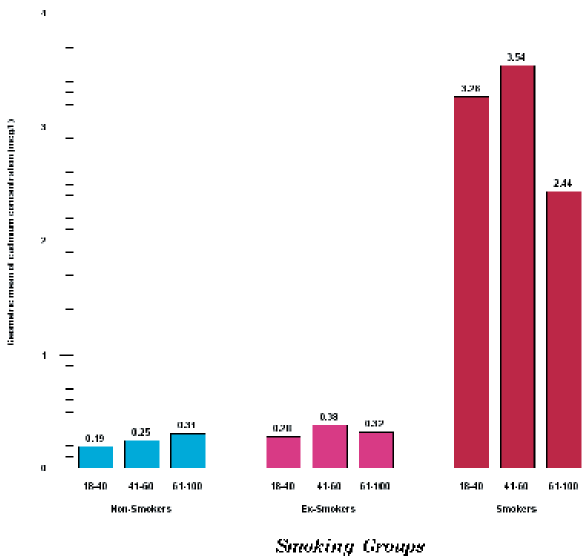

Figure 1. Geometric mean of Blood-Cadmium by smoking habits in the participants of the Inuit Health Survey conducted in Nunatsiavut, 2008. (µg/L whole blood)

Nevertheless, smoking is a still a major problem for Inuit in Nunatsiavut and smoking is the major source of Cd intake. The percentage of non-smoker was only 10.7% which was higher than the 8.9% observed in Nunavik in 2004 (Fontaine et al. 2008). However, the number of ex-smokers was high at 34.5% which is an encouraging sign that many people are quitting smoking.

Results for participant profiles and health status are being reported back to the communities. A communication plan will be developed with the Inuit Health Survey Steering Committee of Nunatsiavut.

Expected Project Completion

The entire project is expected to be completed by March 2012.

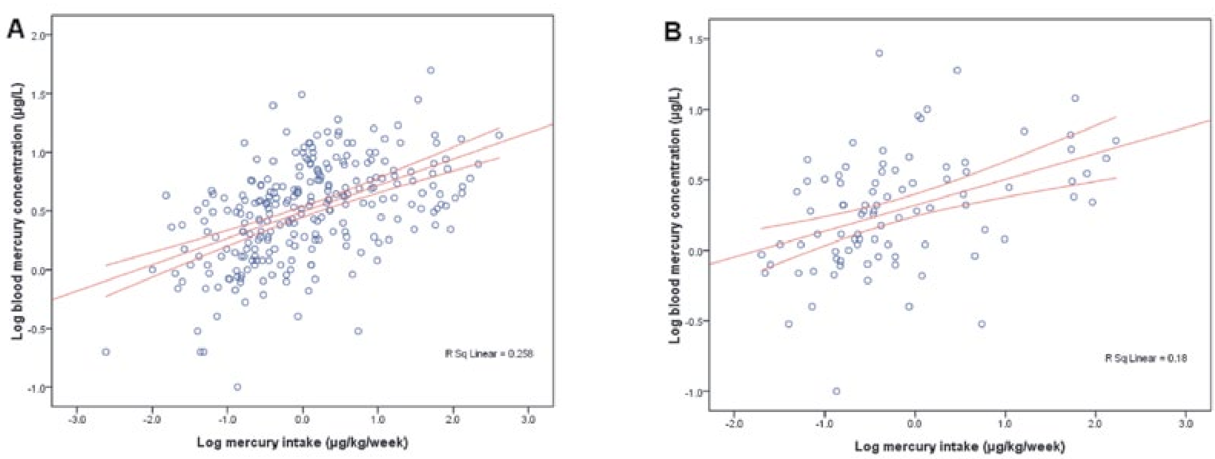

Figure 2. Scatter plot for blood mercury concentrations and daily total mercury intake of Inuit in Nunatsiavut (log-scale). A. General Public and B. Women of child-bearing age.

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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

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Abstract

An *in vivo* study is being conducted to investigate the potential role of exposure to Northern contaminants in the development of metabolic and cardiovascular diseases using rodent models of human disease, the obese and lean JCR rats, as well as to examine the influence of lifestyle factors such as alcohol on the health effects of Northern contaminants. Obese and lean JCR rats at 8 weeks old were acclimatized on a purified AIN93G diet. Animals were treated with 10% alcohol in drinking water or drinking water only for 6 weeks. From the third week of alcohol treatment, animals were orally dosed with a mixture of 23 Northern contaminants (NCM) at 0 (corn oil), 1.6, or 16 mg/kg BW/day for 4 weeks. During the whole study, body weight and water/alcohol consumption were measured daily. Food consumption was measured weekly. Blood, 12h-urine and various organs were collected, weighed or processed at the end of the study. Hematological endpoints and serum NCM, glucose, insulin, and ethanol levels, as well as serum biochemistry markers for liver, kidney, pancreas, and heart/muscle injuries, and lipid and protein metabolism, and ion balance were analyzed. Our preliminary findings suggest that the lean animals had greater capacity in regulating food and water/alcohol intake than the obese animals. As compared with the lean animals, the obese animals were in a higher state of systemic inflammation and had a compromised immune function and liver steatosis, in addition to hyperlipidemia and hyperinsulinemia. The NCM concentrations 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. Treatment with 10% ethanol did not cause binge drinking, but decreased, to some extent, serum concentrations of some organic components of NCM, resulting in slightly lessened effects of NCM in the obese rats. The high dose of NCM worsened the degree of liver steatosis, and inhibited release of lipids, proteins, and enzymes from liver to circulation in the obese rats. This dose of NCM also decreased heart and pancreas weight in 2 the obese rats given

Résumé

Une étude in vivo est réalisée pour étudier le rôle potentiel de l'exposition aux contaminants du Nord dans le développement de maladies métaboliques et cardiovasculaires au moyen de modèles de maladies humaines appliqués à des rongeurs – rats JCR obèses et maigres – et pour examiner l'influence de facteurs liés au mode de vie comme l'alcool sur les effets qu'entraînent les contaminants du Nord sur la santé. Des rats JCR obèses et maigres de huit semaines ont été acclimatés par l'application d'un régime purifié AIN93G. Durant six semaines, les animaux ont consommé soit de l'eau mélangée à de l'alcool à 10 % ou de l'eau pure. À partir de la troisième semaine du traitement à l'alcool, les animaux ont reçu oralement un mélange de 23 contaminants présents dans le Nord (CN) à une teneur de 0 (huile de maïs), de 1,6 ou de 16 mg/kg BW/par jour durant 4 semaines. Durant toute l'étude, le poids corporel et la consommation d'eau-alcool ont été mesurés quotidiennement. La consommation de nourriture a été mesurée chaque semaine. Le sang, l'urine sur une période de 12 heures et différents organes ont été recueillis, pesés ou traités à la fin de l'étude. Les paramètres hématologiques et les niveaux de CN dans le sérum, de glucose, d'insuline et d'éthanol, les marqueurs de biochimie sérique pour le foie, les reins et le pancréas, les lésions cardiaques et musculaires, le métabolisme lipidique et protéinique ainsi que le bilan ionique ont été analysés. Nos premières constatations donnent à penser que les animaux maigres étaient plus aptes à réguler l'apport de nourriture et d'eau/alcool que les animaux obèses. En comparaison des animaux maigres, les rats obèses présentaient un niveau d'inflammation généralisée plus élevé, une fonction immunitaire compromise et une stéatose du foie, en plus d'une hyperlipidémie et d'une hyperinsulinémie. Il a été établi que les concentrations de CN dans le sérum des rats ayant reçu un mélange de contaminants se situaient entre la moyenne géométrique et les concentrations maximales trouvées dans le plasma d'Inuits. Le traitement avec l'éthanol à 10 % n'a pas provoqué

no alcohol, and decreased circulating insulin levels and relative kidney weight regardless of alcohol treatment. These preliminary findings suggest that liver, pancreas, heart and kidney are important targets of NCM toxicity. Their dysfunction and injuries caused in response to NCM exposure may play a part in the development of metabolic and cardiovascular diseases

les symptômes associés à une forte consommation ponctuelle d'alcool mais a réduit, dans une certaine mesure, les concentrations de certains composés organiques des CN dans le sérum, résultant en une légère réduction des effets des CN chez les rats obèses. La dose élevée de CN a intensifié la stéatose du foie et inhibé la libération par le foie de lipides, de protéines et d'enzymes dans l'organisme des rats obèses. Cette dose de CN a aussi réduit le poids du cœur et du pancréas chez les rats obèses n'ayant pas reçu d'alcool ainsi que les niveaux d'insuline en circulation et le poids relatif des reins, sans égard au traitement à l'alcool. Ces premières constatations laissent à penser que le foie, le pancréas, le cœur et les reins sont des cibles importantes quant à la toxicité des CN. La dysfonction de ces organes et les lésions qu'ils ont subies en réaction à l'exposition aux CN pourraient intervenir dans le développement de maladies métaboliques et cardiovasculaires.

Key Messages

Conclusions presented in this report were made based on data obtained so far from limited numbers of animals (4–6/treatment group). Conclusions may change with more data generated from the remaining part of the animal work, which is expected to finish by the end of Sept. 2011.

- Obesity may be associated with increased systemic inflammation, compromised immune function, liver steatosis, hyperlipidemia and hyperinsulinemia.
- Moderate alcohol use may alter the circulating levels of Northern contaminants, therefore modulating their effects.
- With or without moderate alcohol use, exposure to NCM at levels resulting in serum concentrations above geometric mean concentrations found in the Inuit plasma may cause liver damage resulting in changes in and protein metabolism and transportation, as well as pancreatic injury leading to decreased circulating insulin levels, and therefore increasing the risk of metabolic and cardiovascular diseases.
- Obese individuals, as compared with non-obese individuals, may not be more susceptible to NCM-mediattoxicity, however, may have more health problems resulting from dysregulation of

Messages clés

Les conclusions présentées dans ce rapport se fondent sur des données obtenues à ce jour à partir d'un nombre restreint d'animaux (entre quatre et six par groupe de traitement). Les conclusions pourraient changer avec un plus grand nombre de données provenant des travaux qu'il reste à accomplir avec les animaux et qui devraient être achevés d'ici la fin de septembre 2011.

- L'obésité pourrait être associée à une inflammation généralisée plus élevée, à la compromission de la fonction immunitaire, à la stéatose du foie ainsi qu'à l'hyperlipidémie et à l'hyperinsulinémie.
- Une consommation modérée d'alcool pourrait agir sur le niveau de circulation des contaminants présents dans le Nord et en moduler ainsi les effets.
- Sans égard à une consommation modérée d'alcool, l'exposition aux CN à des niveaux entraînant des concentrations dans le sérum supérieures aux concentrations moyennes géométriques observées dans le plasma d'Inuits peut causer des dommages au foie occasionnant des changements dans le métabolisme et le transport des lipides et des protéines ainsi que des lésions au pancréas qui réduisent les niveaux

metabolisms and immune function, and thus increased risks of metabolic, immunological, and cardiovascular diseases.

d'insuline en circulation et, par conséquent, augmentent le risque de maladies métaboliques et cardiovasculaires.

- Les sujets obèses, en comparaison de ceux qui ne le sont pas, ne sont pas nécessairement plus vulnérables à la toxicité associée aux CN mais peuvent connaître plus de problèmes de santé liés au dérèglement des métabolismes et de la fonction immunitaire et donc présenter des risques plus élevés de maladies métaboliques, immunologiques et cardiovasculaires.

Objectives

Short-Term: **a)** 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 b) 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: **a)** 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; **b)** To provide more biomarker tools for monitoring and assessing the health risk of Northern populations; and **c)** 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 (Morgan et al. 1980, Baker et al. 1980, Sorensen et al. 1999, Jokinen et al. 2003, Lind et al. 2004, Carpenter, 2005, 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 Kim et al. 2008, 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 (Ralph-Campbell et al. 2009, 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.

Blood vessels are protected by the endothelium, which represents a single layer of cells that line all blood vessels in the body (Cersosimo and DeFronzo, 2006). By virtue of direct contact with circulating blood, the endothelial layer provides a critical interface between the elements of blood and the tissue, and plays a vital role in the regulation of vessel tone, blood coagulation, and vascular permeability. Endothelial dysfunction, defined as an impaired vascular reactivity, or a proinflammatory and prothrombotic state, plays an essential role in the development of cardiovascular diseases including hypertension, atherosclerosis, and coronary artery disease. These diseases are also characterized by insulin resistance. Insulin resistance is the hallmark of metabolic disorders including obesity, diabetes, glucose-intolerance, and dyslipidemia, all of which are also characterized by endothelial dysfunction. Metabolic disorders are well-known major risk factors of cardiovascular diseases.

During 2009–2010, we conducted an in vitro study, in which we investigated the effects of Northern contaminant mixtures (NCMs) on structure and function of human coronary artery endothelial cells grown in the presence or absence of high fat/sugar and alcohol. Data from this in vitro study suggest that NCMs at concentrations relevant to human exposure levels can alter endothelial structure and function. Presence of high fat/sugar may or may not affect the effects of NCMs depending on the chemical natures of the mixture and the endpoints examined. Ethanol is less likely than fat/sugar to alter effects of NCMs. To further verify the effects of NCMs on endothelial function and related metabolic and cardiovascular disease, as well as effects of binge drinking on NCM toxicity, we conducted an in vivo study using a rat model of human metabolic and cardiovascular disease. Some preliminary findings are presented in this report.

Activities in 2010–2011

1. Study Design

a) Choosing Animal Model

In this study, we chose to use JCR (LA)-Lepr^{cp} obese (*cp/cp*) male rats with JCR (LA)-Lepr^{cp} lean (+/?) male rats as controls. JCR obese rat is an ideal animal model of cardiovascular disease. The *cp/cp* rats are homozygous for the autosomal recessive cp gene, resulting from the Tyr763Stop mutation for the leptin receptor (ObR). Without ObR, these rats are hyperleptinaemia, and become obese, hyperlipidemic, and hyperinsulinemic. The *cp/cp* male phenotype spontaneously develops ischemic lesions in heart, and is prone to stress-induced myocardial infarction. The atherosclerotic lesions formed in major vessels throughout their arterial systems resemble the intimal atherosclerosis commonly seen in human coronary arteries, and appear in anatomic locations similar to those found in humans. The *cp/cp* rats also show numerous small thrombi on the endothelial surface of major arteries with increased activity of PAI-1 in the blood. Insulin resistance develops rapidly in young *cp/cp* male rats, being associated with increased circulating levels of LDL and VLDL that resembles a hyperlipidemic profile seen in prediabetic human. In contrast to *cp/cp* rats, the heterozygous +/cp or homozygous +/+ rats (collectively known as +/? rats), are lean and metabolically normal, will therefore serve as controls for the *cp/cp* rats. These suggest that the *cp/cp* rats may share the same or similar pathogenic pathways leading from obesity to insulin resistance, and then to cardiovascular disease. Although the *cp/cp* rats have profound hyperinsulinaemia, they don't lose pancreatic function, neither they become diabetic. This allows us to examine the effects of NCM on beta cell functions, insulin secretion, and insulin-regulated glucose uptake and metabolism. Although effects of NCMs on leptin-dependent metabolic processes cannot be examined in the *cp/cp* rats, the effects of NCM on processes involving lipid transport, fatty acid oxidation, and lipolysis can still be studied. By using the +/? rats as a comparison, we are hoping to also examine the effects of NCM on leptin-dependent pathogenic pathways.

Obesity and related metabolic and cardiovascular diseases are complicated multi-factoral diseases. It is increasingly recognized that the initiation, progression and health consequences of these diseases in humans are results of complicated interaction of genes, environment, life style, and nutritional status. No single animal model or study can represent a complete picture of these diseases in humans. By using this disease-prone animal model, we can shorten the time required for the development of metabolic and cardiovascular disease and the duration of chemical exposure, thereby reducing the experimental cost.

b) Choosing Contaminants and Their Doses:

The proposed research included a mixture of 23 inorganic and organic contaminants that were frequently detected at high concentrations in the Inuit blood samples (Table 1). Three dose levels were used in this study. The zero, low, and high doses are a) vehicle control, b) the highest contaminants of the chemical detected in Inuit blood, and c) a ten-fold concentration of the highest levels of contaminants detected in Inuit blood respectively.

In the proposed study, a total of 1.6 mg NCM/kg BW will be given to the animals in the low dose group. This will hopefully to generate blood contaminant levels in rats similar to those found in the Inuit blood. The highest levels of contaminants found in the Inuit blood are normally 10-40 times higher than the average levels. In our study, the “10x of the highest level” will be used as a positive control and also cover extreme exposure situations.

Lead acetate and cadmium acetate were dissolved in water. Methylmecury, PCBs, organochlorines, PBDE 47, and toxaphene were dissolved in corn oil, and PFOS was dissolved in acetone. Chemicals were loaded on two Teddy Gram Cookies and aired-dried overnight in a fume hood. The volumes of vehicle or NCM loaded on cookies were calculated based on the animals' body weights measured on the day before dosing. Two cookies were given to each animal to obtain the required dose.

c) Choosing Ethanol (EOH) Doses

The use of 10% ethanol in drinking water has been shown to be an effective way to achieve binge ethanol exposure in rats (Riikonen et al. 1999, 23(7): 1245-1250). Blood ethanol concentration in the rats received 10% ethanol in drinking water either continuously or intermittently reached 10 mmol/l (or 0.05%). This is the

Table 1: The chemical composition of the Northern contaminant mixture (NCM) and concentrations to be used.

Contaminants (% detected in Inuit plasma) (Dewailly et al. 2006, Dallaire et al. 2009)	**Chemical Dose**		
	Mean levels detected in Inuit plasma samples (ng/L)	**Low Dose** (the highest level detected in Inuit plasma samples) (μg/L)	**High Dose** (10 times of the highest level detected in Inuit plasma samples) (μg/L)
Heavy Metals (3)			
Cadmium (100%)	3035	146.1	1461.00
Mercury (methylmercury) (100%)	**10997**	241.0	2410.00
Lead (100%)	39368	497.3	4972.80
Total concentrations of contaminants	*53400*	*884.4*	*8843.80*
PCBs (12)			
99 (98%)	170	4.70	47.00
138 (100%)	534	19.0	190.00
146 (97%)	180	6.10	61.00
153 (100%)	**1333**	40.0	400.00
163 (98%)	221	6.20	62.00
170 (99%)	216	6.18	61.82
180 (100%)	813	22.7	227.27
187 (100%)	287	9.10	91.00
194 (95%)	182	5.10	51.00
201 (97%)	167	4.70	47.00
203 (92%)	105	2.50	25.00
Total concentrations of contaminants	*13977*	*126.3*	*1263.09*

Contaminants (% detected in Inuit plasma) (Dewailly et al. 2006, Dallaire et al. 2009)	**Chemical Dose**		
	Mean levels detected in Inuit plasma samples (ng/L)	**Low Dose** (the highest level detected in Inuit plasma samples) (µg/L)	**High Dose** (10 times of the highest level detected in Inuit plasma samples) (µg/L)
Organochlorine (4)			
Oxychlordane (100%)	431	16.0	160.00
p,p'-DDE (100%)	**3232**	50.0	500.00
Trans-nonachlor (100%)	725	22.0	220.00
Pentachlorophenol (100%)	914	18.0	180.00
Total concentrations of contaminants	*5302*	*106.0*	*1060.00*
Toxaphene (1)			
Parlar # 50	**142**	59.1	59.13
Total concentrations of contaminants	*142*	*59.1*	*59.13*
Brominated flame retardants (2)			
PBDE IUPAC #47 (55%)	**72**	2.40	24.00
2,3,4,6-tetrabromophenol (63%)	36	1.39	13.95
Total concentrations of contaminants	*108*	*3.79*	*37.95*
Perfluorinated compounds (1)			
PFOS (100%)	**29000**	470.0	4700.00
Total concentrations of contaminants	29000	470.0	4700.00
Total concentrations of contaminants	**101929**	**1596.4**	**15963.97**

ethanol level defined by the Canadian Medical Association as the blood alcohol level of impairment associated with mild signs of alcohol intoxication (Alberta Alcohol and Drug Abuse Commission 2000). In the proposed study, we hope to achieve this blood ethanol level in the dosed animals. The purpose of using 10% ethanol in drinking water in our proposed study is to imitate the binge drinking situation in the Inuit population. This will allow us to investigate if heavy use of alcohol will affect the toxicity of Northern contaminants. To avoid acute ethanol poisoning, rats were acclimatized to increasing concentrations of ethanol, starting from 1%, with 1% increase per day until 5% for the first five days. This was followed by two days of water only, and then starting from 6%, with 1% increase per day until 10% for another five days. The rats were then maintained on 10% ethanol for five days a week with Saturday and Sunday given water only, except that on the last Saturday and Sunday before necropsy, the animals were given 10% ethanol.

d) Animal Treatments

In the *Sub-study I*, the effects of a NCM on the development of cardiovascular and metabolic diseases under a binge drinking condition will be investigated. Forty eight 8-weeks old male JCR (LA)-Lepr^{cp} obese (*cp/cp*) and 18 8-weeks old male lean JCR (+/?) rats were obtained from the University of Alberta. The animals were maintained on AIN93G purified casein-based diet for 10 weeks, during which they will be subjected to cookie, ethanol and chemical treatments as illustrated in Table 2 and Fig. 1. Teddy Gram cookies will be used as carriers of NCM.

e) Endpoints Analysis

Water/Ethanol and Food Consumption: Water/ethanol consumption was measured daily by weighing the water/ethanol bottle before and after refill. Food consumption was measured weekly by weighing the food bin before and after refill.

Body Weight: Rats were weighed daily in early afternoon.

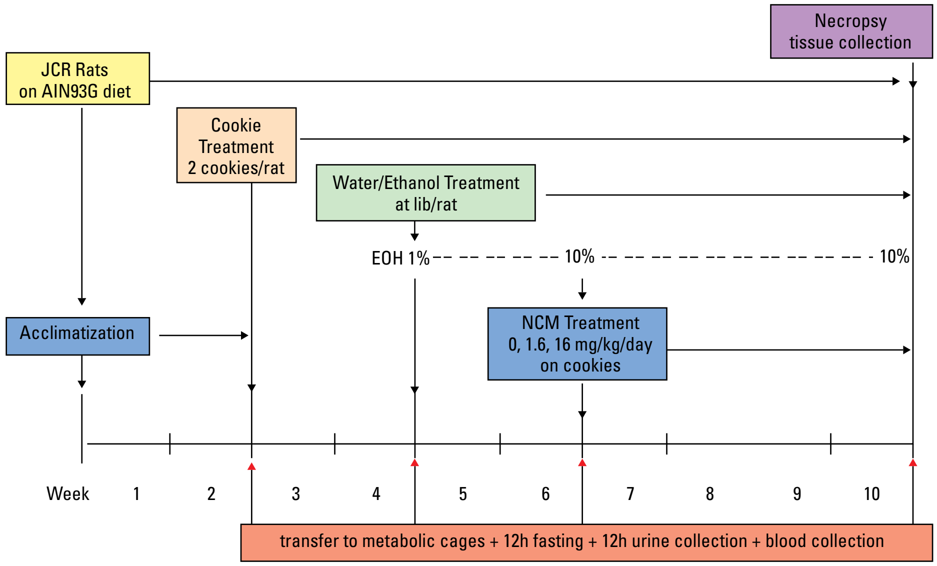
Urine and Blood Collection: Rats were transferred to metabolic cages and fasted for 12h before urine and blood collection. Blood samples were collected from tail vein on the day before cookie feeding being started (collection I), before EOH treatment being started (collection II), before NCM treatment being started (collection III), and before necropsy (collection IV).

Organ/Tissue Weight: Liver, kidney, brain, thymus, heart, pancreas, spleen, adrenal, kidney, epididymis, testis, prostate, aorta, skeletal muscle, brown fat and white fat were dissected at necropsy and weighed before being frozen in liquid nitrogen or fixed in 10% neutral buffered formalin.

Table 2. Sub-Study I: Investigation of the Effects of a NCM on the Development of Cardiovascular and Metabolic Diseases under a Binge Drinking Condition

Treatment after two weeks of acclimatization			Dietary treatment	Alcohol treatment	Chemical (NCM) treatment	Tissues to be collected	Endpoints to be analyzed
Treatment timing and duration			3rd week on, for 8 weeks	5th week on, 5 days per week for 6 weeks	7th week on, daily dosing on cookies for 4 weeks	During study or at necropsy	At or After completing animal phase
Animal Strain	**Treatment Group**	**Number of Animals**				Blood (4 collection) Urine (4 collection) Brain Liver Heart Aorta Kidney Abdominal fat Brown fat Muscle Thyroid Pancreas Spleen Adrenal Prostate Testis Thymus Epididymis	Body weight Water consumption Food consumption Blood glucose Blood insulin Blood ethanol Blood/tissue contaminants Organ weights Serum biochemistry Hematology Serum fatty acid profile Urinalysis Systemic inflammation Oxidative stress Endothelial function Cardiac lesions Artery lesions Brain stem lesions
Obese (O) (cp/cp)	OWV	8	normal diet (ND)	Drinking water only	0 mg/kg BW (V)		
Obese (O) (cp/cp)	OWL	8	ND		1.6 mg/kg BW (L)		
Obese (O) (cp/cp)	OWH	8	ND		16 mg/kg BW (H)		
Obese (O) (cp/cp)	OEV	8	ND	Drinking water containing EOH from 1% to 10%	0 mg/kg BW (V)		
Obese (O) (cp/cp)	OEL	8	ND		1.6 mg/kg BW (L)		
Obese (O) (cp/cp)	OEH	8	ND		16 mg/kg BW (H)		
Lean (L) (+/-)	LWV	6	ND	Drinking water only	0 mg/kg BW (V)		
Lean (L) (+/-)	LEV	6	ND	Drinking water containing EOH from 1% to 10%	0 mg/kg BW (V)		
Lean (L) (+/-)	LEL	6	ND		1.6 mg/kg BW (L)		

Figure 1: Experimental design for Sub-Study 1



Serum Glucose: Serum glucose levels were measured using Glucose Assay Kit from Abcam (#ab65333) according to manufacture's instruction.

Serum Insulin: Serum insulin levels were measured using an Ultra Sensitive Rat Insulin ELISA kit from Crystal Chem Inc. (#90060) according to an instruction provide by the kit.

Serum Ethanol: Serum ethanol levels were measured using Ethanol Assay Kit from Abcam (#ab65343) according to kit insert.

Serum PCBs, Organochlorines, and PBDE: Serum (0.2~0.5g) were weighed and extracted with 3 mL of acetone and 2+2 mL of acetone:hexane (2:1). The sample extracts were combined and concentrated with nitrogen stream to a volume of 2.5 mL, and re-extracted with 3+1.5+1.5 mL of dichloromethane (DCM). The samples were laid in fume hood overnight to let the solvent to evaporate to dry. The samples were weighed and the lipid contents were measured gravimetrically. The samples were re-dissolved in 1 mL of 30% DCM in hexane and 30 μL methanol. Derivatization of pentachlorophenol and tetrabromophenol was conducted by adding 30 μL of 2M trimethyldiazomethane solution in hexane. The samples were dried and redissolved in 1 mL 30% DCM in hexane and cleaned with columns packed with 3.0 g 2% deactivated Florisil. The analytes were eluted with 30 mL of 30% DCM in hexane. The samples were concentrated with a ratovapor and nitrogen stream to a final volume of 0.5 mL prior to analyses with gas chromatography (GC). The GC analyses were conducted with an Agilent 7890A GC equipped with electron capture detector.

Hematology: Whole blood was collected into EDTA tube, and analyzed for hematology using Beckman Coulter AcT 5 Diff Hematology Analyzer. The Act 5diff CP system employs Absorbance cytochemistry and Volume (AcV) technology. Monocyte, neutrophil and eosinophil populations were identified, using the absorbance patterns produced by differential cytochemical staining of their granules versus volume. Lymphocytes remained unstained, and the basophil population was analyzed on a separate channel using volume gating and selective lysis. Red blood cell and platelet parameters were also measured, including red blood cell count, hematocrit, hemoglobin, mean corpuscular volume, mean corpuscular hemoglobin concentration, red blood cell distribution width, platelet counts, and mean platelet volume.

Biochemistry: A panel of 23 serum clinical/biochemical markers were analyzed using a Roche Hitachi 917 biochemistry analyzer with corresponding reagents. These markers include serum amylase (U/L), albumin (g/L), alkaline phosphatase (U/L), alanine transaminase (ALT-U/L), aspartate transaminase (U/L), g-glutamyl transpeptidase (U/L), conjugated bilirubin (mmol/L), total bilirubin (mmol/L), calcium (mmol/L), chloride (mmol/L), cholesterol (mmol/L), creatinine (mmol/L), creatine kinase (U/L), glucose (mmol/L), lipase (U/L), magnesium (mmol/L), phosphorous (mmol/L), potassium (mmol/L), sodium (mmol/L), total protein (g/L), uric acid (mmol/L), triglycerides (mmol/L), and urea (mmol/L).

Results

a) Effects of Treatments on Serum NCM Concentrations

Serum PCBs: Serum PCB99 concentrations in the obese rats increased with NCM dose, however, was not completely proportional to NCM dose (Fig. 2). Serum PCB99 concentrations were generally lower in the rats treated with than without EOH for both NCM dose groups. For the same NCM dose and EOH condition, higher serum PCB99 concentrations were found in the lean than the obese rats. Serum PCB99 concentrations from all dosed animals were in the range between geometric mean (Geo-Mean) and maximum Inuit plasma PCB99 levels found in the Nunavik Health Survey (Dewailly et al. 2006).

As with PCB99, similar trend was also found for PCB153 (Fig. 3), although the serum PCB153 concentrations in the 16 mg NCM/kg BW dosed animals given water only exceeded the maximum level found in the Inuit plasma. Serum concentrations of other PCBs (138, 146, 163, 170, 180, 187, 194, 201, and 203) followed similar trend (data not shown) as the aforementioned PCBs.

Serum Organochlorines: Serum oxychlordane concentrations increased with NCM dose, and were lower in the rats treated with EOH than those without for all NCM dose groups and higher in the lean than the obese rats for the same NCM dose (Fig. 4). Similar trend was also found for DDE, although the serum DDE concentrations in the lean and obese rats did not differ for the same dose of NCM (Fig. 5). In the obese rats, serum trans-nonachlor concentrations increased with NCM dose, but were the same with or without EOH treatment. For the same dose of NCM, the lean rats accumulated twice as much trans-nonachlor as the obese rats in the serum (Fig. 5). The dose effect of NCM on serum pentachlorphenol concentration was also seen in the obese rats. However, the influence of EOH and rats strain on serum pentachlorphenol was absent (data not shown).

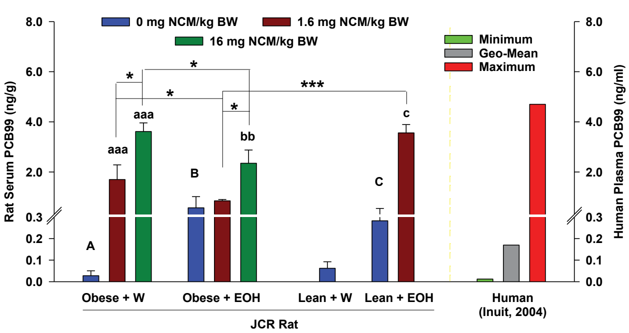


Figure 2. Effects of treatments on serum PCB99 concentrations in the obese and lean rats. Data points are the mean values of 4–6 animals. The error bars are the standard deviations of the means. "A" is significantly different from "aaa" at p<0.001. "B" is significantly different from "bb" at p<0.01. "C" is significantly different from "c" at p<0.05. "*" and "***" indicate significant difference between the two groups located under the lines at p<0.05 and 0.001. The human plasma values were obtained from Dr. Dewailly et al. (2006).

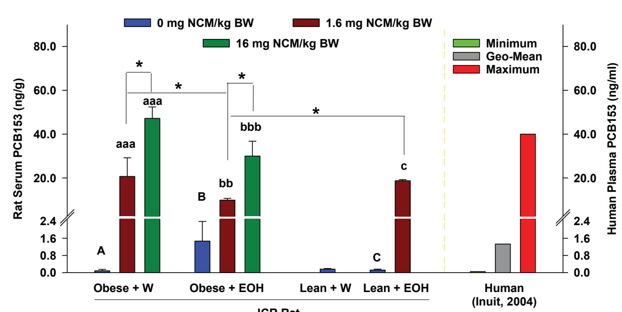


Figure 3. Effects of treatments on serum PCB153 concentrations in the obese and lean rats. Data points are the mean values of 4–6 animals. The error bars are the standard deviations of the means. "A" is significantly different from "aaa" at p<0.001. "B" is significantly different from "bb" and "bbb" at p<0.01 and 0.001. "C" is significantly different from "c" at p<0.05. "*" indicates significant difference between the two groups located under the lines at p<0.05. The human plasma values were obtained from Dr. Dewailly et al. (2006).

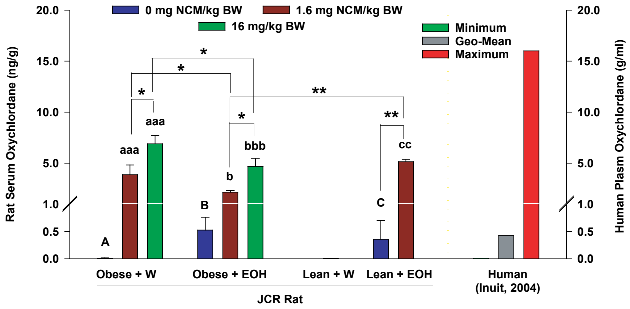


Figure 4. Effects of treatments on serum oxychlordane concentrations in the obese and lean rats. Data points are the mean values of 4–6 animals. The error bars are the standard deviations of the means. "A" is significantly different from "aaa" at p<0.001. "B" is significantly different from "b" and "bbb" at p<0.05 and 0.001. "C" is significantly different from "cc" at p<0.01. "*" and "**" indicate significant differences between the two groups located under the lines at p<0.05 and 0.01, respectively. The human plasma values were obtained from Dr. Dewailly et al. (2006).

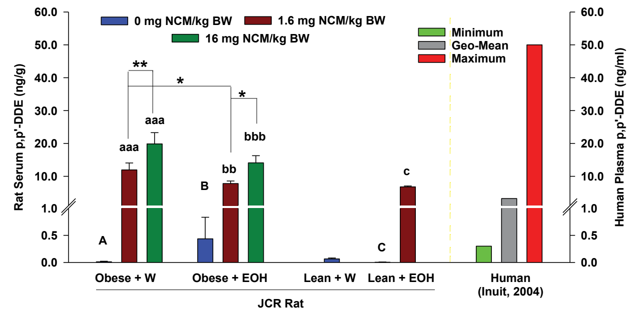


Figure 5. Effects of treatments on serum DDE concentrations in the obese and lean rats. Data points are the mean values of 4–6 animals. The error bars are the standard deviations of the means. "A" is significantly different from "aaa" at p<0.001. "B" is significantly different from "bb" and "bbb" at p<0.01 and 0.001. "C" is significantly different from "cc" at p<0.01. "*" and "**" indicate significant differences between the two groups located under the lines at p<0.05 and 0.01, respectively. The human plasma values were obtained from Dr. Dewailly et al. (2006).

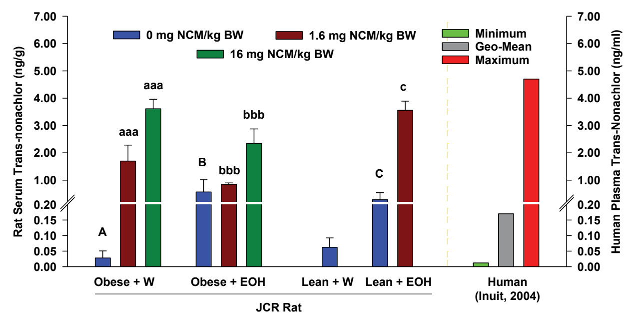


Figure 6. Effects of treatments on serum trans-nonachlor concentrations in the obese and lean rats. Data points are the mean values of 4–6 animals. The error bars are the standard deviations of the means. "A" is significantly different from "aaa" at p<0.001."B" is significantly different from "bbb" at p<0.001. "C" is significantly different from "c" at p<0.05 The human plasma values were obtained from Dr. Dewailly et al. (2006).

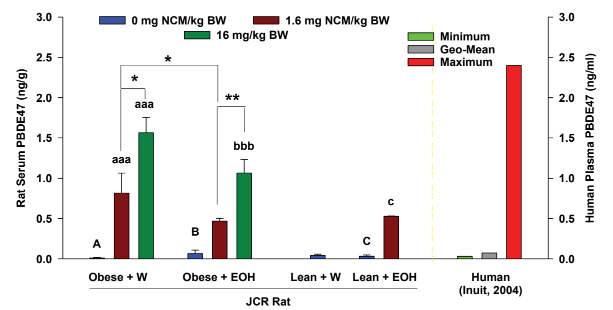


Figure 7. Effects of treatments on serum PBDE47 concentrations in the obese and lean rats. Data points are the mean values of 4–6 animals. The error bars are the standard deviations of the means. "A" is significantly different from "aaa" at p<0.001. "B" is significantly different from "bbb" at p<0.001. "C" is significantly different from "c" at p<0.05. "*" and "**" indicate significant differences between the two groups located under the lines at p<0.05 and 0.01, respectively. The human plasma values were obtained from Dr. Dewailly et al. (2006).

Serum Polybrominated Diphenol Ethers (PBDE): The effects of treatments on serum PBDE47 concentrations followed the same trend as those of DDE (Fig. 7).

Serum Tetrabromophenol: Serum concentrations of 2,3,4,6,-tetrabromophenol also increased with NCM dose, but did not differ significantly between the water and EOH treated rats (Fig. 8). No tetrabromophenol was detected in the serum of lean rats.

Serum Toxaphene and Perflurinated Compounds (PFOS): Serum toxaphenol and PFOS concentrations are being determined. Data will be available later 2011.

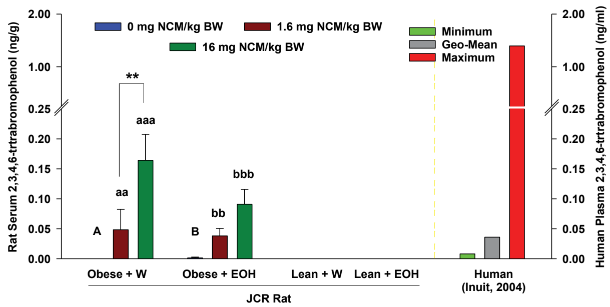


Figure 8. Effects of treatments on serum 2,3,4,6-tetra-bromophenol concentrations in the obese and lean rats. Data points are the mean values of 4–6 animals. The error bars are the standard deviations of the means. “A” is significantly different from “aa” and “aaa” at p<0.01 and 0.001, respectively. “B” is significantly different from “bb” and “bbb” at p<0.01 and 0.001, respectively. “**” indicates significant differences between the two groups located under the lines at p< 0.01. The human plasma values were obtained from Dr. Dewailly et al. (2006).

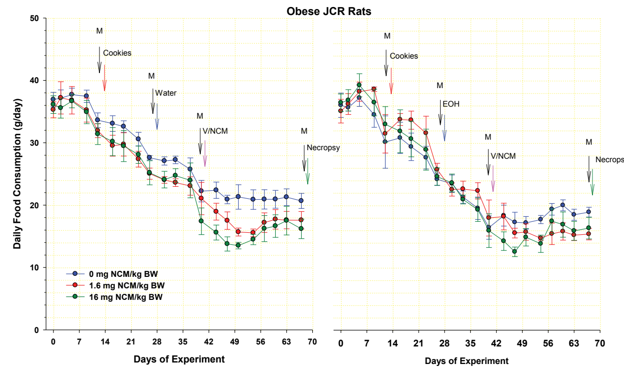


Figure 9. Effects of treatments on daily food consumption of the obese JCR rats. Arrows indicate starting date of the treatment or activities. M: putting in metabolic cage and fast for 12 h. EOH: starting ethanol treatment. V/NCM: starting vehicle or NCM treatment. Necropsy: ending all treatments. Data points are the mean values of 4–6 animals. The error bars are the standard deviations of the means.

Serum Cd, Pb, and Methylmercury(MeHg): Serum Cd, Pb, and MeHg concentrations were not determined due to a delay in NCP funding.

b) Effects of Treatments on Food Consumption

Food consumption of obese rats decreased with age (Fig. 9). EOH accelerated the speed of decrease in food consumption. Food consumption was further decreased by both low and high doses of NCM with or without presence of EOH during the first few weeks of exposure, but stabilized afterwards. The decreasing effect of NCM was less pronounced in the presence of EOH. The effects of high dose NCM was more pronounced than the low dose NCM.

Food consumption of the lean rats decreased with age during the first two weeks of experiment, but stabilized thereafter (Fig. 10). Neither EOH nor low dose NCM affected food consumption. The lean rats consumed much less food per day than the obese rats.

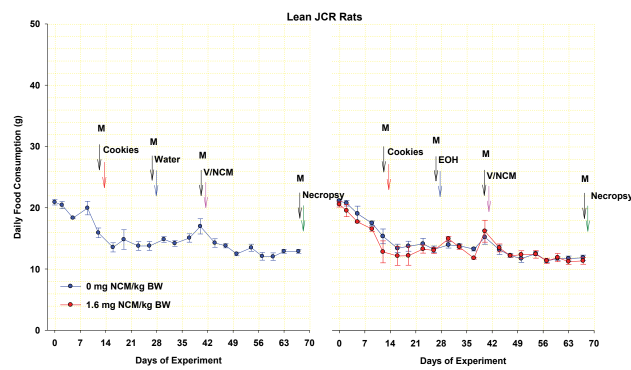


Figure 10. Effects of treatments on daily food consumption of the lean JCR rats. Arrows indicate starting date of the treatment or activity. M: putting in metabolic cage and fasting for 12 h. EOH: starting ethanol treatment. V/NCM: starting vehicle or NCM treatment. Necropsy: sacrificing rats and ending all treatments. Data points are the mean values of 4–6 animals. The error bars are the standard deviations of the means.

c) Effects of Treatments on Water/EOH Consumption

Water consumption of obese rats varied significantly during the first four weeks of experiment, decreased gradually with time for two weeks and stabilized afterwards (Fig. 11). Both low and high doses of NCM further decreased water consumption in the absence of EOH. In the obese rats, EOH consumption also decreased with time for two weeks and stabilized afterwards. Neither low nor high dose of NCM caused further decrease in EOH consumption.

In the lean rats, water consumption remained consistent during the ten weeks of experiment (Fig. 12). EOH consumption decreased with time during the first two weeks of treatment, and stabilized thereafter. Low dose of NCM did not affect

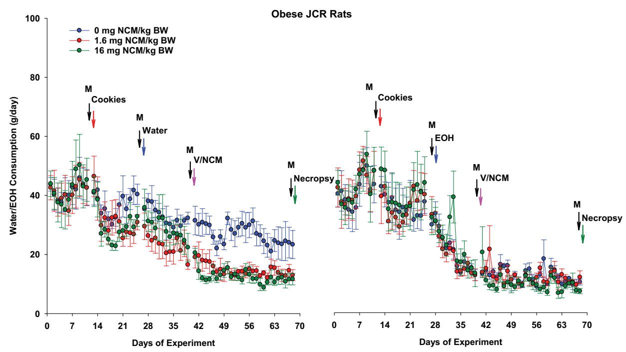


Figure 11. Effects of treatments on daily water or EOH consumption of the obese JCR rats. Arrows indicate starting date of the treatment or activity. M: putting in metabolic cage and fasting for 12 h. EOH: starting ethanol treatment. V/NCM: starting vehicle or NCM treatment. Necropsy: sacrificing rats and ending all treatments. Data points are the mean values of 4–6 animals. The error bars are the standard deviations of the means.

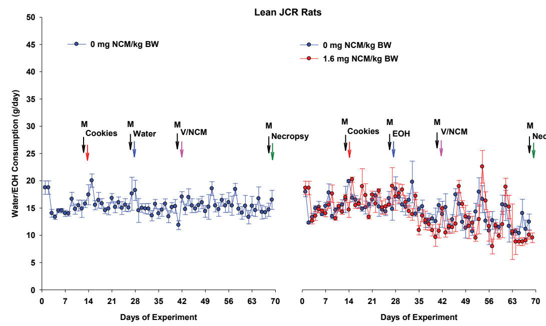


Figure 12. Effects of treatments on daily water or EOH consumption of the lean JCR rats. Arrows indicate starting date of the treatment or activity. M: putting in metabolic cage and fasting for 12 h. EOH: starting ethanol treatment. V/NCM: starting vehicle or NCM treatment. Necropsy: sacrificing rats and ending all treatments. Data points are the mean values of 4–6 animals. The error bars are the standard deviations of the means.

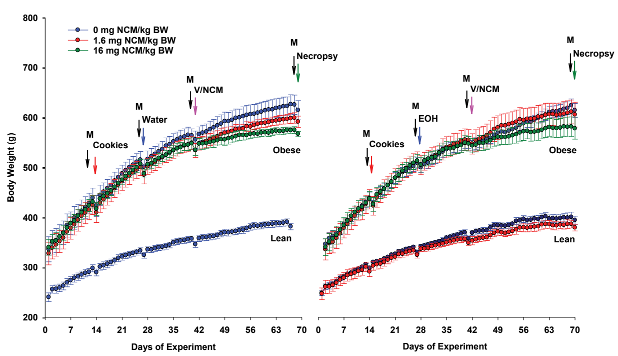


Figure 13. Effects of treatments on body weight gain of the obese and lean JCR rats. Arrows indicate starting date of the treatment or activity. M: putting in metabolic cage and fasting for 12 h. EOH: starting ethanol treatment. V/NCM: starting vehicle or NCM treatment. Necropsy: sacrificing rats and ending all treatments. Data points are the mean values of 4–6 animals. The error bars are the standard deviations of the means.

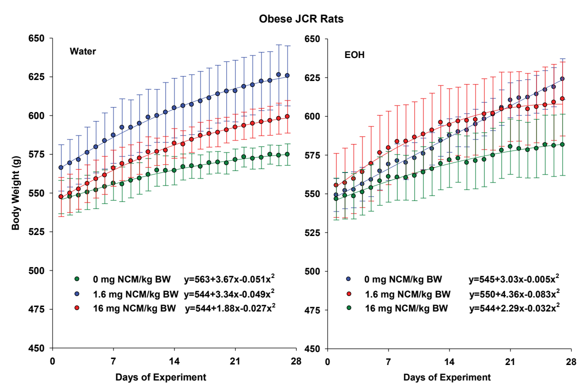


Figure 14. Effects of NCM treatments on body weight gain of the obese and lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard deviations of the means.

EOH consumption. The vehicle treated obese rats consumed more water than the vehicle treated lean rats. However, the NCM treated obese rats consumed similar amount of EOH as the NCM treated lean rats.

d) Effects of Treatments on Body Weight Gain

All rats gained weight with age (Fig. 13). The obese rats gained weight at a much faster rate than the lean rats. EOH treatment had no effect on body weight gain in either obese or lean rats. In the absence of EOH, the low dose NCM slightly decreased body weight gain in the obese rats, while in the presence of EOH, the low dose NCM slightly increased body weight gain during the first two weeks of dosing (Fig. 14). The high dose NCM decreased body weight gain with or without EOH treatment.

e) Effects of Treatments on Urine Volume

Both obese and lean rats produced less urine per 12 h period with age (Fig. 15). The 12h-urine volumes from collection IV were significantly smaller than those from collection I. EOH treatment significantly decreased 12h-urine volume in the obese rats, but not in the lean rats, regardless of the NCM dose. NCM showed no significant effects on 12h-urine volume in either obese or lean rats.

f) Effects of Treatments on Hematological Markers

Mean Corpuscular Haemoglobin (MCH): The obese vehicle control rats given EOH had significantly lower levels of MCH than the lean vehicle control rats treated with EOH (Fig. 16). NCM at 1.6 mg/kg BW significantly decreased MCH in the lean rats treated with EOH.

Neutrophil Counts: NCM at 16 mg/kg BW significantly decreased neutrophil counts as percentage of total white blood cell counts (Fig. 17). The obese rats had markedly higher neutrophil counts than the lean rats, regardless of EOH and NCM treatments.

Eosinophil Counts: NCM at 16 mg/kg BW significantly increased eosinophil counts as percentage of total white blood cell counts (Fig. 18).

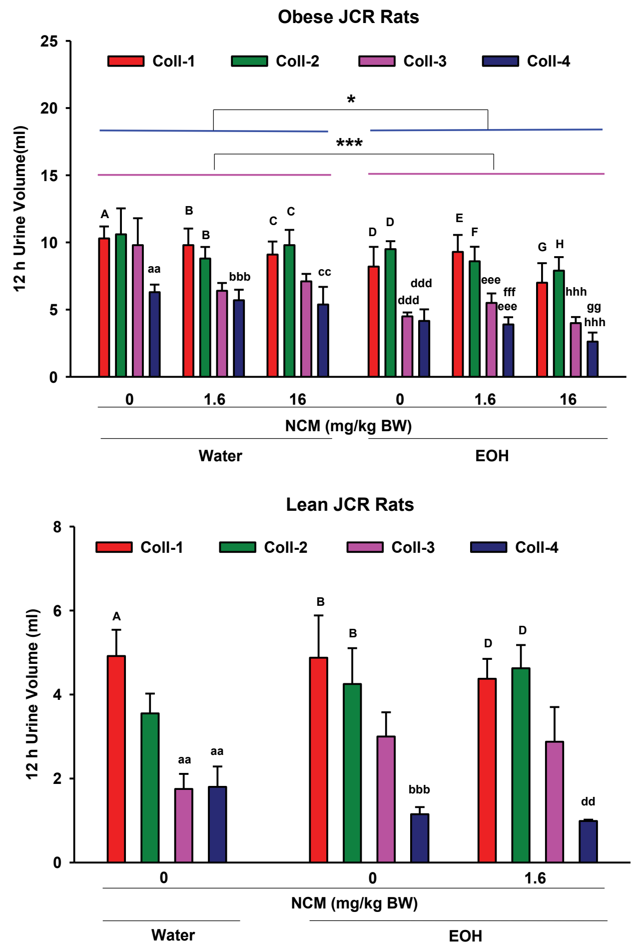


Figure 15. Effects of treatments on 12h-urine volume of the obese and lean JCR rats. Urine samples were collected in metabolic cages during 12 h fasting. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. Coll-I: collection I done on the day before cookie feeding started. Coll-II: collection II done on the day before EOH treatment started. Coll-III: collection III done on the day before NCM treatment started. Coll-IV: collection IV done on the day before necropsy. "*" and "***" indicate significant differences between the two groups located under the lines at p<0.05 and p<0.001, respectively. "A" is significantly different from "aa" at p<0.01. "B" is significantly different from "bbb" at p<0.001. "C" is significantly different from "cc" at p<0.01. "D" is significantly different from "dd" and "ddd" at p<0.01 and 0.001, respectively. "E" is significantly different from "eee" at p<0.001. "F" is significantly different from "fff" at p<0.001. "G" is significantly different from "gg" at p<0.01. "H" is significantly different from "hhh" at p<0.001.

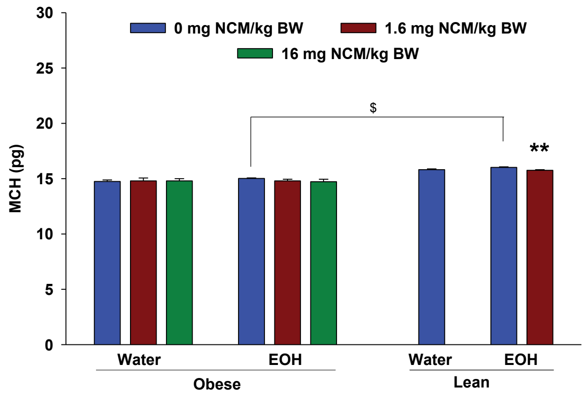


Figure 16. Effects of treatments on mean corpuscular haemoglobin (MCH) of the obese and lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. "**" is significantly different from 0 mg NCM/kg BW at p<0.01. "\$" indicates significant difference between the two groups located under the lines at p<0.05.

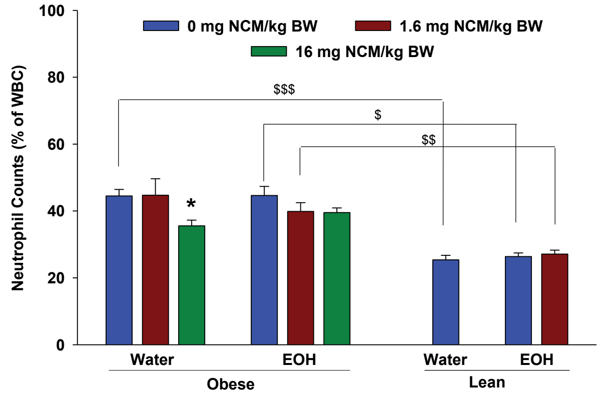


Figure 17. Effects of treatments on neutrophil counts of the obese and lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. "*" is significantly different from 0 mg NCM/kg BW at p<0.05. "\$", "\$\$", and "\$\$\$" indicate significant difference between the two groups located under the lines at p<0.05, 0.01, 0.001, respectively.

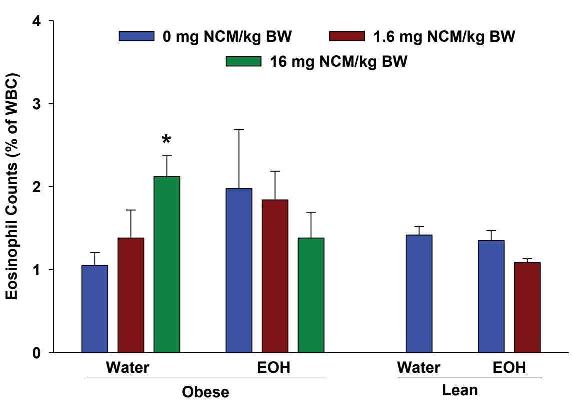


Figure 18. Effects of treatments on eosinophil counts of the obese and lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. "*" is significantly different from the 0 mg NCM/kg BW group at p<0.05.

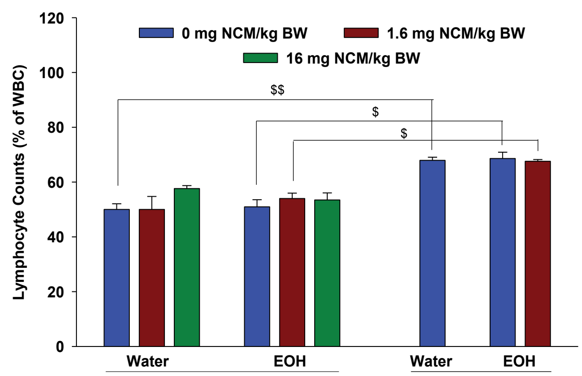


Figure 19. Effects of treatments on lymphocyte counts of the obese and lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. "\$", "\$\$", and "\$\$\$" indicate significant difference between the two groups located under the lines at p<0.05, 0.01, 0.001, respectively.

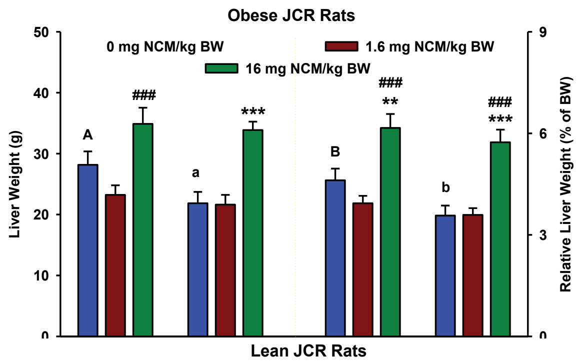


Figure 20. Effects of treatments on absolute and relative liver weight of the obese JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. “A” and “B” are significantly different from “a” and “b” at p<0.05, respectively. “###”indicates significant difference from the 1 mg/kg BW group at p<0.001. “**” and “***” indicate significant differences from the 0 mg/kg BW group at p<0.01 and 0.001, respectively.

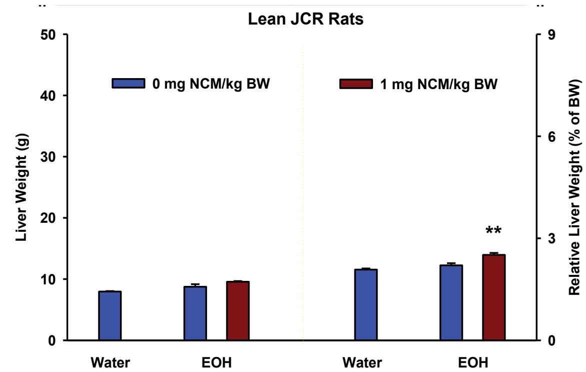


Figure 21. Effects of treatments on absolute and relative liver weight of the lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. “*” is significantly different from 0 mg NCM/kg BW at p<0.05.

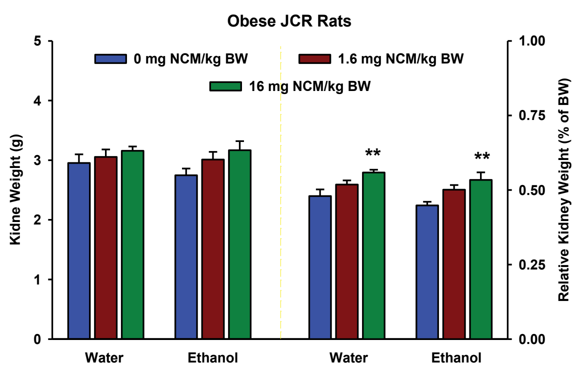


Figure 22. Effects of treatments on absolute and relative kidney weight of the obese JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard deviations of the means. “**” is significantly different from 0 mg NCM/kg BW at p<0.01.

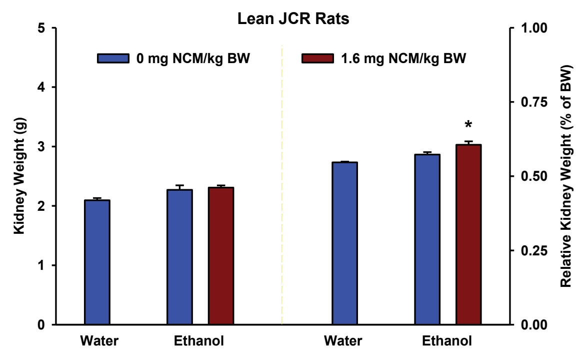


Figure 23. Effects of treatments on absolute and relative kidney weight of the obese JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard deviations of the means. “**” is significantly different from 0 mg NCM/kg BW at p<0.01.

Lymphocyte Counts: The obese rats had significantly lower lymphocyte counts than the lean rats, regardless of the EOH and NCM treatments (Fig. 19).

g) Effects of Treatments on Organ Weights

Liver Weight: In the obese rats, the high dose NCM caused significant increase in absolute and relative liver weight, regardless of EOH (Fig.20). In the vehicle treated obese rats, EOH treatment decreased absolute and relative liver weight. In the lean rats treated with EOH, low dose NCM significantly increased relative liver weight (Fig.21).

Kidney Weight: NCM at 16 mg/kg BW significantly increased relative kidney weight in the obese rats, regardless of EOH (Fig. 22). NCM at 1.6 mg/kgBW significantly increased relative kidney weight in the lean rats treated with EOH (Fig.23).

Heart Weight: NCM at 16 mg/kg BW significantly decreased absolute heart weight in the obese rats given water only (Fig. 24). No effect of NCM on heart weight was found in the lean rats (Fig.25).

Pancreas Weight: NCM at 16 mg/kg BW significantly decreased absolute pancreas weight in the obese rats given water only (Fig. 26). NCM treatment did not affect pancreas weight in the lean rats (Fig. 27)

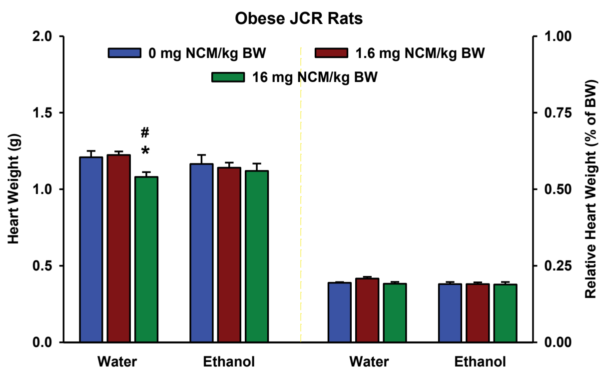


Figure 24. Effects of treatments on absolute and relative heart weight of the obese JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. "*" and "#" are significantly different from 0 mg NCM/kg BW at p<0.05.

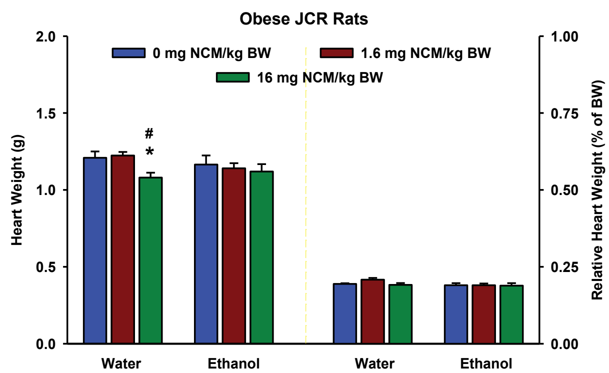


Figure 25. Effects of treatments on absolute and relative heart weight of the lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means.

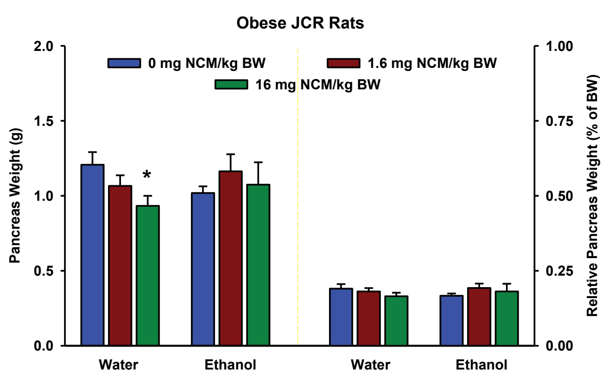


Figure 26. Effects of treatments on absolute and relative pancreas weight of the obese JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. "*" is significantly different from 0 mg NCM/kg BW at p<0.05.

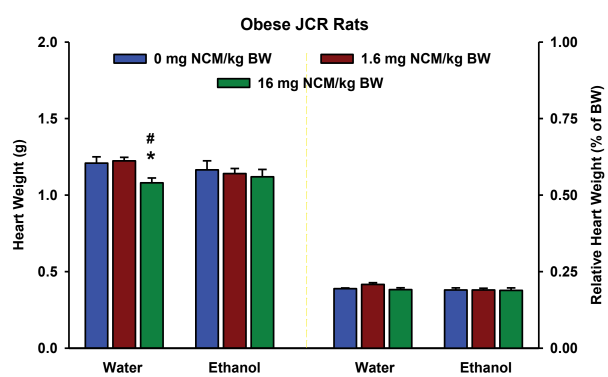


Figure 27. Effects of treatments on absolute and relative pancreas weight of the lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means.

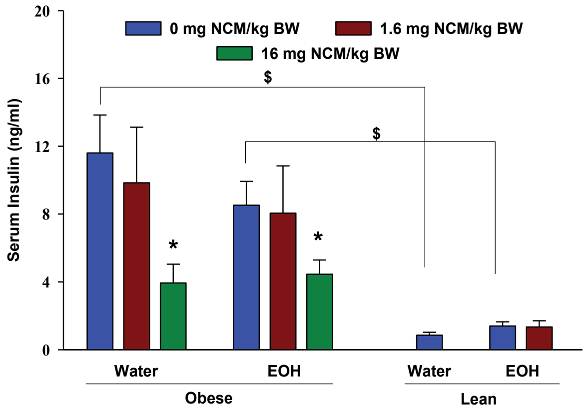


Figure 28. Effects of treatments on serum insulin levels in the obese and lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. "*" is significantly different from 0 mg NCM/kg BW at p<0.05. "$" indicates significant difference between the two groups located under the lines.

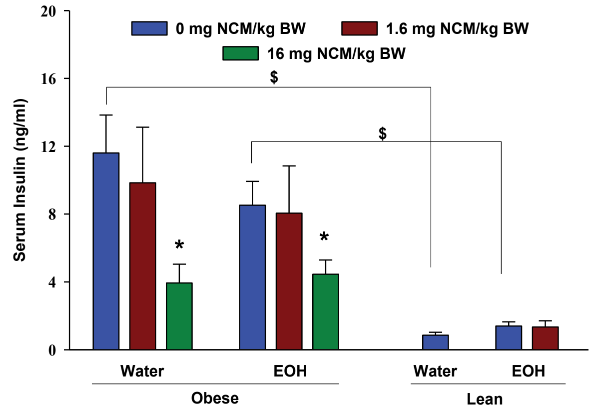


Figure 29. Effects of treatments on serum ethanol levels in the obese and lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. "*" and "**" are significantly different from 0 mg NCM/kg BW at p<0.05 and 0.01, respectively. "###" indicates significant difference from 1.6 mg NCM/kg BW at p<0.001.

h) Effects of Treatments on Serum Markers

Serum Insulin: Regardless of the EOH, 16 mg NCM/kg BW significantly decreased serum insulin level (Fig. 28). Insulin levels in the obese rats were several times higher than those in the lean rats, regardless of the EOH and NCM treatments.

Serum Glucose: A trend of decrease in serum glucose level with NCM dose was found in the obese rats, regardless of EOH (data not shown).

Serum EOHl: Both 1.6 and 16 mg NCM/kg BW significantly increased serum EOH concentrations in the obese rats with or without EOH (Fig. 29). At 1.6 mg/kg BW, NCM also significantly increased serum EOH levels in the rats given EOH.

Serum Cl-: With or without EOH treatment, 16 mg NCM/kg BW significantly increased serum Cl- levels in the obese rats (Fig. 30).

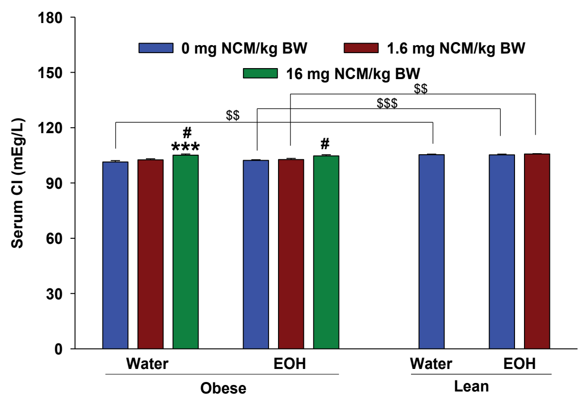


Figure 30. Effects of treatments on serum Cl- levels in the obese and lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. "***" is significantly different from 0 mg NCM/kg BW at p<0.001. "#" is significantly different from 1.6 mg NCM/kg BW group at p<0.05. "$$", and "$$$" indicates significant difference between the two groups located under the lines at p<0.01 and 0.001, respectively.

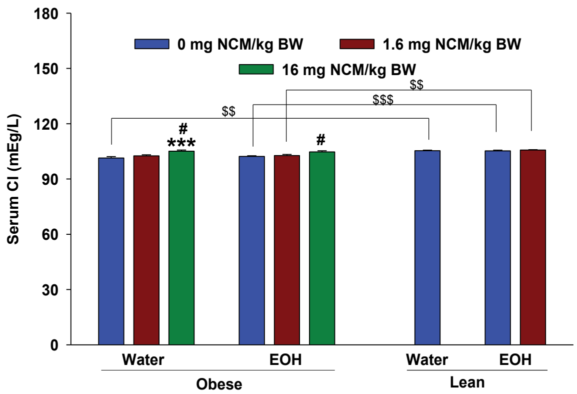


Figure 31. Effects of treatments on serum creatine kinase (CK) levels in the obese and lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. "***" is significantly different from 0 mg NCM/kg BW group at $p<0.001$. "#" is significantly different from 1.6 mg NCM/kg BW group at $p<0.05$.

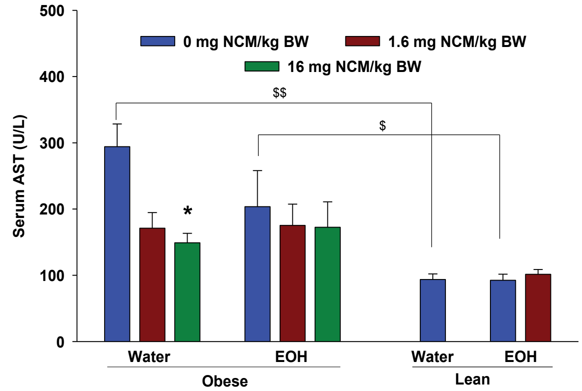


Figure 32. Effects of treatments on serum AST levels in the obese and lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. "*" is significantly different from 0 mg NCM/kg BW at $p<0.05$. "#" is significantly different from 1.6 mg NCM/kg BW group at $p<0.05$. "$" and "$$" indicates significant difference between the two groups located under the lines at $p<0.05$ and 0.01, respectively.

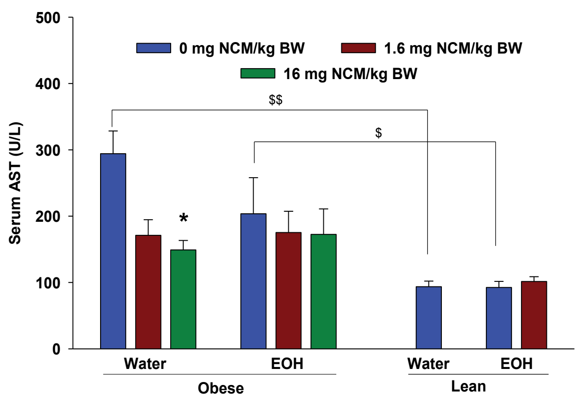


Figure 33. Effects of treatments on serum cholesterol levels in the obese and lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. "*" and "**" are significantly different from 0 mg NCM/kg BW at $p<0.05$ and "0.01", respectively. "$", "$$", and "$$$" indicates significant difference between the two groups located under the lines at $p<0.05$, 0.01, and 0.001, respectively.

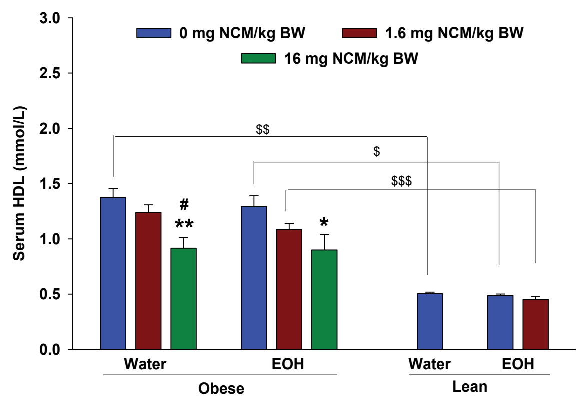


Figure 34. Effects of treatments on serum HDL levels in the obese and lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. "*" and "**" are significantly different from 0 mg NCM/kg BW at $p<0.05$ and 0.01, respectively. "#" is significantly different from 1.6 mg NCM/kg BW group. "$", "$$", and "$$$" indicate significant differences between the two groups located under the lines at $p<0.05$, 0.01, and 0.001, respectively.

Serum Creatine Kinase (CK): In the obese rats treated with water only, 16 mg NCM/kg BW significantly decreased serum CK activity (Fig.31). A trend of decrease in serum CK activity with NCM dose was also seen in the obese rats given EOH.

Serum Aspartate Aminotransferase (AST): NCM at 16 mg/kg BW significantly decreased serum AST activities in the obese rats given water only (Fig. 32). Serum AST activities were much higher in the obese than the lean rats, regardless of EOH.

Serum Cholesterol: In the obese rats given water only, 16 mg NCM/kg BW significantly decreased serum cholesterol levels, while in the obese rats given EOH, the 1.6 mg NCM/kg BW significantly decreased serum cholesterol levels (Fig.33). Regardless of the EOH and NCM, the obese rats had several times higher levels of serum cholesterol than the lean rats.

Serum High Density Lipoprotein (HDL): With or without EOH, 16 mg NCM/kg BW significantly decreased serum HDL in the obese rats (Fig.34). The obese rats had much higher serum HDL levels than the lean rats, regardless of the EOH and NCM.

Serum Low Density Lipoprotein (LDL): NCM at 16 mg/kg BW significantly decreased serum LDL in the obese rats given water only (Fig.35). The obese rats treated with EOH and 1.6 mg NCM/kg BW had significantly lower serum LDL than those treated with water only and the same dose of NCM. The obese rats had much higher serum LDL levels than the lean rats, regardless of EOH and NCM.

Serum Triglyceride: NCM at 16 mg/kg BW significantly decreased serum triglyceride levels in the obese rats with or without EOH treatment (Fig. 36). The obese rats had much higher levels of serum triglyceride than the lean rats, regardless of EOH and NCM.

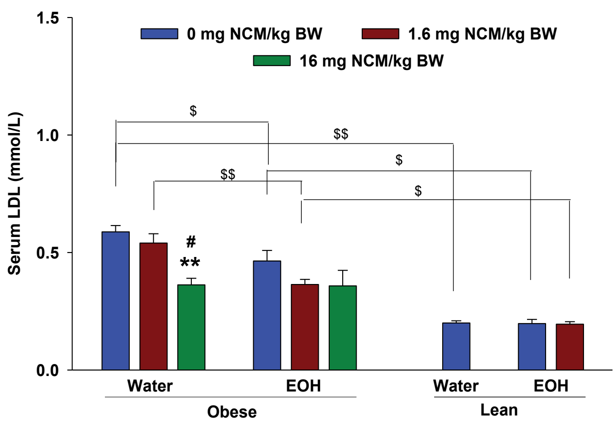


Figure 35. Effects of treatments on serum LDL levels in the obese and lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. "**" is significantly different from 0 mg NCM/kg BW at p<0.01. "#" is significantly different from 1.6 mg NCM/kg BW at p<0.05. "$" and "$$" indicate significant differences between the two groups located under the lines at p<0.05 and 0.01, respectively.

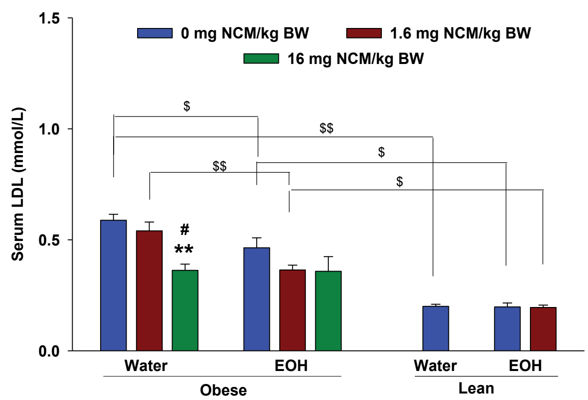


Figure 36. Effects of treatments on serum triglyceride levels in the obese and lean JCR rats. Data points are the mean values of 4–6 animals. The error bars are the standard errors of the means. "***" is significantly different from 0 mg NCM/kg BW at p<0.001. "###" is significantly different from 1.6 mg NCM/kg BW at p<0.001. "$" and "$$$" indicate significant differences between the two groups located under the lines at p<0.05 and 0.001, respectively.

Discussion/Conclusions/ Future Work

a. Discussion

This report presented data from an on-going animal study, which is expected to compete by the end of Sept. 2011. Although the data were obtained from limited numbers (4–6) of animals per treatment group, many significant changes caused by NCM and EOH treatments were observed. Due to limitations in animal supplies and funding, and the cost of the JCR rats, we could not include all dose groups for the lean rats. This prohibited us from making a systematic comparison between the two rat strains for the effects of NCM and ethanol. For the lean JCR rats, only the low dose (1.6 mg/kg BW) NCM could be used as the animals refused to eat the cookies carrying the high dose of NCM. The NCM doses and duration of exposure used in this study caused no loss of animals due to toxicity, but allowed significant effects of NCM to be revealed. With the dosing scheme used, serum concentrations of organic components of NCM in the dosed animals were in the range of NCM concentrations found in the Inuit plasma (Dr. Dewailly et al. 2006), although serum concentrations of some individual contaminants in the dosed animals exceeded the maximum concentrations found in the Inuit plasma. Our preliminary data suggested that serum NCM concentrations increased, but not proportionally, with NCM dose in the obese JCR rats. This could be due to that at high NCM doses, absorption/uptake of these chemicals in the rats were inhibited or reached maximum capacity, or the metabolism/excretion of these chemicals in the experimental animals were increased by the high doses of NCM. The higher serum levels of PCBs and some organochlorines in the lean than the obese rats could be due to that the obese rats had more fat mass and bigger livers than the lean rats to distribute these lipophilic chemicals.

Although we intended to induce binge drinking by giving animals 10% ethanol in drinking water, the treatment scheme did not cause binge drinking in these animals. On the contrary, as compared with water only treatment, ethanol treatment decreased drinking volume/day in both obese and lean rats. This could be due to changes in metabolic activities induced by ethanol or an unfavourable taste of ethanol to these rats. The obese animals given ethanol also produced less urine/12h than those given water only, reflecting a change in drinking volume. NCM treatment decreased water consumption more pronouncedly than ethanol consumption in the obese rats. This could be a reflection of higher NCM levels found in the serum of rats given water only than those given ethanol.

The obese rats consumed nearly twice as much food per day as the lean rats, in accordance with their faster body weight gain than the lean rats. The obese rats were more easily addicted to the Teddy Gram cookies than the lean rats, possibly due to stronger desire for food as a result of defect in regulation of appetite by leptin signalling. The obese rats also consumed less food with age, possibly due to decreased physical activity with fast increasing body weight, as well as aging. In contrast, daily food consumption of the lean rats was fairly consistent with age, except a drop at the first two weeks of the study. This suggests that the lean animals are capable of regulating its food intake and body weight gain. The effects of NCM on food consumption and body weight gain were more pronounced in the obese rats given water only than those given ethanol. This is in concurrence with the higher serum NCM concentrations detected in the rats given water only than those given ethanol.

Regardless of EOH and NCM, the obese rats had markedly higher neutrophil counts than the lean rats, suggesting a more inflammatory state of the former than the latter, which is in agreement with the notion that obesity is associated with systemic inflammation. The high dose of NCM significantly decreased neutrophil counts in the obese rats, although the mechanisms involved remain unclear. The obese rats also had significantly lower levels of lymphocyte counts than the lean rats regardless of the EOH and NCM, suggesting a compromised immune system of the obese animals. The high dose of NCM caused a two fold increase in eosinophil counts in the obese rats given water only. This could be a result of allergic reaction of the obese rats to NCM, or a secondary effect of NCM-induced liver injury. More in depth pathological and biochemical analyses are required to confirm this.

The obese rats had much larger and fattier liver than the lean rats. The high dose of NCM further increased liver weight and fattiness in the obese rats with or without EOH treatment, suggesting that a non-alcoholic steatosis. The effects of high dose of NCM could not be examined in the lean rats since they refuse to take the cookies carrying the high dose of NCM. The low dose of NCM significantly increased relative liver weight in the lean rats, implying that liver is a major target of NCM in both obese and lean rats. Liver steatosis is known to be associated with obesity and insulin resistance. An increase in liver fat content has been shown to predict type II diabetes, independently of other cardiovascular risk factors. This is because the liver, once fatty, overproduces most of the known cardiovascular risk factors such as very low density lipoprotein (VLDL), glucose, C-reactive protein (CRP), plasminogen activator inhibitor-1 (PAI-1), fibrinogen and coagulation factors. The obese rats had several folds higher levels of serum insulin, cholesterol, triglyceride, and LDL than the lean rats, pointing to an increased risk of diabetes and cardiovascular disease for the obese than the lean rats. Interestingly, NCM at the high dose used did not increase, but rather decreased serum insulin, cholesterol, triglyceride, HDL, and LDL levels. Although the mechanisms underlying these effects of NCM remain to be elucidated, it is possible that NCM inhibited the transport/release of these molecules from their origin (liver and pancreas) of synthesis to circulation, which could be a result of decreased enzyme activities and altered transporter function by NCM treatment. The obese rats also had three time higher serum AST activity than the lean rats. This could be an indication of liver injury, although other possibilities could not be ruled out before further examination. The decreased serum CK and AST by NCM in the obese rats further suggest a potential inhibitory effect of NCM on liver and other organ enzymes. The decreasing effects of NCM on pancreatic weight and circulating insulin levels point to pancreas and possibly beta cell function as an import target of NCM, which warrant more detailed investigation.

It was surprising that with or without ethanol treatment, both low and high doses of NCM increased serum levels of ethanol in the obese rats. The low dose of NCM also increased serum ethanol concentrations in the lean rats receiving ethanol treatment. This suggests that the ethanol detected in the sera was produced endogenously, possibly by microbial activity in the gut. The increase in serum ethanol concentrations by NCM treatment was likely a result of decreased metabolism of ethanol by alcohol dehydrogenase in the liver, suggesting a potential inhibitory effect of NCM on this enzyme, even at the low dose used. It remains to be confirmed if the increase in serum ethanol levels can be used as a marker of NCM exposure.

The increased serum chloride concentrations in the NCM-dosed obese rats could be a result of dehydration or decreased reabsorption of chloride in the kidney. Although high dose NCM increased relative kidney weight in both lean and obese rats, serum clinical markers revealed no severe kidney damage. However, more detailed pathological and biochemical examination is required to reveal NCM-mediated changes in kidney structure and function. The high dose of NCM also decreased absolute heart weight implying a potential effect of NCM on heart health, which is currently under investigation.

b. Conclusions

- The two NCM doses used in this study generated serum concentrations of organic NCM in the dosed rats similar to, or in the range of, those found in the Inuit plasma.
- Ethanol treatment did not induce binge drinking, but decreased serum concentrations of organic components of NCM in the obese rats.
- The effects of NCM examined were more pronounced in the rats treated with water only than those treated with 10% ethanol.
- With the doses of NCM used, the obese rats did not show higher susceptability to NCM treatment than the lean rats.
- In general, the lean rats showed more capacity then the obese rats in regulating their food and water intake.
- The obese rats had a systemic inflammatory state, and a compromised immune system.
- The obese rats were hyperlipidemia and hyperinsulinemia, and had liver steatosis.

- Pancreas and liver were found to be the major targets of NCM, although heart and kidney toxicities were also observed.
- NCM treatment increased degree of liver steatosis in the obese rats, but decreased metabolism and/or transport/release of cholesterol, triglyceride, lipoproteins, and enzymes from liver into circulation.
- NCM decreased pancreas weight insulin secretion.
- NCM decreased ethanol metabolism in the liver leading to increased endogenous ethanol concentrations in the serum.

c. **Future Work**

- Further analyses are under way to confirm these preliminary findings.
- NCM contents in liver and fat will be analyzed as soon as funding becomes available.
- Cd, Pb and mercury in serum will be analyzed when NCP funding is resumed.
- The effects of NCM on makers of endothelial function and insulin signalling will be determined in the near future.
- The effects of NCM on serum and liver lipid profile will be examined as soon as funding is resumed.
- The effects of NCM on pathological changes in target organs will be examined as soon as the animal dosing is completed.

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;
- annual project report to NCP for 2010 and 2011;
- oral and poster presentations at NCP Results Workshop and other scientific meetings in 2010–2012; and
- publications in peer reviewed scientific journals in 2012-2013.

Relevant Publications

- Jin X., N. Hidiroglou, E. Lok, M. Taylor, K. Kapal, N. Ross, K. Sarafin, A. Lau, A.D. Souza, H.M. Chan, R. Mehta (2011) Dietary Selenium (Se) and Vitamin E (VE) Supplementation Modulated Methylmercury-mediated Changes in Markers of Cardiovascular Diseases in Rats. Submitted to *Cardio Toxicol*.
- Cao, X-L, J. Corriveau, S. Popovic, M. Coughlan, N. Chepelev, W. Willmore, T. Schrader, **X. Jin** (2010) Backgroud bisphenol A in experimental materials and its implication to low-dose in vitro study. *Chemosphere 81*, 817-820.
- Yan, J., M. Coughlan, **X. Jin** (2010) Changes in gene expressions following methylmercury exposure-induced glutathione depletion and oxidative stress in human coronary artery endothelial cells. *Free Rad. Biol. Med. 49*, S 33.

- Florian, M., J. Yan, S. Ulhaq, M. Coughlan, W. Willmore, **X. Jin** (2010) Effects of a Northern contaminant mixture on cardio-vascular markers in human coronary artery endothelial cells under conditions typifying the diet and lifestyle of Northerners. *Free Rad. Biol. Mad. 49, S21.*
- Chepelev N.L., M. Enikanolaiye, Q. Chen, K. Scoggan, **X. Jin**, M. Coughlan, W. Willmore (2010) Human antioxidant response element-Nrf1/2 pathway-mediated defense against BPA exposure. *Free Rad. Biol. Med. 49, S127.*
- Chen, Q., J. Djokic, M. Coughlan, N. Chepelev, C. Qiao, W. Willmore, **X. Jin**, K.A.Scoggan (2010) Global gene response to bisphenol A exposure in human fetal lung and whole fetal fibrioblasts. *2010 Health Canada Science Forum. Ottawa, Canada.*
- **Jin, X**, W. Willmore, J. Yan, M. Florian, M. Coughlan, S. Ulhaq. In vitro screening and identification of Northern contaminant mixtures for their effects on insulin action and endothelial function under conditions typifying specific diets and lifestyles of Northern populations: implication for identification and assessment of the metabolic and cardiovascular health risk of Northern populations. *Synopsis of Research conducted under the 2009–2010 Northern Contaminants Program. P: 53-71.*
- Ayotte, P., D. Kumar, **X. Jin**, S. Shahbaz, P. Tremblay, O. Fiehn (2010) Alteration of urinary metabolic profile in rats treated with methylmercury. *6th Annual Advances in Metabolic Profiling Conference in Florence, Italy.*
- **Jin, X**., M. Coughlan, J. Yan, K. Kapal, M. Taylor, H.M. Chan and R. Mehta (2009a) In vivo and in vitro effects of methylmercury on markers of metabolic and cardiovascular diseases. 2009 Health Canada Science Forum (Abs.1.19) and 2009 NCP Workshop, Ottawa
- **Jin, X.**, E. Lok, D. Caldwell, R.Mueller, K. Kapal, V. Liston, S. Kubow, H.M.Chan†, and R. Mehta (2009b). Dietary fats altered nephrotoxicity profile of methylmercury in rats. J. *Appl.Toxicol. 29:126-140.*
- **Jin, X**., N. Kearns, M.C. Coughlan. (2009c). Effects of Furan on Markers of Systemic Oxidative Stress and Antioxidant Defense in Rats. Departmental Report to FECFA
- **Jin, X, S**. Ulhaq, M. Coughlan, J. Roberts, J. Yan, R. Mehta, J. Raju. (2009d) Effects of Dietary Acrylamide on Systemic Oxidative Stress and Inflammatory Markers in Rats. Departmental Report to JECFA.
- **Jin, X**., E. Lok, K. Kapal, M. Taylor, S. Kubow, R. Mehta, H.M. Chan. (2008) Dietary fats modulate methylmercury-mediated systemic oxidative stress and oxidative DNA damage in rats", *Food Chem. Toxicol.* 46: 1706–1720.
- Coughlan, M., J. Yan, **X. Jin** (2008) Methylmercury Cytotoxicity and Effects on Cellular Distribution and Protein Expression of Paraoxonase-2 (PON2), Thioredoxin Reductase-1 (TrxR1), Glutathione Peroxidase-1 (GPx1) in Human Coronary Artery Endothelial Cells (HCAEC). *Free Rad. Biol. Med. Vol. 45, sup. 1, s145.*
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- **Jin, X.,** E. Lok, G. Bondy, K. Kapal, M. Taylor, L.C.H. Chan, and R. Mehta. (2007) Differential effects of dietary fish meal and casein on methylmercury toxicity in rats. *11th Meeting of the Internation Congress of Toxicology.* Abs#. 262.
- **Jin, X.,** E. Lok, K. Kapal, M. Taylor, A. Lau, A. De Souza, N. Kearns, H.M. Chan, and R. Mehta. (2007) Selenium and vitamin E modulate methylmercury-induced systemic inflammatory response in rats. 2007 *Health Canada Science Forum*. Abs.# 2.19.

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- **Jin, X.,** E. Lok, D. Calswell, Rudi Mueller, K. Kapal, M. Taylor, L.H.M. Chan, and. R. Mehta. (2006) Can selenium and vitamin E alleviate or aggravate methylmercury toxicity? Clinical biochemistry data from a short term animal study. *2006 Federal Food Safety and Nutrition Research Meeting. Abstract Book. p:102*
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- **Jin, X.,** E. Lok, R. Mueller, K. Kapal, M. Taylor, L.H.M. Chan, R. Mehta. (2006) Is there a link between dietary fats, methylmercury exposure, and cardiovascular disease? *14th Annual Results Workshop, Northern Contaminants Program, Abstract Book. p:69-70.*
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- **Jin, X.,** R. Mehta, E. Lok, D. Caldwell, R. Mueller, K. Kapal, M. Taylor and L. H.M. Chan. (2005) Is methylmercury exposure a risk factor for cardiovascular disease? Evidence from an animal study. *2005 Federal Food Safety and Nutrition Research Meeting*, p.124.

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Examining Benefits and Risks of Traditional and Market Food: Focus on Fish Consumption in the Dene/Métis Community of Tulita, NWT

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Abstract

Mercury is a toxic pollutant which can pose risks to human health. In June 2010, the community of Tulita, NT, population 565, raised concerns over a public health advisory to reduce consumption of lake trout from Kelly lake, a source of fish for the community, due to high concentrations of mercury. A dietary study was requested and designed to estimate the possible mercury contaminant risk, as well as the nutrient, and social benefits of fish consumption for the people of Tulita. With assistance from local research assistants knowledgeable of community food sharing customs, study participants were identified as consumers of fish from the Kelly Lake area. Sixty seven community residents

Résumé

Le mercure est un polluant toxique pouvant poser des risques pour la santé humaine. En juin 2010, la collectivité de Tulita, T.N. O., d'une population de 565 personnes, s'est inquiétée d'un avis de santé publique recommandant une réduction de la consommation de touladis du lac Kelly, source de poissons pour la collectivité, en raison des fortes concentrations de mercure. Une étude en diététique a été demandée et conçue en vue d'estimer le risque possible de contamination au mercure ainsi que les bienfaits nutritionnels et sociaux liés à la consommation de poissons par la population de Tulita. Avec l'aide d'adjoints à la recherche locaux connaissant les coutumes de partage de la nourriture pratiquées

completed the dietary interview and provided a hair sample. Information on fish consumption for the summer 2010 and winter 2010–11 season were collected using a validated, semi-quantitative food frequency questionnaire. Hair samples were collected and shipped for analysis of total mercury concentration to assess exposure to mercury in the same summer and winter seasons. The study is being carried out in partnership with Tulita through the Tulita Renewable Resource Council. Ethical approval for the study was obtained from McGill University Ethics Review Board III, and a Northwest Territories Scientific Research License was issued from the Aurora Research Institute. What is learned will inform community stakeholders and public health advisers on appropriately addressing concerns about mercury contamination and fish consumption. This report summarizes the data collection activities for the initial phase of this two part study.

dans la collectivité, des participants de l'étude ont été désignés comme consommateurs de poissons du secteur du lac Kelly. Soixante-sept membres de la collectivité ont participé à une entrevue sur leur alimentation et ont fourni un échantillon de cheveux. L'information sur la consommation de poisson pour l'été de 2010 et l'hiver 2010–2011 a été recueillie au moyen d'un questionnaire semi-quantitatif validé sur la fréquence de consommation. Les échantillons de cheveux recueillis ont été envoyés à une analyse de la concentration totale de mercure, afin d'évaluer l'exposition au mercure au cours des mêmes saisons d'été et d'hiver. L'étude est menée en partenariat avec la collectivité de Tulita par l'entremise du Conseil des ressources renouvelables de Tulita. Le Conseil d'examen déontologique de l'Université McGill a jugé l'étude conforme à l'éthique et l'Institut de recherche Aurora lui a délivré un permis de recherche scientifique des Territoires du Nord-Ouest. L'information ainsi recueillie éclairera les parties intéressées de la collectivité et les conseillers en santé publique sur la façon d'aborder les préoccupations concernant la contamination au mercure et la consommation de poisson. Ce rapport résume les activités de collecte des données pour la première des deux phases de l'étude.

Key Messages

- From December 2010 to March 31 2011, a study to assess methylmercury exposure risk through fish consumption was collaboratively designed with the community of Tulita and the project team.
- Semi-quantitative food frequency interviews and hair specimens were successfully collected by local research assistants.
- Data management is underway to meet proposed data analysis objectives for 2011–12 study activities.

Messages clés

- De décembre 2010 au 31 mars 2011, une étude visant à évaluer le risque d'exposition au méthylmercure par la consommation de poisson a été conçue conjointement avec la collectivité de Tulita et l'équipe du projet.
- Des adjoints à la recherche locaux ont mené des entrevues semi-quantitatives sur la fréquence de consommation et prélevé des échantillons de cheveux.
- Le processus de gestion des données est en cours et devrait atteindre les objectifs d'analyse des données proposés pour les activités de l'étude de 2011–2012.

Project Objectives

- To assess the risk for mercury exposure posed by fish consumption in the community of Tulita in the past summer (2010) and current winter (2010–11) seasons.
- To examine the relationship between the consumption of sweetened beverages (low nutrient market food) and fish consumption.
- To explore the social and cultural importance of fish (traditional food) to the Dene/Métis in Tulita.

Introduction

In June 2010, concerns in the Dene/Métis community of Tulita, NT, population 565, were raised over the finding of high concentrations of mercury in lake trout from lakes where the community harvests fish. In Tulita key informants describe consumption patterns of fish, and dried fish, including lake trout, throughout the winter suggesting that exposure to mercury through consuming fish continues outside of the summer lake trout harvest period. Dietary consumption data to verify contaminant risk do not exist for Tulita. Therefore the need to conduct a dietary study to assess risk of methyl mercury exposure through fish consumption was jointly identified by the community of Tulita and Public Health office of the GNWT and Health Canada. Hair mercury analysis will provide an independent measure of mercury exposure. The question posed specifically by the community is, "Are current patterns of fish consumption in Tulita safe?"

Activities

November 26/10
Dr. Treena Delormier was contacted through the Centre for Indigenous Peoples' Nutrition and the Environment (CINE) at McGill University to design and coordinate the study. The project team was identified at this time. Using CINE's dietary methodologies, consulting with project team members and collaborating with the Tulita Renewable Resource Council a research study, work plan and time line were agreed upon.

December 17/10
Dr. Treena Delormier, research co-PI, with approval from the research team submitted the proposed study to the Northern Contaminants Program secretariat.

December 20/11–January 13/11
The ethical review application was prepared and submitted to the McGill Ethics Review Board. This involved finalizing data collection instruments, developing a protocol with the Sahtu Regional Health Authority for returning participant hair mercury concentration results, finalizing informed consent protocols for adults and children, consulting with McGill ethics officer, and project partners to ensure the quality and appropriateness of the research tools and a timely and complete review. The application process to obtain the required Northwest Territories Scientific Research License was started during this time.

January 24
En route to Tulita, Dr. Delormier met with Dr. Kami Kandola in Yellowknife for briefing on the upcoming project activities and to finalize and submit the NCP proposal 2011–12 for the second, data analysis phase of the study.

January 25/11–January 31/11
Dr. Delormier met with the Sahtu Regional Health Authority in Norman Wells to discuss the protocol for returning research results from hair mercury analysis to individual study participants. Protocol was later written by Mirelle Gionet Director of Health & Social Programs.

In Tulita, Delormier was introduced and oriented to the community. TRRC hosted the visit during which Delormier was introduced to and met with the Tulita Dene Band, Tulita District Land Corporation, The Tulita municipal Land Corporation and the Sahtu Renewable Resource Board to discuss the study. Visits were made to introduce the research project at the Harriet Gladue Health Center, Chief Albert Wright School, the Family Support Centre, the Catholic and Pentecostal churches. Information was also informally shared with enquiring community members through community social events (drum dance, volleyball tournament, cribbage tournament). At a public meeting of community members, primarily elders, Delormier gave a presentation on the study. Translation was provided. A number of questions and concerns were raised and each of these was discussed in turn. The meeting ended with those gathered adding their support to the study as presented, and Delormier assured her commitment to working with the community through the TRRC on the research.

Over this time meetings were held with Tulita Renewable Research Council (TRRC), and other interested stakeholders, to share information about the study, coordinate the resources and timing of the planned data collection, and finalize data collection tools. Local research assistants, identified by TRRC, met with Dr. Delormier. Their input on the practical aspects of the study design, in particular the questionnaire, and sampling were integrated into the final work plan.

February 8/11–28/11
Dr. Delormier, along with Jayne Murdoch, Master's student in nutrition and research assistant, returned to Tulita. Data collection began after training the local research assistants, and receiving approval from the McGill Ethics Review Board (Feb. 10/11), and being issued the NWT Scientific Research License. The participant recruitment strategy was finalized and participant recruitment was formally publicized by print and radio media. The recruitment goal was 3 individuals, a child, adult and elder; from 25 households for a total of 75 participants. If one or more individuals were not present in a household, a replacement was identified from the next household identified on the final list of potential participants.

Three public events were organized to provide an opportunity for people to participate in the study. The first was suggested by the local research assistants who felt that some people would prefer to come out and participate rather than have interviewers come into often busy households. A light meal was offered at the arena/community hall and everyone was welcomed, interviewers were on hand for those who wanted to complete the interview on site. Some people had requested an interview at this venue ahead of time. The second was organized after school, for parents and school children who wanted to participate. The third was organized around a meal/cooking class at the Family Support Center, to provide an additional opportunity for parents and children to participate.

Despite a number of events going on in the community, and one of the local research assistants having to leave, data collection was deemed successful as we managed to recruit and interview 67 people for the dietary study and collect hair specimens into the study. As well, Dr. Delormier interviewed eight knowledgeable community members on fish consumption and its meaning in Tulita.

Data Management
(March 9–April 30/11)
The data entry software was programmed, debugged and tested to accept the data from specific questionnaires designed for the study. A student was hired and trained to enter the dietary data. Raw data entry was completed April 22/11.

Hair specimens were sent to the Centre de Toxicologie/ Institut National de Santé Public du Québec March 22/11. The hair specimens analysis report of total mercury was received April 28, 2011.

Study Coordination

It is noteworthy that a significant amount of the study coordinator's time was invested in communication and coordination between the TRRC president and board, the NCP secretariat and the study team advisers in order to manage both the NCP funding requirements, and the challenges for a rigorous, timely and ethical research process. The commitment of the research team and the community of Tulita allowed us to mobilize the required resources to fulfil the numerous research and project management needs (and challenges) and to meet our data collection objectives within the an extremely short time frame. The feedback thus far from the project team members, the TRRC, the community of Tulita have been very positive.

Capacity-building activities

- local research assistants' skills in research methods
- academic student researcher's skills in community-based research with an Aboriginal community
- project teams capacity to collaboratively address public health issues
- community organisation assumes responsibility for the study they requested and participates in all activities related to the study objectives

Communication activities

- ongoing communication among project team to ensure up to date information, progress and timely decision-making.
- public communication within the community to discuss the proposed study and to inform on study progress and activities.
- researchers being present in the community (4 weeks total) and available to address all study questions in the concerns and to accommodate study related requests for information/activities.

Table 1. Characteristics of study participants

Age group	% (n=)	age range (years)	
child	23.9 (16)	6–11	
adult	52.2 (35)	20–64	
elder	23.9 (16)	66–87	
total	**100 (67)**		
Age group	Gender		
	female % (n=)	**male % (n=)**	**total %**
child	37.5 (10)	62.5 (6)	100 (16)
adult	54.3 (19)	45.7 (16)	100 (35)
elder	37.5 (10)	37.5 (6)	100 (16)
total	**58.2 (39)**	**41.8 (28)**	**100 (67)**

Traditional knowledge

- study incorporates qualitative interviews to provide the socio-cultural context of traditional practices related to fishing.

Results

Study Participants

Table 1. shows the age and gender characteristics of the study sample. We obtained equal proportions (24%) of participants in the child and elder age groups, about half of the participants were in the adult age group. There were slightly more female participants (58.2%) than male participants over all. Participants represented 52 households; 37 households had a single participant; 15 household had 2 participants and no households had 3 participants.

Hair specimens

Sixty-nine (69) specimens were sent for analysis of total mercury. Forty seven hair specimens were of adequate length permitting analysis of total mercury along the portion 0–2 cm (representing the winter season) and portion 6–7 cm (representing the previous summer season). Twenty-two hair specimens were analyzed for the portion 0–2 cm only. Levels of mercury in hair specimens will be interpreted and discussed among the project team before publishing.

Discussion and Conclusions

There are no data interpretations at this time since this report describes the activities related to the data collection phase of this study only.

Expected Project Completion Date

August 2011.

Mercury Exposure and Emergence of Cardio-Vascular Diseases in Inuit

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Abstract

More and more data suggest that the cardiovascular system should be considered a potential target for Arctic contaminants. For example, work conducted in the Faeroe Islands in children and in Greenland suggests association between mercury exposure, blood pressure and heart beat variability which are known risk factors for cardiac health. Other studies conducted elsewhere suggest association between mercury and heart diseases, the later of which are on the rise in the Arctic. Our hypothesis is that this rise is not only due to a changing lifestyle but also to contaminant exposure. This project aims to investigate associations between exposure to mercury and the emergence of heart disease and related risk factors using two large epidemiological studies conducted among adults and children in Arctic Canada. Since heart disease represents one of the leading causes of death, even a slight negative impact on the

Résumé

De plus en plus, les données indiquent que le système cardiovasculaire devrait être considéré comme cible potentielle pour les contaminants de l'Arctique. Par exemple, des travaux menés auprès d'enfants aux îles Féroé et au Groenland laissent à penser à une association entre l'exposition au mercure, la pression sanguine et la variabilité de fréquence cardiaque, qui sont des facteurs de risque connus en matière de santé cardiaque. D'autres études menées ailleurs laissent entrevoir un lien entre le mercure et les cardiopathies, qui sont en hausse dans l'Arctique. Notre hypothèse est que cette hausse est due non seulement à la transformation du mode de vie, mais aussi à une exposition à des contaminants. Ce projet vise à étudier les liens entre l'exposition au mercure et l'émergence de cardiopathies et les facteurs de risques connexes, au moyen de deux vastes études épidémiologiques menées chez des adultes et des enfants de

cardiovascular system could be of greater public health relevance than any other health effects related to contaminant exposure.

l'Arctique canadien. Étant donné que les cardiopathies représentent l'une des principales causes de décès, même un effet négatif léger sur le système cardiovasculaire pourrait revêtir une plus grande importance sur le plan de la santé publique que tout autre effet lié à l'exposition aux contaminants.

Key Messages

Inuit are among the people in the world most exposed to mercury and this exposure is not decreasing. In parallel, many health indicators show that cardiovascular diseases (CVD) are increasing. Recent international studies support the association between mercury and CVD. With this project, we are studying two Inuit cohorts (one with adults and one with children), the relationship between exposure to mercury and various risk factors of CVD such as high blood pressure, low heart rate variability, increase in blood oxidation and increase of artery thickness. These results will guide decision makers at the local, national and international levels.

Messages clés

Les Inuits sont parmi les groupes les plus exposés au mercure dans le monde et cette exposition ne va pas en décroissant. Parallèlement, bon nombre d'indicateurs de santé montrent que les maladies cardiovasculaires sont en hausse. Des études internationales récentes concluent à l'association entre le mercure et les maladies cardiopathies. Dans ce projet, nous étudions deux cohortes d'Inuits (un groupe d'adultes et un groupe d'enfants), le lien entre l'exposition au mercure et divers facteurs de risque pour les cardiopathies, comme l'hypertension, la faible variabilité de fréquence cardiaque ainsi que l'accroissement de l'oxydation sanguine et de l'épaisseur artérielle. Ces résultats vont guider les décideurs aux niveaux local, national et international.

Objectives

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

a. Mercury exposure is associated with elevated blood pressure in adults and children even after controlling for major confounders.

b. Mercury decreases *heart rate variability* in adults and children.

c. Mercury is a risk factor for *atherosclerosis and oxidation*.

d. Mercury is associated with higher prevalence of cardio vascular diseases.

e. Study the role of *omega-3 fatty acids and selenium* in the above mentioned hypotheses.

Introduction

Most studies on the relationship between toxic metals and the risk for clinical cardiovascular disease has been on mercury exposure. The first studies reporting a relationship between methylmercury exposure and carotid intima-media thickness came from Finland (Salonen et al. 2000). Since then, several other studies have been published offering support to varying degrees. The same study group in a follow-up study showed that a high content of mercury in hair may be a risk factor for acute coronary events and cardiovascular disease (CVD), CHD, and all-cause mortality in middle-aged eastern Finnish men, and that mercury also may attenuate the protective effects of fish on cardiovascular health (Virtanen et al. 2005). The US Health Professionals' Follow-up Study (Yoshizawa et al. 2002) showed only a minimal overall risk. However, when analyses were performed after the exclusion of dentists, the relative risk for myocardial infarction (MI) increased to 1.7 (in green below). The most important study was conducted in Europe and found a dose response relationship between Hg in toenails and MI (Guallar, 2002) (in red below) (figure 1).

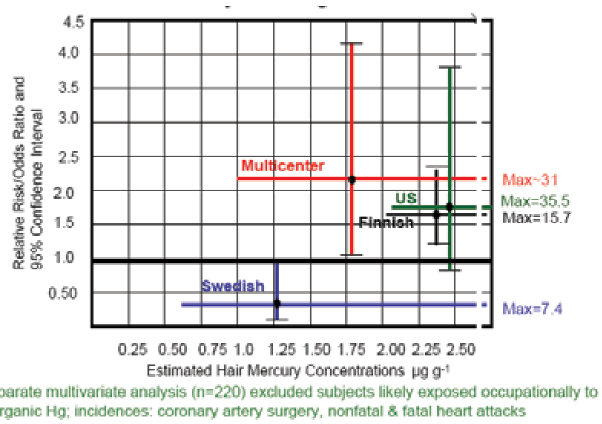

Figure 1: Cardiovascular Risks: Consistency & Strength of Association

Intake of mercury through food items from sea mammals and fish has been suggested to be involved in cardiovascular disease, and the relationship between mercury in blood and 24-h ambulatory blood pressure (BP) was studied in Greenland. Blood pressure in childhood is an important determinant of hypertension risk later in life, and methylmercury exposure is a potential environmental risk factor. A birth cohort of 1,000 children from the Faeroe Islands was examined for prenatal exposure to methylmercury, and at the age of 7, blood pressure, heart rate and heart rate variability were determined (Sorensen et al., 1999). In Nunavik, we aimed to study the impact of mercury levels on BP among Nunavik Inuit adults. The Health Survey «Qanuippitaa?» was conducted in Nunavik. Mercury was associated with increasing BP and pulse pressure among adults after considering the effect of fish nutrients (n-3 fatty acids and selenium) and other confounders (Valera et al. 2009).

Some studies have reported an association between in utero exposure to mercury and reduced heart rate variability (HRV) (Sorensen et al. 1999; Oka et al., 2002; Grandjean et al., 2004). This latter effect reflects the balance between the cardiac parasympathetic and sympathetic activities of the autonomic nervous system (ANS) but information concerning the influence of MeHg on HRV is sparse.

Activities in 2010–2011

This project is based on the following epidemiological studies and data bases:

- ***The Qanuippitaa Survey*** was conducted in fall 2004. Most of participants accepted to enter the cohort (n=929) study (follow up).
  - Mercury in blood;
  - Oxidative parameters (LDL-Ox);
  - Holter (HRV), carotid ultrasound (IMT), blood pressure a in 40+ yrs old adults (n=280);
  - Red blood cell (n=929) and plasma (n=500) fatty acids available;
  - All medical files have been scanned and cleaned;
  - For this study, only work was conducted on Hg and HRV and blood pressure in 2008-2009.
- ***The Nunavut/NWT/Nunatsiavut IPY Inuit Study***:
  - Mercury in blood from all participants;
  - Blood pressure;
  - Holter (n=997);
  - Red blood cell fatty acids available for everybody;
  - IMT: Nunavut-Baffin: 284; NWT: 63; Nunavut: 196 and Nunatsiavut: 130 total IPY: n=749;
  - No medical file yet but collect ongoing.

Activities: We completed major data bases and conducted epidemiological analyses in available data bases (Nunavik 2004 and children cohort)

f. **Completing the IPY data base (2007–2008) (Hg, IMT, BP, HRV)**. The data base is now operational. All chart reviews in the field are to be done by the end of this coming March and then all information should be entered later in 2011.

g. **Epidemiological analyses**

i. **Blood pressure and Hg** in children: In the cohort, both pre and post natal Hg exposure were considered. Major confounding factors were child gender (modifying) mother weight, mother BP, birth weight, child weight, mother and child BMI, child n-3 PUFA in blood, child physical exercise. For adults: BMI, gender, age, Se and n-3 PUFA. Analyses of BP-Hg in Nunavik adults has been published previously (Valera et al, 2009). Analyses of IPY data will be done in 2011–2012.

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

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

iv. **Carotid thickness (IMT) and Hg** in 40+ yrs old adults from the entire Inuit Cohort study (n=1033). We have finished the reading of the entire IPY cohort and Greenland. Preliminary analyses were performed on Nunavik data. Further epidemiological analyses for IPY and Greenland data will be conducted in 2011–2012.

Results

Oxidation: Atherosclerosis and oxidation. Methylmercury (MeHg) exposure has been linked to an increased risk of coronary heart diseases (CHD). Paraoxonase 1 (PON1), an enzyme located in the high density lipoprotein (HDL) fraction of blood lipids, may play a role in CHD by metabolizing toxic oxidized lipids associated with low density liproprotein and HDL. MeHg has been shown to inhibit PON1 activity in vitro but this effect has not been studied in human populations.

This study was setup to determine whether blood mercury levels are linked to decreased serum PON1 activities in Inuit people who are highly exposed to MeHg through their seafood-based diet. We measured serum PON1 activity using a fluorogenic substrate and blood concentrations of mercury and selenium by inductively-coupled plasma mass spectrometry in 896 Inuit adults. Sociodemographic, anthropometric, clinical, dietary and lifestyle variables as well as PON1 gene variants (rs705379, rs662, rs854560) were considered as possible confounders or modifiers of the mercury-PON1 relation in multivariate analyses. In a multiple regression model adjusted for age, HDL-cholesterol levels, omega-3 fatty acid content of erythrocyte membranes and PON1 variants, blood mercury concentrations were negatively associated with PON1 activities [beta=-0.022, standard error (SE)=0.005, $p < 0.001$) (Figure 2), whereas blood selenium concentrations were positively associated with PON1 activities (beta=0.024, SE=0.004, $p < 0.001$). We found no interaction between

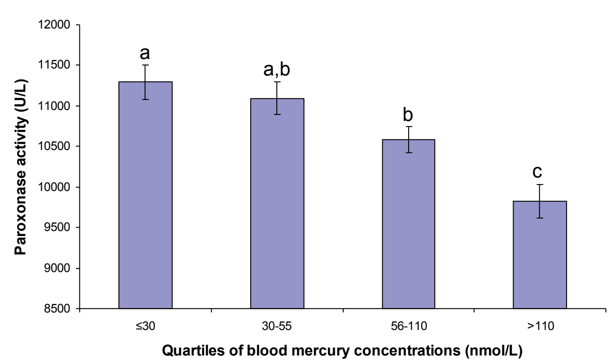

Figure 2: PON 1 activity and Hg exposure

blood mercury levels and PON1 genotypes. Our results suggest that MeHg exposure exerts an inhibitory effect on PON1 activity, which seems to be offset by selenium intake (Ayotte et al. 2011).

Atherosclerosis in adults: As described previously, IMT increased with age (p≤0.001) and differed between gender (p≤0.001). The plasmatic concentration of EPA + DHA was comparable between gender and increased with age (p≤0.001). Concomitantly, the trends were comparable with mercury. More specifically, the correlation (r-value) between circulating concentrations of mercury and EPA + DHA was 0.48 (p≤0.0001; adjusted for age and gender). Likewise, IMT was positively correlated with mercury. Such associations were confirmed in multivariated analysis where age, gender and documented medical history of hypertension were entered as confounding factors (adjusted r-square: 0.52, p≤0.001). The statistical model remained significant even when adjusted for selenium (p≤0.01) We stratified the cohort by individuals that demonstrated a medically documented history of IHD or stroke and others that did not (healthy) and compared IMT and mercury level. As expected, IMT was higher in individual with CVD compared with those without (0.89 ± 0.02mm vs. 0.75 ± 0.01 mm respectively; p≤0.001 adjusted for age and gender).

Mercury and Blood pressure and Heart Rate Variability in Nunavik children. The objective was to assess the impact of mercury on HRV and BP among Nunavik Inuit children. A cohort of 226 children was followed from birth to 11 years old. Mercury concentration in cord blood and in blood and hair at 11 years were used as markers of prenatal and childhood exposure, respectively. HRV was measured using ambulatory 2h-Holter monitoring while BP was measured through a standardized protocol. Simple regression was used to assess the relationship between mercury and the BP and HRV parameters, while multiple regressions were performed to control for potential confounders [age, sex, birth weight, body mass index (BMI), maternal smoking during pregnancy, and levels of total n-3 fatty acids, polychlorinated biphenyls (PCB 153), lead, selenium in cord blood and child blood]. Median cord blood mercury and blood mercury levels at 11 years old were 16.3 μg/L (IQR: 9.0-28.0) and 2.9 μg/L (IQR: 1.5-5.6), respectively. After adjusting for confounders, child blood mercury was associated with low frequency (LF) (β= -0.18, p= 0.01), the standard deviation of R-R intervals (SDNN) (β= -0.18, p= 0.02), and the standard deviation of R-R intervals measured over 5-minute periods (SDANN) (β= -0.26, p= 0.002). No significant association was observed with BP. Mercury exposure during childhood seems to affect HRV among Nunavik Inuit children at school age.

n-3 fatty acids and HRV: n-3 polyunsaturated fatty acids (n-3 PUFAs) have a beneficial impact on heart rate (HR) and heart rate variability (HRV). However, it is unknown if this beneficial impact remains significant in populations with high mercury exposure. Our objective was to assess the impact of n-3 PUFAs [Docosahexaenoic (DHA) and Eicosapentaenoic acid (EPA)] on resting HR and HRV among Nunavik Inuit adults considering mercury and other potential confounders. Complete data were collected among 181 adults ≥ 40 years old (109 women and 72 men) living in the 14 coastal villages of Nunavik. Several indices of HRV were derived from a 2-hour Holter monitoring assessment. Simple linear regression was used to analyse the relationship between n-3 PUFAs levels and resting HR and HRV parameters while multiple linear regressions were carried out to control for confounders. In overall analyses, EPA was associated with SDANN (β=0.07, p= 0.04) and LF norm (β= -1.84, p= 0.03) after adjusting for confounders. Among women, DHA was associated with resting HR (β= -1.40, p= 0.03) while EPA

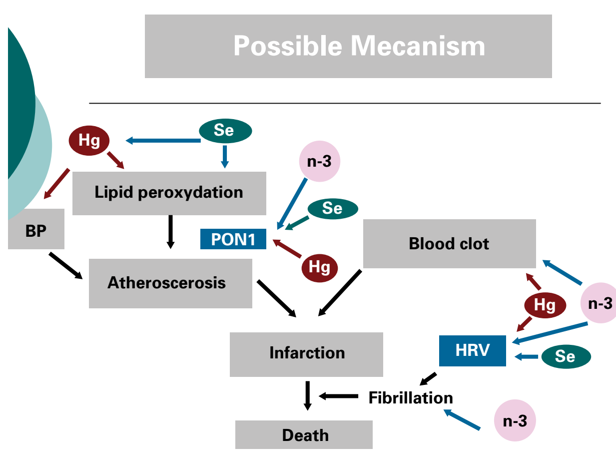

Figure 3: Possible mechanisms for Hg cardiotoxicity

was associated with SDNN (β= 0.08, p= 0.03), SDANN (= 0.09, p= 0.02) and resting HR (β= -2.61, p= 0.002). No significant association was observed in men. These results suggest a beneficial impact of n-3 PUFAs on resting HR and HRV among Nunavik Inuit women.

Discussion and conclusion

Epidemiological analyses of the relationship between mercury exposure and cardiovascular risk factor show some consistency (Figure 3). There is more and more scientific evidence for this relationship. A review paper was published in January 2011 (Roman et al. 2011). However, results from a large cohort recently published continue to raise questions about the exact role of mercury exposure in the development of cardiovascular diseases (Mozaffarian et al, 2011). Our role in this scientific debate will be 1) to focus work on risk factors rather than CVD themselves considering the relative small size of our cohorts; 2) study high exposure populations such as the case with Inuit; and 3) support the public health management of mercury exposure in the Canadian Arctic. However in the near future, the follow-up of our Inuit international cohort constituting more than 6 500 participants will certainly bring very valuable data. In addition, an international convention on Hg was initiated in March 2010 and all data generated by this project will certainly influence related decisions.

NCP performance indicators

- *The number of northerners engaged in your project:* Since data collection for the two cohorts were done previously, this phase of the project did not involve northerners. Most of the data collection took place in 1992 (Nunavik adults), Fall 2004 (Nunavik adults) and 2007–2008 and Nunavut Health Study), 2007–2008 (Nunavut/NWT/Nunatsiavut adult cohort and Inuit students were trained by Nasivvik, ITK and other staff.
- *The number of meetings/workshops you held in the North:* One NNHC meeting in Kuujuuak. Data we also presented in Whitehorse in 2010.
- *The number of students (both northern and southern) involved in your NCP work:* 6: Beatriz Valera, Martin Noel, Claire Dupont, Antoine Carrier, and Véronique Boiteau.
- *The number of citable publications (e.g., in domestic/international journals, and conference presentations, book chapters, etc):* Peer review papers: 5 conferences: 6.

Expected Project Completion Date

2013–2014.

Acknowledgments

We are grateful to the Nunavik population for their participation in this study and to the medical and health care professionals from the health centers and nursing stations for their assistance. This research on children was funded by annual grants from Indian and Northern Affairs Canada (Northern Contaminants Program) and grants from the NIH/National Institute of Environmental Health and Sciences (R01 ES007902), Health Canada, March of Dimes Birth Defect Foundation, FRSQ-Hydro-Québec, the Joseph Young, Sr. Fund from the State of Michigan, and Nunavik Regional Board of Health and Social Services. Paul Poirier is a senior clinician-research scholar from the FRSQ. Beatriz Valera is supported by doctoral grants from the FRSQ and from the Nasivvik Centre for Inuit Health and Changing Environments. For the work on PON 1 activity, the authors gratefully acknowledge the support of the NSERC MITHE Strategic Network. We also acknowledge the support of FRSQ's Environmental Health Research Network. Funding for the Nunavik Health Survey was provided by the Northern Contaminants Program (Indian Affairs and Northern Development Canada), Nunavik Regional Board of Health, Quebec's Ministry of Health and Social Services and ArcticNet Network of Centres of Excellence of Canada. We thank Louis Rochette and Denis Hamel (Institut national de santé publique de Québec) for managing the database and writing the programs for bootstrap estimation of statistical parameters.

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Building Capacity in Knowledge Translation of Northern Contaminants: Phase I

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NWT Regional Contaminants Committee

Abstract

The Government of the Northwest Territories (GNWT) has the responsibility to deliver information in the form of timely health messaging stemming from research and routine testing for environmental contaminants that pose a threat to health. During the past four months for three days per week, Myrna Matheson, a designated health professional, has reviewed, sorted, and synthesized contaminant information collected over the past seventeen years. The information existed in the department of Health and Social Services (HSS) in a total of thirty file boxes. Acquiring NWT contaminant information from all available sources was also part of the process. Additional information came from the GNWT Department of Environmental Health, the Regional Contaminants Committee headquarters in Yellowknife, and from Jody Walker, formerly of the GNWT HSS. The vast amount of work involved in sorting, synthesizing, organizing and filing the final information dominated the limited time given to this short term project.

Through the above processes of sorting and synthesizing, two decades of GNWT contaminant information were catalogued and timely information

Résumé

Le gouvernement des Territoires du Nord Ouest (T.N. O.) est responsable de diffuser, sous forme d'avis ponctuels sur la santé, les données obtenues à partir de recherches et d'analyses de routine portant sur des contaminants environnementaux qui présentent un risque pour la santé. Au cours des quatre derniers mois, à raison de trois jours par semaine, Myrna Matheson, une professionnelle de la santé reconnue, a examiné, trié et mis en rapport les données sur les contaminants recueillies au cours des dix sept dernières années et que le ministère de la Santé et des Services sociaux (SSS) avait conservées dans trente boîtes-classeurs. Dans le cadre du processus, nous avons aussi fait appel à toutes les sources disponibles pour obtenir des données sur les contaminants dans les T.N. O. Le ministère de la Santé environnementale des T.N. O., le bureau principal du Comité régional des contaminants (CRC), situé à Yellowknife, et Jody Walker, ancienne employée du ministère de la SSS des T.N. O., nous ont aussi fourni des données utiles. La quantité de travail nécessaire pour

converted to important health messaging related to northern contaminants and human health risks written for and made available on the GNWT website. This has set the foundation for Phase II of the proposal where information on the website will be further refined and translated into aboriginal languages of the NWT.

The co-ordinator of this project initiated discussions with the geomatics division of the GNWT Department of Environment and Natural Resources (ENR) and meetings were held regarding the development of an interactive map. The map will be available on the GNWT website in the fall of 2011. Existing health advisories, recent research related to fish and mammals in the NWT, graphics of NWT fish as well as links to the 2011/2012 NWT Sport Fishing Guide http://www.enr.gov.nt.ca and the GNWT Department of Health and Social Services (HSS) for health advisories and country food consumption guidelines http://www.hlthss.gov.nt.ca were provided to ENR for inclusion in this map. Permission has been obtained from Manitoba Department of Fisheries and Oceans (DFO) officer and author, Douglas Watkinson, to use high quality photographs of fish from the newly published Freshwater Fishes of Manitoba. These photos will assist sport fishermen and NWT residents to readily identify analogous species that have had health advisories issued. A wall map of the NWT pinpointing bodies of water that have been tested for contaminants as well as those with existing health advisories has been developed using a GNWT data base generated by the coordinator of this project from existing research on NWT water bodies. In phase II of this project, additional sites that have been tested for persistent organic pollutants, heavy metals, radionuclides and their effect on marine, mammal and plant life will also be noted on the map as new research becomes available and health advisories are issued.

A contaminants library has been re-established in the Department of HSS, Health Protection Section, 6th Floor, 5022-49th St. Yellowknife. Through the efforts of the designated health professional for this project, a library cataloguing system has been developed for archived publications and current research gathered from the sorting and filing process. The review and conversion of archival electronic documents to current and standard data formats has been a time-intensive activity and the development

trier, mettre en rapport, structurer et classer les données finales a entraîné un dépassement du délai strict accordé à ce projet à court terme.

Dans le cadre des processus de tri et de mise en rapport susmentionnés, nous avons catalogué des données sur les contaminants recueillies pendant deux décennies par le gouvernement des T.N. O. et nous avons rédigé, pour diffusion sur le site Web des T.N. O., des avis importants sur la santé à partir des données ponctuelles sur les contaminants dans le Nord et de l'information sur les risques pour la santé humaine. Ce travail a jeté les bases de la phase II de la proposition qui consiste à peaufiner l'information diffusée sur le site Web et à la traduire dans les langues autochtones parlées dans les T.N. O.

Le coordonnateur de ce projet a lancé des discussions avec la division de la géomatique du ministère de l'Environnement et des Ressources naturelles (ERN) des T.N. O., et des réunions ont été tenues concernant la création d'une carte interactive qui sera diffusée sur le site Web du gouvernement des T.N. O. à l'automne 2011. Les avis sur la santé en vigueur, des rapports de recherche récents sur le poisson et les mammifères dans les T.N. O., des graphiques sur les stocks de poisson dans les T.N. O. et les liens pour consulter le document 2011/2012 NWT Sport Fishing Guide (http://www.enr.gov.nt.ca) ainsi que les avis sur la santé et les lignes directrices sur la consommation de la nourriture du pays publiés par le ministère de la Santé et des Services sociaux des T.N. O. (http://www.hlthss.gov.nt.ca) ont été fournis à ERN en vue de la création de la carte. Douglas Watkinson, auteur et agent au ministère des Pêches et des Océans du Manitoba, nous a donné l'autorisation d'utiliser les photographies de poissons réalisées en haute définition parues dans le nouveau guide intitulé Freshwater Fishes of Manitoba. Ces photographies aideront les pêcheurs sportifs et les résidents des T.N. O. à cibler rapidement les espèces analogues pour lesquelles un avis sur la santé a été diffusé. Une carte murale repérant les plans d'eau des T.N. O. qui ont été analysés en vue de dépister des contaminants et les plans d'eau visés par un avis sur la santé a été créée au moyen d'une base de données du gouvernement des T.N. O. générée par le coordonnateur de ce projet à partir de recherches effectuées sur les plans d'eau des T.N. O.

of an e-library is in the development phase. Included among these converted documents are e-documents from archival material from Jody Walker and Erica Myles, contaminants experts and former GNWT HSS employees. The e-library will include important links to Health Canada, Indian and Northern Affairs Canada and the Arctic Monitoring Assessment Program to name a few.

Over the past four months, Myrna Matheson, as the GNWT representative on the Regional Contaminants Committee (RCC), has participated in a meaningful way in face to face meetings, teleconferences, the RCC Social and Cultural review and NCP peer review. In February 2011, the GNWT participated in NCP communications information meetings when Myrna accompanied Lorna Skinner, Indian and Northern Affairs (INAC), Deanna Leonard (DFO), and Dr. Marlene Evans, research scientist with Environment Canada to the communities of Hay River, Lutsel K'e and Fort Resolution. Dr. Evans presented her fish research studies on Great Slave Lake. The designated role of the GNWT on this particular trip was to develop an understanding of the questions and concerns the communities had concerning contaminants, particularly mercury in fish. Concerns regarding contaminants in the NWT were documented and questions relating to the consumption of fish directly addressed at the meetings, beginning the process of SAO capacity building in affected communities related to relevant health messaging. A fact sheet on general fish consumption guidelines for the NWT as well as a recent brochure on the Benefits of Eating Fish prepared by the Sahtu Health Authority were provided at the meetings. Later in the month, these contaminant information materials were provided to Community Health Representative (CHR) students completing their environmental module at Aurora College in Yellowknife.

Dans le cadre de la Phase II de ce projet, d'autres sites ont été analysés en vue de dépister des polluants organiques persistants, des métaux lourds et des radionucléides et de déterminer les effets de ces contaminants sur la faune marine, les mammifères et les plantes aquatiques. Ces sites seront ajoutés sur la carte au fur et à mesure que les résultats des analyses seront disponibles et que les avis sur la santé seront diffusés.

Le ministère de la SSS, Section de la protection de la santé dont les bureaux sont situés au 6e étage du 5022, 49e Rue à Yellowknife, a rétabli sa bibliothèque des contaminants. Grâce aux efforts des professionnels de la santé désignés pour mener à bien ce projet, on a mis en place un système de catalogage des publications archivées et des rapports de recherches en cours réunis dans le cadre du processus de tri et de classement. L'examen et la conversion, dans un format actuel de données standard, des documents électroniques archivés ont exigé beaucoup de temps, et la création d'un répertoire électronique est actuellement à la phase de développement. Parmi les documents convertis, il y a des documents électroniques provenant des archives de Jody Walker et d'Erica Myles, spécialistes des contaminants et anciennes employées du ministère de la SSS du gouvernement des T.N. O. La bibliothèque électronique comprendra des liens importants vers les sites Web de Santé Canada, du ministère des Affaires autochtones et du Développement du Nord et du Programme de surveillance et d'évaluation de l'Arctique, pour n'en nommer que quelques uns.

Au cours des quatre derniers mois, Myrna Matheson, en tant que représentante des T.N. O. au Comité régional des contaminants (CRC), a participé activement aux réunions en personne, aux téléconférences et à l'examen social et culturel mené par le CRC ainsi qu'à l'examen du Programme de lutte contre les contaminants dans le Nord (PLCN) mené par les pairs. En février 2011, le gouvernement des T.N. O. a participé aux réunions d'information au sujet du PLCN; Myrna a accompagné Lorna Skinner (AADNC), Deanna Leonard (MPO) et Marlene Evans, Ph. D., chercheuse scientifique à Environnement Canada, dans les collectivités de Hay River, Lutsel K'e et Fort Resolution. Madame Evans y a alors présenté les résultats de ses recherches sur le poisson dans Great Slave Lake. Le rôle désigné du gouvernement des T.N. O. dans ce dernier voyage en particulier était de comprendre les questions et les préoccupations des collectivités au sujet des contaminants, en particulier le mercure présent dans le poisson. Les préoccupations concernant les contaminants dans les T.N. O. ont été consignées, et on a répondu sur place aux questions concernant la consommation de poisson. C'est ainsi que SSS a commencé à développer des ressources dans les collectivités touchées pour ce qui est de la diffusion d'avis sur la santé pertinents. Une fiche d'information sur les lignes directrices générales relatives à la consommation de poisson dans les T.N. O. et une brochure sur les avantages de consommer du poisson qui a ont été élaborés récemment la régie de la santé de Sahtu ont été présentées à ces réunions. Plus tard le même mois, les documents d'information sur les contaminants ont été fournis aux étudiants en santé communautaire inscrits dans le module de l'environnement au Collège Aurora à Yellowknife.

Key Messages

It is the responsibility of the GNWT to provide generic advice on the consumption and safe handling of country foods that are important to aboriginal people in the NWT. In order to fulfil this responsibility, pertinent and timely information on contaminants must be part of existing public health messages.

Subsequent proposals have requested funds to create point community health representatives (CHRs) who will be taught the skills necessary to disseminate information on country food consumption and human health risks. In-depth training will occur in this phase and these "go to" persons will be supported by the GNWT HSS when there are questions about contaminants.

Meaningful participation in the RCC provides the GNWT with a forum for the two-way transfer of contaminant information that is relevant to the regions and builds capacity in key community representatives as they communicate subsequent specific health messaging on northern contaminants.

Messages clés

Le gouvernement des T.N. O. est responsable de fournir des avis génériques sur la consommation et le traitement sécuritaire de la nourriture du pays qui occupe une place importante dans la vie des Autochtones dans les T.N. O. Pour s'acquitter de cette responsabilité, les avis de santé publique doivent présenter de l'information pertinente et à jour sur les contaminants.

Des propositions subséquentes nécessitaient que des fonds soient déployés pour former des représentants de la santé communautaire qui acquerraient les compétences nécessaires pour diffuser de l'information sur la consommation de la nourriture du pays et sur les risques pour la santé humaine. Une formation complète sera offerte à cette phase, et ces personnes-ressources seront appuyées par le ministère de la SSS du gouvernement des T.N. O. lorsqu'il sera question des contaminants.

La participation active du CRC offre au gouvernement des T.N. O. un forum pour échanger l'information sur les contaminants qui est pertinente pour les régions et

l'occasion de renforcer la capacité des représentants clés dans les collectivités relative à la communication des avis sur la santé concernant les contaminants dans le Nord.

Objectives

1. Review and synthesize information on contaminants held by the GNWT-HSS and provide pertinent plain language information on the GNWT-HSS website. If time permits, an interactive map will be created on the website.
2. Research and prepare generic advice on the consumption and safe handling of country foods important to aboriginal people and post this information on the GNWT website.
3. Begin to build the capacity of the CHRs of each affected community to ensure creation and delivery of community specific health messaging on northern contaminants and food.
4. Re-establish meaningful participation by the GNWT on the RCC.

Introduction

As stated, the GNWT has the responsibility to deliver timely health messages from research and routine testing for environmental contaminants that pose a threat to health. In June 2010, a Public Health Advisory on mercury in fish was issued on four lakes in the NWT, advisories that were based on data from 2008 that had been communicated to the GNWT in 2010. The reason for the delay in responding to the data was multi-factorial. Many reasons for the delay were out of control of the GNWT. During investigation of this issue it was found that advisories from previous years were still in place and no follow up had been carried out. It was concluded that if the GNWT was to deliver timely, appropriate health messaging, it needed to create a user friendly format of information dissemination that could be transmitted to the public as new information becomes available. As a first step, this would involve reviewing and synthesizing extensive contaminant information that had been compiled over the past seventeen years.

The GNWT HSS had participated on the NWT Regional Contaminants Committee (RCC) since 1991. Jack MacKinnon, who retired in 2008, was the main person responsible for this file. Since his retirement and the elimination of his position, the GNWT HSS has not had the capacity to participate in a meaningful way with the Northern Contaminants Program until recently.

Myrna Matheson, a health professional, currently employed part-time by the GNWT-HSS had the interest and capacity to take on this project

Activities

A contaminants library has been set up in the Department of Health and Social Services, Population Division, 6th Floor, 5022-49th, Yellowknife, NT. Through the aforementioned processes of sorting and synthesizing thirty boxes of contaminant information and files, two decades of GNWT contaminant information have been catalogued and timely information converted to important health messaging related to northern contaminants and human health risks written for and made available on the GNWT website. This has set the foundation for Phase II of the proposal where information on the website will be further refined and translated into aboriginal languages of the NWT.

Health messaging related to northern contaminants and human health risks, synthesized from the reviewing, sorting and updating of stored information, is now available on the GNWT website at http://www.hlthss.gov.nt.ca/ with links to important web sites such as Health Canada. Regular reviews and the incorporation of new information based on current research from NWT studies has been a key responsibility of the designated individual. The GNWT is now able to provide up to date generic health messaging on the website and begin the preparation for CHRs to communicate contaminant information effectively and appropriately.

Meetings held with Norm Mair and Dan Gibson, Geographic Information Systems (GIS) Specialists, NWT Centre for Geomatics, ENR, have led to the development of an interactive map where existing health advisories, recent research related to fish and mammals in the NWT, identifiable graphics of NWT fish as well as links to the NWT Sport Fishing Guide and the GNWT HSS for health advisories and country food consumption guidelines will be readily available to the public.

Meetings were attended with Patricia Handley ENR to incorporate fish advisory messages into the 2011/2012 NWT Sport Fishing Guide http://www.enr.gov.nt.ca as General Fish Consumption

Guidelines in the NWT. These messages will be disseminated with the annual application process for NWT license renewal.

As part of the Federal Contaminated Sites Action Plan (FCSAP), the project team attended Health Canada's two day workshop on communicating health risk assessment results to stakeholders. It was an opportunity to network with individuals from the Contaminants and Remediation Directorate as well as others.

The GNWT attended NCP meetings in Yellowknife, Hay River, Fort Resolution and Lutsel K'e to accompany Environment Canada research scientist, Dr. Marlene Evans. Dr. Evans reported on her fish research in Great Slave Lake specifically in the East and West Basins. The overriding message was that fish are safe to eat. Although not formally presenting, the GNWT health representative was able to respond to questions on the safe consumption of fish in the NWT and provide general fish consumption guidelines. This enabled the GNWT representative to begin identifying concerns related to contaminants in fish as well as those individuals qualified to act as resource people for community members looking for information on contaminants.

The Health Benefits of Fish, a recent brochure prepared by the Sahtu Health and Social Services Authority as well as the NWT Fish Consumption Guidelines prepared as the insert for the 2011/2012 NWT Sport Fishing Guide were distributed in the four affected communities.

As mentioned, the GNWT has a seat on the RCC and over the past four months, Myrna Matheson has participated in the RCC meetings, teleconferences, and proposal reviews.

Results

The library, website health messaging and interactive map enhance the creation of community-specific northern contaminant messages that can be delivered to affected communities by CHRs.

Face to face meetings in the communities of Yellowknife, Hay River, Lutsel K'e and Fort Resolution have begun the process of capacity building. The GNWT representative responded to various concerns including accessing contaminant information online, diet issues related to mercury in fish and inquiries related to the public advisory process.

The groundwork has been laid for the second proposal in 2011/2012 entitled Building Capacity in Knowledge Translation of Northern Contaminants. Phase II follows up on the objectives of the short term 2010–2011 proposal.

Discussion and Conclusions

It is important that the GNWT participate meaningfully in NWT RCC and communicate with all members. Contamination through long range transport of different chemicals used in industrial nations and their impact on the north are of great concern to the people of the NWT. The role of the GNWT is to address the health risk aspect through timely health messaging. Through participation in the NWT RCC, the GNWT will continue to effectively raise community concerns and have these concerns addressed.

Face to face meetings in the communities have begun the process of capacity building. Due to the time limits of the short term proposal, many specific "go to" individuals in the communities have yet to be identified as partners with the GNWT HSS in disseminating information on country food consumption and human health risks. The funding requested in the 2011/2012 proposal will allow the next GNWT HSS health professional to further this search for qualified individuals who will ultimately be provided with the skills and necessary information they need to be a resource in their community when there are questions about contaminants.

In the second phase, in-depth training and support of all designated individuals in communities will occur. Effective risk communication methods will be shared with local leaders. The aim will be to leave skills within communities to interpret health information related to contaminants in a meaningful manner. Overall, promotion of safe consumption of traditional foods will be the aim.

In addition, the coordinator will work with RCC and other northern researchers by disseminating any knowledge generated related to health to all community stakeholders. Specifically, in Phase II, working with the researcher involved in the dietary research project in Tulita will provide the opportunity to tailor the communication of results to the community.

The health professional responsible for the project will continue to refine, update and maintain the contaminants library as research results and scientific information become available. By doing so, the GNWT will be able to provide up to date generic health messaging on the website and prepare CHRs to communicate contaminant information effectively and appropriately. Information will be translated into the official languages of the NWT. The interactive map cited in the initial proposal will provide the location of any affected areas with information on any related human health risks.

Building capacity among regional frontline workers in the NWT to deliver unique, individualized messages based on specific cultures, realities and values will focus on the importance of country foods in the diet despite risks of contaminants and what can be done to maximize the benefits of country food consumption. The health messages created by CHRs will provide pertinent information to people who use country foods. The effectiveness of these activities will be evaluated through changed behaviour of the message recipients.

The designate health professional in Phase II will be expected to actively participate at the Results Workshops as well as accompany researchers to communities to directly disseminate results.

The work done by the health professional this final year of the project will set the foundations for a strong contaminants presence within the department. Duties will then be subsumed by the Deputy Chief Public Health Officer and designated DHSS employee in terms of ongoing updates and technical support to the communities.

Expected Project Completion Date

This is a continuing project and 2011–2012 is the anticipated final year.

Acknowledgments

We wish to acknowledge the following individuals for their support:

- Norm Mair, GIS specialist, Shared Services, Informatics, GNWT Environment & Natural Resources/Industry, Tourism & Investment.
- Lorna Skinner, Planning and Reporting Coordinator Indian and Northern Affairs CONTAMINANTS AND REMEDIATION DIRECTORATE

Nunavik Cohort Study on Exposure to Environmental Contaminants and Child Development

Project Leader:

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Abstract

Prenatal Exposure to PCBs and mercury were associated to growth and developmental effects in children. The Inuit from Nunavik are among the most highly exposed populations 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 three studies in Nunavik since the last 18 years: monitoring of prenatal exposure from cord blood sampling, effect study with infants up to 12 months of age, and effect study at preschool age (5 years). We completed during year 2009/2010 the follow-up up 294 school age (10–11 years) children. The aims of the current proposal are to complete the analyses of this dataset and present those results to the Public Health Director (PHD) of Nunavik and the Nunavik Nutrition and Health Committee (NNHC), to create a working group involving researchers, the

Résumé

L'exposition prénatale aux biphényles polychlorés et au mercure était associée à des effets développementaux et de croissances chez les enfants. Les Inuits du Nunavik sont parmi les plus exposés aux polluants environnementaux. Cette exposition est due à la bioaccumulation des polluants au sein des poissons et des mammifères marins qu'ils ingèrent. Toutefois, la consommation de poissons et de mammifères marins leur fournit une alimentation riche en nutriments tels les acides gras oméga-3, qui sont reconnus pour leurs propriétés mélioratives sur le développement du cerveau en bas âge. Nous avons fait trois études au Nunavik depuis les 18 dernières années : surveillance de l'exposition prénatale à partir d'échantillons de sang ombilical, examen des effets sur des nourrissons jusqu'à l'âge de 12 mois et examen des effets sur des enfants d'âge préscolaire (5 ans). Nous avons aussi terminé durant l'année 2009–2010 un suivi de 294 enfants d'âge scolaire (10-11 ans). La cible établie pour la présente proposition est de compléter l'analyse des données et de

PHD, members of the NNHC and other community representatives in order to develop the public health messages, the communication tools and the communication plan for dissemination of study results to stakeholders and the population of Nunavik. Furthermore, we proposed to examine the feasibility of conducting a follow-up at the adolescence period.

présenter les résultats au directeur de la santé publique du Nunavik ainsi qu'aux membres du Comité de la santé et de la nutrition du Nunavik (NNHC). Nous créerons un groupe de travail impliquant les chercheurs, le directeur de la santé publique, les membres du NNHC et les représentants des communautés. Ce groupe de travail aura pour mandat de développer les messages de santé publique, les outils de communication et le plan de communication en vue de diffuser les résultats des recherches aux partenaires et à la population du Nunavik. Par ailleurs, nous proposons d'examiner la faisabilité de faire des suivis auprès de la population adolescente.

Key Messages

- The data collection for this study started in October 2005 and ended in February 2010, with 294 Nunavik children successfully tested at 11 years of age.
- Year 2010–2011 was devoted to data analyses and publications, communication of study results to the Public health Director (PHD) and the Nunavik Nutrition and Health Committee (NNHC), and the development of a communication plan and communication tools to be use when communicating the study results to the Nunavik population.
- The release of the study results to the stakeholders and to the population of Nunavik is schedule to take place in October 2011.

Messages clés

- La collecte de données pour cette étude a commencé en octobre 2005 et a pris fin en février 2010; 294 enfants âgés de 11 ans ont été testés au Nunavik.
- L'année 2010–2011 a été consacrée à l'analyse des données et des publications, à la communication des résultats de recherche au directeur de la santé publique et aux membres du Comité de la santé et la nutrition du Nunavik et à l'élaboration d'un plan et d'outils de communication pour diffuser les résultats des recherches à la population du Nunavik.
- La diffusion des résultats de recherche aux partenaires et à a population du Nunavik sera faite en octobre 2011.

Objectives

Project objectives for year 2010–2011 were:

a. To complete the main analyses of the dataset.

b. To communicate the main study results to the PHD, the NNHC and selected frontline workers.

c. To set up a working group whose mandate was to develop:

   i. The public health messages related to the study results.

   ii. The communication tools for dissemination of results.

   iii. The detailed plan for communication of study results to stakeholders and the population of Nunavik.

d. To develop a research protocol and research procedures with regard to conducting a follow-up of the cohort at the adolescence period.

Introduction

A recent review of evidence from several Canadian studies underlines an alarming burden of illness resulting from environmental exposures (Boyd & Genuis, 2008). The reviewers conclude that environmental contaminants

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

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

In 1994, we met with the PHD of the Nunavik Regional Board of Health and Social Services, the NNHC and several municipal councils to discuss a plan to study effects of pre- and postnatal exposure to contaminants on infant and child development. These actors expressed their support for such a study if it would also focus on a broad range of factors that influence child development, including nutrients from traditional food (omega-3 fatty acids), life habits during pregnancy (smoking, alcohol and drug use), and other influences (e.g., maternal stimulation, food insecurity), in addition to environmental contaminants (PCBs and pesticides, mercury and lead). The researchers readily agreed to this proposal and subsequently obtained funding from many sources, particularly the U.S. National Institute of Environmental Health Sciences and the Northern Contaminants Program (NCP) from Indian and Northern Affairs Canada. The first phase of the study was initiated in 1996. We investigated the role that nutrients from traditional food, life habits during pregnancy, environmental contaminants and other factors have on infant development. Almost 300 mothers and their infants from Puvirnituq, Inukjuak and Kuujjuaraapik participated in the study between 1996 and 2002. Results and implications from the first phase of this study, when infants were examined at 6 and 11 months of age, were communicated to the Nunavik population by the researchers and public health officials in 2003 and 2004. Key findings of the infancy study were:

- Fatty acids were found to be beneficial for infants' birth weight, vision, ability to communicate or solve problems, ability to sit, stand and walk.
- Prenatal exposure to PCBs had some negative effects on birth weight, duration of pregnancy and visual memory. This exposure did not result in an increased number of low birth weight babies or premature births. Prenatal fatty acid exposure partially reduced the adverse effects associated with PCBs.
- Prenatal exposure to mercury was associated with a decrease in the infant's ability to maintain attention.
- Prenatal exposure to lead was associated with slower processing of information in memory.
- Smoking and alcohol consumption were both associated with some negative effects on infant's growth and/or development. Both alcohol and smoking have the same negative impact as PCBs were found to have on birth weight in this study.
- Maternal intellectual stimulation has a positive effect on infant's mental development.

Based on these findings, public health recommendations were provided at that time to the population by the PHD. However it was not clear if adverse effects found at 6 and 11 months of age would impact on child development at school age. It was therefore decided to continue to follow children to monitor their development and its influencing factors. An evaluation was conducted at age 5 years and similar results were found. Between September 2005 and February 2010, 294 children and their mothers from all 14 Nunavik communities participated to the last follow-up of the cohort. The participants were 11 year old children who participated at birth to the Cord Blood Monitoring Program (1993–1998), which was designed to document the amounts of environmental contaminants and nutrients in newborns. Participants met with the research staff about half a day in the three larger Nunavik villages (Puvirnituq, Kuujjuaq, Inukjuaq). Participants who resided in other communities were transported by plane with their mother to one of the larger villages for testing. Mothers were contacted by phone, were provided with information about the study protocol, and invited to participate with their 11 year old children. Written informed consent was obtained from the mother of each participant; oral assent, from each child. The research was approved by the NNHC, and ethics committees from Laval University and Wayne State University.

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). Child growth (weight, height, head circumference) and vision was assessed by the research nurse. Intellectual function was assess by our research professional, with the test that is used most extensively to assess overall intellectual competence in children, the Wechsler test. The Wechsler test is useful because it is a good predictor of how the child will do in school and how, as an adult, he or she will perform in intellectually challenging work.

Questionnaires were provided to the child's teacher through the school principal, who obtained the forms from our research nurse. The teacher was ask to report whether specific behaviours were not seen, somehow/sometimes seen or very/often seen. Examples of questions are:

- To document rule breaking behaviours..." disrupts class discipline"
- To document aggressive behaviours... "gets in many fights"
- To document attention problems... "can't concentrate, pay attention for long"

Research on the effects of exposure to contaminants on child development is challenging because a child who is exposed to one contaminant is also likely to be exposed to others. For example, if a child is exposed to both mercury and PCBs, it can be difficult to determine which contaminant is responsible for how the child performs on a test. To deal with this challenge, we use statistical analysis. We start with one contaminant, such as prenatal mercury exposure and then add prenatal PCB exposure to the analysis. The statistics program then can determine how much of the child's score is affected by the mercury and how much by the PCBs. A second challenge comes from the fact that other variables that affect child development may also be particularly prevalent in more heavily exposed children. For example, more heavily exposed children may come from intellectually less stimulating homes. Again, statistical analysis makes it possible to assess how much of the effect is attributable to the contaminant and how much to the social environment. The following variables were assess during an interview conducted with the child's mother to document known risk factors for child development that needed to be taken into account in analyses looking at effects of environmental contaminants:

- child characteristics: age, gender, birth weight, duration of the pregnancy with this child, adoption status, breastfeeding status;
- maternal and family characteristics: caregiver (usually the mother) age, education, employment, marital status and non-verbal reasoning abilities, number of persons living in the house, food insecurity, current use of tobacco, alcohol and drugs;
- other prenatal exposures: smoking, alcohol, and drug use during pregnancy.

Activities in 2010–2011/Results

The analyses of the dataset related to the following outcomes were conducted: growth, intellectual development, child behaviour and cardiac variability. These analyses were completed mostly during summer and fall of 2010, and were presented to a working group (WG) during few meetings, starting in September 2010. In interaction with key researchers, this WG accomplished the following work:

- identified the main and most relevant results of the study;
- identified which other information should be considered along with the study results (ex: temporal trend data; contaminants in food items; frequency of consumption of most contaminates food items, etc);
- identified public health implications of study results, taking into account all other relevant information such as temporal trends, sources of exposure and results from other child studies;
- supported the PHD of Nunavik in the development of the public health messages to be provided to the population when communicating the study results;
- determined how and when the results should be communicate to the stakeholders and the population of Nunavik;
- revised the communications tools developed in 2004 by the NNHC and the PHD for communication of results from a previous follow-up of the cohort;
- developed new written materials required for communication activities;
- developed new written material to be provided to study participants during the communication campaign.

As described in the table below, this WG was composed of researchers, public health authorities of the region, NNHC members, and representatives of other governmental agencies.

Name	Institution
Gina Muckle (chairperson)	Researcher at CRCHUQ – Université Laval
Annie Augiak	Childcare Consultant on Nutrition; Income Support & Childcare Department of Kativik Regional Governement; NNHC member
Louisa Thomassie	Nasivvik Inuit Research Advisor for Nunavik; Renewable Resource Department, Kativik Regional Governement
Alacie Pov	Child tester during 11-year follow-up
Elena Labranche	Assistant Public Healh Director of Nunavik, Nunavik Regional Board of Health and Social Services; NNHC member
Serge Déry	Public Healh Director of Nunavik, Nunavik Regional Board of Health and Social Services; NNHC member
Suzanne Bruneau	Vice president of scientific affairs, Aboriginal Health Department, National Institute of Public Health; NNHC member
Marie-Josée Gauthier	Nutritionist, Nunavik Regional Board of Health and Social Services; NNHC member
Chris Furgal	Researcher at Trent University; NNHC member
Éric Duchesneau	Communication agent, Nunavik Regional Board of Health and Social Services
Éric Dewailly	Researcher at CRCHUQ – Université Laval
Joseph L. Jacobson	Researcher at Wayne State University
Jason Stow (observer)	Northern Contaminant Program; Indian and Northern Affairs Canada

Meetings and activities of the WG are detailed below.

Meeting	Activities
Sept 23 Videoconference (1/2 day)	Presentation of members, mandate and working plan of WG New results on cardiac variability: B Valera & É Dewailly Contaminants and DHA to the ERP recognition memory task, and binge alcohol to ERP response inhibition and recognition memory: J Jacobson & O Boucher New results on growth: G Muckle, N Forget-Dubois & R Dallaire
Nov 15 to 17 Working session, Kuujjuaq (2 full days)	New results on environmental contaminants and intellectual development: J Jacobson New results on sensory function: D Saint-Amour New results on child behavior: G Muckle, P Plusquellec Results on child growth: G Muckle Summary of all study results per contaminant and per outcome: Group of researchers Overview of communications tools from previous phase and communication tour conducted in 2004 Discussion Participants by phone: E Dewailly, J Stow (from NCP) and Eric Loring (from Inuit Tapiriit Kanatami)
Dec 14 Videoconference (1/2 day)	Presentation of 1st draft of summary of study results and conclusions to be use for communication activities
February 10 Working session, Quebec (WG & NNHC) (1 full day)	Working session on the public health messages, communication plan and communication tools
March 24 Working session, Quebec (1 full day)	Working session on the public health messages, communication plan and communication tools
June 9 Meeting of the NNHC, Kuujjuaq (1/2 day)	Presentation of public health messages, communication plan and communication tools by the PHD to the NNHC
June 22 Working session, Quebec (1/2 day)	Revision of public health messages Revision of communication tools Planning of communication activities for fall 2011

Clearly, the exchange of information that took place within the WG benefited to each member, scientists as well as Inuit representatives: scientists improved their understanding of the Northern context because specific key information were provided to the WG by Inuit members during working sessions, and capacity building in the region was improved with sharing results from multiple studies conducted in Nunavik since the last two decades and information about how the study was conducted, how children were tested and how research data were analyzed.

The last objective of this project was the completion of the work required prior to conduct a feasibility/pilot of a follow-up of the cohort at the teenage period. We determined the outcomes of interest, selected the instruments to be use document the outcomes and the confounders, projected the minimal sample size required to reach adequate statistical power, developed the research procedures likely to be most appropriate for use with Inuit adolescents. All this work was conducted during fall 2010 and a research protocol was submitted to the NCP in January

2011, was supported by the NNHC, and positively evaluated by the NCP technical committee. However, the proposal was not financed during year 2011–2012 due to budget constraint.

Additionally, results from this prospective study were published in following peer reviewed journals:

1. Boucher, O., Bastien, C.H., Saint-Amour, D., Dewailly, É., Ayotte, P., Jacobson, J.L., Jacobson, S. W., Muckle, G. (2010). Using event-related potentials in the assessment of the neurotoxic effects of seafood contaminants in Inuit children from Arctic Quebec. *Clinical Neurophysiology, 121, S124*.
2. Boucher, O., Burden, M.J., Muckle, G., Saint-Amour, D., Ayotte, P., Dewailly, É., Nelson, C.A., Jacobson, S.W., & Jacobson, J.L. (2011). Neurophysiologic and neurobehavioral evidence of beneficial effects of prenatal omega-3 fatty acid intake on memory function at school age. *The American Journal of Clinical Nutrition, 03, 1025–1037*.
3. Burden, M.J., Westerlund, A., Muckle, G., Ayotte, P, Dewailly, É., Nelson, C.A., Jacobson, S.W., & Jacobson, J.L (2010). The effects of maternal binge drinking during pregnancy on neural correlates of response inhibition and memory in childhood. *Alcoholism: Clinical and Experimental Research, 35(1):1–14*.
4. Jacques, C., Levy, É., Muckle, G., Jacobson, S.W., Bastien, C.H., Dewailly, É., Ayotte, J.L., Saint-Amour, D. (2011). Long-term Effects of Prenatal Omega-3 Fatty Acid Intake on Visual Function in School-Age Children. *The Journal of Pediatrics. 158(1) 83–90*.
5. Muckle, G., Laflamme, D., Gagnon, J., Boucher, O., Jacobson, J.L. and S. W. Jacobson. (2011), Smoking, and Drug use among Inuit women of childbearing age during pregnancy and the risk to children. *Alcoholism: Clinical and experimental research. 35(6); 1081–2091*.

Study results were also presented in the following conferences:

Polevoy, C., Verner, M. A., Muckle G., Dewailly, E., Ayottte, P., Haddad, S. & Saint-Amour, D. (2010/12). Alteration of visual brain responses in 5-year old children from Nunavik exposed to polychlorinated biphenyls (PCBS): Evidence for an early postnatal period of vulnerability. 42e Symposium annuel de la Société de toxicologie du Canada, Montréal, Canada.

Boucher, O., Burden, M.J., Muckle, G., Saint-Amour, D., Ayotte, P., Dewailly, É., Nelson, C.A., Jacobson, S.W., Jacobson, J.L. (2010/08) Neurophysiologic evidence of beneficial effects of prenatal omega-3 fatty acids intake on visual recognition memory at school age. World Congress of Psychophysiology: The Olympics of the Brain. Budapest. Hongrie.

Boucher, O., Burden, M.J., Muckle, G., Saint-Amour, D., Ayotte, P., Dewailly, É., Nelson, C.A, Jacobson, S.W., Jacobson, J.L. (2010/08). An ERP study on the beneficial effects of prenatal omega-3 fatty acid intake on visual recognition memory at school age. World Congress of Psychophysiology: The Olympics of the Brain. Budapest. Hongrie.

Ethier, A.A., Polevoy, C., Muckle, G., Bastien, C.H., Dewailly, E., Ayotte, P., Plusquellec, P., Jacobson, S.W., Jacobson, J.L. & Saint-Amour, D. (2010/07). Effects of environmental contaminants exposure on spatial orientation of visual attention in children: a study from arctic Quebec. XII International Congress of Toxicology. Barcelona, Spain.

Muckle, G., Bastien, C., Dewailly, É., Ayotte, P., Plusquellec, P., Jacobson, S.W., Jacobson, J.L., Saint-Amour, D.(2010/07). Effects of environmental contaminants exposure on spatial orientation of visual attention in children: a study from Arctic Quebec. XII International Congress of Toxicology. Barcelona, Spain.

Saint-Amour, D., Muckle, G., Ethier, A. A., Bastien, C.H., Dewailly, É., Ayotte, P., Jacobson, S.W., Jacobson, J.L. (2010/07). Developmental follow-up of the effects of PCB exposure on visual processing in Inuit children from Arctic Quebec. The Asia-Pacific Conference on Vision (APCV). Taipei, Taiwan.

Ethier, A.A., Polevoy, C., Muckle, G., Bastien, C., Dewailly, É., Ayotte,P., Plusquellec, P., Jacobson, S.W., Jacobson, J.L., Saint-Amour, D. (2010/06). Effets de l'exposition aux contaminants environnementaux sur l'attention visuo-spatiale des enfants Inuits du Québec Arctique. Colloque printanier du Réseau de Recherche en Santé Environnementale du FRSQ. Montréal, Canada

Ethier, A. A., Muckle, G., Jacobson, J.L. Jacobson, S.W., Bastien, C.H., Dewailly, É., Ayotte, P., Levy, E., Plusquellec, P. & Saint-Amour, D. (2010/05). Effets de l'exposition chronique au plomb sur l'attention spatiale chez des enfants Inuits de 11 ans. 78e congrès de l'ACFAS. Montréal, Canada.

Ethier, A. A., Muckle, G., Jacobson, J.L. Jacobson, S.W., Bastien, C.H., Dewailly, É., Ayotte, P., Plusquellec, P. & Saint-Amour, D. (2010/04). Effects of chronic low-level lead exposure on allocation of spatial attention in 11-year-old Inuit children from Arctic Quebec. 17th annual Cognitive Neuroscience Society meeting. Montreal, Canada.

Discussion and Conclusions

Activities planned for the current year were successfully conducted, without significant changes, and there was no significant modification to the expected timeline and deliverables. The next phase is the communication campaign of study results, which is scheduled to take place in Nunavik in October 2011. Study results will be presented along with their public health implications by research leaders, public health authorities and the NNHC.

NCP Performance Indicators

- *Number of northerners engaged in project:* 7 (4 of them are Inuit)
- *Number of meetings/workshops in the North:* 2 (2.5 days total)
- *Number of students involved in this work:* six PhD students (4 from Laval University and 2 from University of Montreal) and two post-doctoral researchers from Laval University.
- *Number of citable publications:* 5 publications in international peer-reviewed journals and 9 communications in international and national conferences.

Expected Project Completion Date

2011–2012.

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World Health Organization (2006). Principles for evaluating health risks in children associated with exposure to chemicals. *Environnemental Healt Criteria*, 237.

Long-Term Effects of Prenatal and Current Exposure to Environmental Toxins on Activity, Attention and Emotionality in 10 Year-Old Inuit: Statistical Analysis

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Abstract

Traditional Inuit diet is contaminated by environmental pollutants such as organochlorines (Ocs), methylmercury (MeHg), and lead (Pb). Prenatal exposure to such contaminants has been linked to developmental and cognitive effects in many epidemiological studies but behavioural effects have not been extensively studied. So far, our results have shown that low-level prenatal Pb exposure is related to subtle change in attention level in 11 month-old Inuit children. This prenatal effect does not persist later on in 5 year-old Inuit children, but postnatal exposure to Pb has been related to other subtle behavioural change in the domains of impulsivity, irritability and inattention. Furthermore, background exposure to PCBs in utero was found to be related to subtle behavioural changes targeting emotional outcomes in 5 year-old Inuit children. In the present project, our aim was to determine whether these subtle effects were still there in

Résumé

Le régime alimentaire traditionnel des Inuits est contaminé par des polluants environnementaux comme des organochlorés (OC), le méthylmercure (MeHg) et le plomb (Pb). L'exposition prénatale à ces contaminants a été associée à des effets développementaux et cognitifs dans de nombreuses études épidémiologiques, mais les effets comportementaux n'ont pas été étudiés en profondeur. À ce jour, nos résultats montrent qu'une faible exposition prénatale au plomb est associée à une altération subtile du niveau d'attention chez les enfants inuits âgés de 11 mois. Cet effet prénatal ne persiste pas par la suite chez les enfants inuits âgés de 5 ans, mais l'exposition prénatale au plomb a été associée à d'autres changements comportementaux subtils sous les rapports de l'impulsivité, de l'irritabilité et de l'inattention. De plus, il a été établi qu'une exposition naturelle aux BPC in utero était liée à des changements comportementaux subtils au

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.

niveau émotionnel chez des enfants inuits âgés de 5 ans. Dans le présent projet, notre but est d'établir si ces effets subtils ont persisté chez les enfants de 11 mois. Les résultats montrent que l'exposition postnatale au plomb demeurait associée à une augmentation de l'hyperactivité et de l'inattention et que l'exposition prénatale au BPC demeurait liée à un effet négatif lors de tests sanguins.

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.
- Lead has been related to slight impairments in infants attention levels, and preschoolers impulsivity, irritability and attention levels, and those slight impairments (activity and attention) were still detectable in school-aged children.
- Exposure to PCBs during pregnancy has been related to subtle changes in preschoolers emotional outcomes, and those adverse associations were still detectable in school-aged children.

Messages clés

- Les liens découverts entre les contaminants environnementaux et le développement du comportement sont de nature subclinique. C'est dire que cela n'influe pas sur le fonctionnement des enfants inuits au quotidien, mais les empêche d'exprimer leur plein potentiel de développement comportemental.
- Le plomb a été associé à de légers déficits d'attention chez les jeunes enfants ainsi qu'à des niveaux d'impulsivité, d'irritabilité et d'hyperactivité des enfants d'âge préscolaire et ces déficits (hyperactivité et inattention) étaient encore détectables chez les enfants d'âge scolaire.
- L'exposition aux BPC au cours de la grossesse a été associée à des changements subtils dans les réactions émotives d'enfants d'âge préscolaire, ces associations négatives demeurant détectables chez les enfants d'âge scolaire.

Objectives

Our study is based mainly on behavioural observation. Behavioural dimensions were extracted from video recordings by trained coders. In previous projects, we coded the behaviours of 110 school-aged children in a blood sample situation and of 130 school-aged children in a cognitive test situations. Objectives of the current project were:

(a) to extract behavioural dimensions related to levels of attention, levels of activity and emotional state from the behavioural coding

(b) to statistically look at the association between these behavioural dimensions, and the children levels of exposure to lead, mercury and PCBs

(c) to statistically look at the association between ratings scales, examiners used to assess behaviour in school-aged children following the testing, and the children levels of exposure to lead, mercury and PCBs.

Introduction

In the United States, learning and developmental disabilities (LDD) appear to affect 5 to 15 percent of all children under the age of 18 years (1). LDD include physical impairments, deficits in cognitive abilities such as memory and IQ, and also behavioral problems. A recent statement by experts in the field of environmental toxicology indicated that environmental contaminants can be reliably added to the list of risk factors associated with LDD (2). Indeed, many prospective studies of children have addressed the relationship between background exposure to environmental contaminants and child development during the last several decades. These studies mainly focused on lead (Pb), polychlorinated biphenyls (PCBs) and mercury (Hg).

Main outcomes studied with regard to prenatal exposure were growth, neuromotor development, cognitive development (for example, (3, 4)).

As to behavioral development per se, effects of Pb exposure have been more widely studied than those associated with other environmental contaminants. For example, Pb exposure during infancy was significantly associated with increased hyperactivity and distractibility (5) and increased antisocial behaviors (6). In older children, the effects of Pb exposure during childhood were also documented on various aspects of behaviour, such as symptoms of hyperactivity, inattention and withdrawn behaviors (7, 8). As to PCBs, prenatal exposure to PCBs was related to decreased activity level at 4 years of age (9) and to higher impulsivity at age 11 year (10) in the Michigan study. In the North Carolina cohort, prenatal PCBs were associated with lower activity at birth (11). In the Oswego study, prenatal PCBs exposure were related to response inhibition at 4.5 years of age, which is crucial to the ongoing regulation of behavior (12), and to impulsivity at 8 years of age (13).

Most of these studies revealed that associations between background exposure to environmental contaminants and child behavioral outcomes may be difficult to detect through standard clinical examination designed to identify severe impairments and are more likely to be identified through domain-oriented tests since those are more sensitive to subclinical effects. We thus choose to use observations in addition to classical behavioral tests such as global behavioral scales using parent's or examiner's ratings.

Using this methodology in previous study, we have found the following results:

- in The INFANT study (215 children), direct observation of video recordings revealed that cord blood Pb concentrations were significantly related to poorer infant attention after adjustment for confounding variables. Such effect has even been observed at blood concentrations below 10 μg/dl, demonstrating the power of this innovative approach in the assessment of children behaviour (14). Statistical analysis dealing with the association of Hg and PCBs with activity and emotionality have also been done. Results showed that those contaminants do not seem to impact behavioural indicators extracted from video recordings at 1 year of age, except if we use a mathematical model which simulated the PCB levels of exposure from birth to 1 year of age (15).
- in The PRESCHOOL study (110 children), results showed that prenatal Pb exposure was not related to any behavioural indicators from video recordings in preschoolers, but postnatal Pb exposure was related to behaviour indicators of inattention and to examiner's ratings of impulsivity. Prenatal PCB exposure was significantly associated with anxiety and emotionality assessed from both examiner's ratings and direct observation of video recordings. Finally, Hg exposure was not associated with any behavioural outcomes (16).

Aim of the present study was to look whether these subtle effects were still detectable in 11-year old children from Nunavik.

Activities in 2010–2011

In direct relations with the objectives of the current project, behavioural dimensions have been extracted from the coding and have been integrated into the master database. Then statistical analyses have been done by Pierrich Plusquellec, and results have been presented to the Nunavik Nutrition Health Committee (september, 2010)

Results

In 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.

Discussion and conclusions

In the last meeting with the NNHC, most behavioural results at 1 and 5 years of age have been recalled, and most recent behavioural results at 11 years of age have been presented and discussed. Those results clearly show that lead exposure and PCB exposure, particularly during pregnancy, have sub-clinical effects on behavioural development in Inuit children. Following presentation of these results, the committee has decided to keep the current recommendation on the ban of lead gunshot in Nunavik, and to increase its vigilance on its application since very low level of exposure to lead may have an impact even subtle on child development.

Results on the association between PCB exposure and emotional outcomes is striking and, even if the effect if subtle, it would indicate that environmental contaminants may impair the ability of children to cope with stressors, or to regulate their emotions. 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. Thus, the next generation of studies should have the ambition to understand how these common environmental contaminants impair children's development and functioning in order to be able to precisely generate public health recommendations, and to find adapted way to cope with these effects. In this particular case, it appears important to take into account in the next generation of studies emotional outcomes, at a physiological, but also at a behavioural level.

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). G Muckle has also worked on a communication strategy, in which the present results will be included and presented to the Nunavik population and stakeholders, in the format respecting the communication plan developed during year 2010–2011 within the Working Group (WG) dedicated to this task. This WG is 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. More details are given in G Muckle proposal.

This year, no students have been directly involved in the NCP work,

Two citable publications in relation with the NCP work has been released during the year 2010–2011:

Plusquellec, P., Dewailly, E., Ayotte, P., Begin, G., Desrosiers, C., Després, C, Saint-Amour, D., Muckle, G. The Relation of Environmental Contaminants Exposure to Behavioral Indicators in Inuit Preschoolers in Arctic Quebec. Neurotoxicology, 31(1), 17–25 (2010)

Verner, M.A., Plusquellec, P., Muckle, G., Ayotte, P., Dewailly, E., Jacobson, J., Jacobson, S.W., Charbonneau, M., Haddad, S. Alteration of Infant Attention and Activity by Polychlorinated Biphenyls (PCBs): Unravelling Critical Windows of Susceptibility through the use of Physiologically-Based Pharmacokinetic (PBPK) Modeling. Neurotoxicology, 31(5), 424–431 (2010)

Acknowledgement

Acknowledgements have been included in each scientific publication done in relation with the NCP work.

We are grateful to the Nunavik population for their participation, and to the medical and health care professionals from the health centers and the nursing stations involved. This study was funded by grants from Indian and Northern Affairs Canada (Northern Contaminants Program), Health Canada (Toxic Substances Research Initiative #239), the March of Dimes Birth Defect Foundation (#12-FY99-49), and FRSQ-Hydro-Québec (Environmental Child Health Initiative).

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M. A. Verner et al., *Neurotoxicology* **31**, 424 (Sep, 2010).

P. Plusquellec et al., *Neurotoxicology* **31**, 17 (Jan, 2010).

Contaminant Nutrient Interaction Issues as Part of a Public Health Intervention Study of Inuit Children in Nunavik: Fifth Year of Data Collection

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Abstract

Children are more vulnerable to toxic substances due to their immature physiology and sometimes poor nutritional status. Various nutrients and diet components can protect against or attenuate the adverse effects of contaminants on health. This study is conducted as part of the Nutrition Program in Nunavik Childcare Centres which aims to provide healthy meals rich in iron and containing traditional foods and selected market foods. Over a five year period, blood contaminant levels, dietary intakes and nutritional status were measured at recruitment and twelve months later for participating children. Among children recruited in 2006–2008, 135 have a complete 24-hour diet recall. The 24-hour dietary assessment revealed that 76% and 23% of the children did not meet the recommendations for vitamin D and calcium intakes respectively. The

Résumé

Les enfants sont plus vulnérables aux substances toxiques en raison d'une physiologie immature, et parfois d'un mauvais état nutritionnel. Différents nutriments et constituants du régime alimentaire peuvent protéger ou atténuer les effets négatifs des contaminants sur la santé. Cette étude est menée dans le cadre du Programme de Nutrition des Centres de la Petite Enfance du Nunavik qui vise à procurer des repas santé riches en fer et contenant des aliments traditionnels et une sélection d'aliments du commerce. Au cours d'une période de cinq ans, les niveaux de contaminants dans le sang, l'apport alimentaire et l'état nutritionnel des enfants participants ont été mesurés au début de l'étude puis 12 mois plus tard. Parmi les enfants recrutés pour la période de 2006 à 2008, 135 avaient un rappel alimentaire de 24-heures complet. L'analyse

median blood lead concentration of these children was 0.077 μmol/L (CI=0.086-0.114) which is below the Health Canada level of Intervention.
In a multivariate analysis, blood lead levels were predicted by children's age, the number of smokers in the household and calcium intake. When a multiple imputation approach was used to handle missing data, only children's age and calcium intake remained significant predictors of blood lead levels. Calcium intakes were negatively related to blood lead levels in both regression models, which suggest that calcium intakes may provide a protective effect against lead exposure in young Inuit children. For Nunavimmiut parents and authorities, this study will provide useful information about the use of traditional foods among preschool children.

des rappels alimentaires de 24-heures a révélé que 76% et 23% des enfants ne satisfaisaient pas les recommandations relatives à l'apport en vitamine D et en calcium, respectivement. La concentration médiane de plomb dans le sang chez ces enfants était de 0,0077 μmol/L (CI=0.086-0.114), ce qui est inférieur au seuil d'intervention de Santé Canada. Dans une analyse multivariée, les niveaux de plomb dans le sang ont été prédits par l'âge des enfants, le nombre de fumeurs dans le ménage et l'apport en calcium. Lorsqu'une approche basée sur des imputations multiples a été utilisée pour compenser les données manquantes, seuls l'âge et l'apport en calcium des enfants sont demeurés des prédicteurs significatifs des niveaux de plomb dans le sang. Les apports en calcium étaient inversement proportionnels aux niveaux de plomb dans le sang dans les deux modèles de régression, ce qui laisse croire que les apports en calcium peuvent avoir un effet protecteur contre l'exposition au plomb chez les jeunes enfants Inuits. Cette étude fournira aux parents et aux autorités du Nunavik des informations utiles quant à l'utilisation des aliments traditionnels chez les enfants d'âge préscolaire.

Key Messages

- Between 2006 and 2010, 245 Nunavimmiut children have been recruited from both coasts and 110 of them were seen for a follow-up visit one year after recruitment (which represents about 53% of children recruited from 2006 to 2009).
- In a subsample of children recruited in 2006–2008, we observed that 76% and 23% of these children did not meet the dietary recommendations for vitamin D and calcium respectively, and the median blood lead concentration (0.077 μmol/L or 15.96 μg/L) was below the Health Canada level of Intervention.
- In multivariate analyses, calcium intakes were negatively related to blood lead levels which suggest that calcium intake could have a protective effect against lead exposure.
- Statistical analyses will continue in the 2011–2012 fiscal year. On a theoretical basis, we will explore the association between POPs exposure and the consumption of other nutrients/food components potentially protec-

Messages clés

- Entre 2006 et 2010, 245 enfants du Nunavik ont été recrutés sur les deux côtes et 110 d'entre eux ont été revus un an après le recrutement (soit environ 53 % des enfants recrutés de 2006 à 2009).
- Dans un sous-échantillon d'enfants recrutés entre 2006 et 2008, nous avons observé que 76 % et 23 % de ces enfants ne recevaient pas l'apport recommandé en vitamine D et en calcium, respectivement, et que la concentration médiane de plomb dans le sang (0,077 μmol/L ou 15,96 μg/L) était inférieure au seuil d'intervention de Santé Canada.
- Dans des analyses multivariables, l'apport calcique était inversement proportionnel aux niveaux de plomb dans le sang, ce qui laisse croire que les apports calciques peuvent avoir un effet protecteur contre l'exposition au plomb.
- Des analyses statistiques vont se poursuivre au cours de l'exercice 2011–2012. Théoriquement, nous allons étudier le lien entre l'exposition aux POP et la consommation d'autres nutriments et denrées alimentaires pouvant avoir un effet

tive, such as fruits and vegetables. Using our data, we also plan to describe the consumption of traditional/country and market foods and eating practices of these young preschool Inuit children.

protecteur, comme les fruits et les légumes. En nous appuyant sur nos données, nous prévoyons aussi décrire la consommation d'aliments traditionnels/nourriture du pays et d'aliments du commerce ainsi que les habitudes alimentaires de ces jeunes Inuits d'âge préscolaire.

Objectives

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

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

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

The **specific objective** of this report is to explore the association between blood lead levels and dietary calcium intake, based on data collected during the first three years of the project (2006–2008).

Introduction

Lead exposure has been a major public health issue for several years. In many areas there have been major decreases in blood lead levels over the last decades, mainly because of the phasing out of leaded petrol (CDC 2009). High levels of lead can still be found in Inuit populations in certain Arctic regions due to the past and/or present use of lead shot ammunition to harvest wild games (Dewailly et al. 2001; Levesque et al. 2003). One study conducted in Inuit and southern Quebec newborns revealed that the mean isotope ratios for Inuit newborns was similar to that reported for four major brands of leaded ammunition commonly used in Nunavik, whereas in southern Quebec newborns, it suggested a mixture of atmospheric lead and urban lead found in paint, dust, tires, etc (Levesque et al. 2003). This may partly explain why the consumption of goose and eggs from game birds, although not frequent, were the food items related to higher blood lead concentrations in a group of 10 years old Inuit children from Nunavik (Muckle et al. 2008).

Exposure to lead can affect the hematological system resulting in inhibition of heme synthesis and anemia (Peraza et al. 1998). Lead can also have a wide range of negative effects on a child's neuropsychological and motor functions (Banks et al. 1997; Canfield et al. 2004; Lidsky and Schneider 2006; Walkowiak et al. 1998; Wasserman et al. 2000). There are indications that lead is harmful even at levels below 0.483 μmol/L (100 μg/L) which is the Health Canada level of Intervention (Health and Welfare Canada 1994). Exposure to blood lead concentrations of 0.242-0.483 μmol/L (Chandramouli et al. 2009) and lower than 0.242 μmol/L were associated with deficits in cognitive and academic skills (Canfield et al. 2003; Chiodo et al. 2004; Lanphear et al. 2000). In preschool children from Nunavik, deficits in several fine motor tasks have been observed at blood lead concentrations below 0.483 μmol/L (Després et al. 2005). Thus, no level of lead exposure appears to be 'safe' and evidence regarding the blood lead levels at which morbidities occur have led to calls for the Centers for Disease Control and Prevention to reduce the current screening guideline of 0.483 μmol/L (Bellinger 2008).

Children face a greater probability of adverse effects from lead exposure than adults for several reasons. A greater proportion of systemically circulating lead crosses their blood-brain barrier and their developing nervous system is more vulnerable to lead exposure (Lidsky and Schneider 2003). Moreover, absorption of ingested lead can be as much as five times greater in children than adults and even greater when intakes of dietary minerals are deficient (CDC 2009; Ziegler et al.

1978). Most studies investigating the interactions between lead and dietary minerals such as calcium have been done mostly through research based on experimental animals. These studies indicate that ingestion of diets low in calcium increases lead absorption and toxicity (Bogden et al. 1992; Fullmer and Rosen 1990; Mahaffey 1974; Mahaffey 1990; Mahaffey 1995). For example, a low calcium diet (20% of recommended levels) increased blood lead concentration of rats exposed to lead approximately fourfold (Mahaffey 1974). Studies in infants and children also suggest that, within the range of typical dietary calcium intakes, higher intakes are associated with lower blood lead concentrations. Indeed, in American children aged 1 to 11 years who participated in NHANES II (1976–1980), a small inverse association was observed between calcium intakes and blood lead levels (Mahaffey et al. 1986). Results of other smaller published cross-sectional studies support an inverse association between children's calcium intake and blood lead levels (Elias et al. 2007; Lacasana et al. 2000; Schell et al. 2004; Ziegler et al. 1978), although this association has not been confirmed in a group of young American children at risk for lead poisoning (Gallicchio et al. 2002). However, to the best of our knowledge, the relationship between blood lead levels and dietary calcium intakes has not been studied in Aboriginal children. Yet, studies carried out in the nineties revealed that low calcium intakes were a concern for Inuit children from remote Canadian Northern communities (Berti et al. 1999; Kuhnlein et al. 1996). Insufficient calcium intakes were also observed in a recent survey of Inuit children from Nunavut where almost a third of the children had insufficient calcium intakes when considering the new recommendation for calcium issued few months after the publication of this survey (Johnson-Down and Egeland 2010). Thus, the objective of the present report is to determine the association between blood lead levels and dietary calcium intake in a group of Inuit preschool children attending childcare centres in Nunavik.

Activities for 2010–2011

Data collection. The fifth and last data collection took place in the fall of 2010 (October 11–November 19) in 6 communities: Kangiqsualujjuaq, Quaqtaq, Kangiqsujuaq, Inukjuak, Umiujaq and Kuujjuarapik. Two nutritionists, a nurse and 6 Inuit liaison persons participated in the field. They recruited 36 children and saw 30 other children for a follow-up visit. Most of the data collected in 2010 have been computed and blood samples were analyzed.

Statistical analysis. Statistical analyses on data collected from 2006–2008 continued in 2010–2011. Two of our team members worked on statistical analysis along with the support of a statistician from Université Laval. More specifically, we explored predictors of blood mercury and lead levels using data from the food frequency questionnaires and the 24-hour recalls. We also determined the prevalence of heavy metals and persistent organic pollutants in these children.

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

Communications. As part of the data collection process, results of the complete blood count were communicated to local clinics so children who had abnormal results could be treated. Nunavik health authorities were also informed about children's blood mercury and lead levels when they exceeded the reporting threshold values in Quebec (MSSS 2010). Preliminary results were published in the 2009–2010 NCP Synopsis report and presented to the NCP meeting in Whitehorse in September 2010. Some results were also presented to the NNHC meeting in June 2010. We are currently working on three scientific articles to be published in peer reviewed journals.

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

Results

Results presented in this section are based on a subsample of 135 children recruited in 2006–2008 and for whom we have a complete 24-hour dietary recall at recruitment (T1). Selected characteristics of these children, including socio-economic

Table 1. Characteristics of the 135 participants with dietary data for the reference day, data from 2006–2008 (at recruitment)

Characteristics	n	%	Mean (SD)	Median (95% CI)
Child				
Age (months)	135		25.2 (9.4)	24.7 (23.6–26.8)
Gender (% male)	135	51.9		
Coast of origin (% Ungava)	135	51.1		
Body mass index (kg/m^2)	129		19.2 (2.3)	19.1 (18.8–19.6)
Breastfeeding (% ever breastfed)	133	72		
Breastfeeding duration (months)[1]	96		10.7 (10.3)	19.1 (18.8–19.6)
Duration of childcare centre attendance (months)	133		13.2 (9.5)	12.0 (11.6–14.8)
Blood Pb level (µmol/L)	119		0.100 (0.079)	0.077 (0.086–0.114)
Family				
Child respondent working status (% working)	135	83		
Child respondent living in her/his parents (% yes)	135	27.4		
No. of children in the household	135		3.0 (1.7)	3.0 (2.7–3.3)
Residential crowding[2]	135		1.9 (0.6)	2 (1.8–2.0)
No. of smokers in the household	135		2.1 (1.7)	2 (1.9–2.4)
Smoking (% forbidden inside the house)	133	85.7		
Respondent worried about having enough food in the child's first year of life (% yes)	132	33.3		

CI: confidence interval; SD: standard deviation.

[1] For breastfed children only. Breastfeeding duration is equal to the child's age for children who were still breastfed at the time of the interview (n=25).

[2] No. of adults and children in the house / No. of bedrooms in the house.

Table 2. Total intakes of energy, proteins and selected nutrients and prevalence of dietary micronutrient inadequacy in children on the reference day

Nutrient	Mean (SD)	Median (95% CI)	Intake < EAR, %
Energy (kJ/d)	4844 (1616)	4668 (4572–5116)	NA
Proteins (g/d)1	47 (20)	45 (44–50)	1.5
Calcium (mg/d)2	881 (485)	871 (800–963)	23.0
Vitamin D (IU/d)3	285 (189)	275 (253–317)	75.6

CI: confidence interval; EAR: Estimated average requirement; NA: not applicable; SD: standard deviation.
[1] EAR for proteins: 0.87 g/kg/day for children 1-3 years old and 0.76 g/kg/day for children 4–8 years old.
[2] EAR for calcium: 500 mg/day for children 1-3 years old and 800 mg/day for children 4–8 years old.
[3] EAR for vitamin D: 400 IU/day.

Table 3. Regression analysis between blood log Pb level and potential contributors to Pb exposure in children

	Complete data set n=117 children				Imputed data set n=135 children			
Predictors	**ß**	**SE**	***P* value**	**R^2**	**ß**	**SE**	***P* value**	**R^2**
Breastfeeding duration (months)[1]	0.008	0.006	0.163		0.009	0.006	0.126	
Children's age (months)	0.018	0.006	**0.001**		0.019	0.006	**0.002**	
No. of smokers in the household	0.063	0.031	**0.041**		0.056	0.033	0.083	
Calcium intake (in 100mg)	-0.031	0.011	**0.003**		-0.033	0.011	**0.004**	
Country food consumer (Yes/No)[2]	0.023	0.102	0.822		-0.037	0.109	0.736	
Model R^2				**0.173**				**0.157**

SE: standard error.

[1] Breastfeeding duration equals the child age for children who were still breastfed at the time of the interview.
[2] A country food consumer was defined as a child who ate at least one country food (local animals, fish, birds or berries) on the day of the 24-hour recall (reference day). In the regression analysis, 0=non consumer and 1=consumer.

characteristics, blood lead levels and some factors associated with lead exposure, are summarized in **Table 1**.

Total intakes of energy, proteins and some nutrients (calcium & vitamin D) were obtained using a 24-hour diet recall that included foods consumed at home and at the childcare centre. Mean and median intakes of these nutrients and prevalence of inadequacy are presented in **Table 2**. The proportion of children who did not meet the recommended intakes for these nutrients is high, especially for vitamin D (76%) and, to a lower extent for calcium (23%). Forty-two percent (42%) of the children ate some country foods, defined as local animals, fish, birds or berries, during the 24-hour recall (data not presented). Given that our sample is young, it is pertinent to note that local animals, fish or birds were not yet introduced in the diet of 4% (n=6) of the participants.

We examined predicting factors of blood lead levels in these participating children (Table 3). Potential contributors were selected on a theoretical basis. Multiple linear regression analyses were performed on children with a complete data set for the predictors included in the model (n=117) and on the whole subsample of 135 children, using a multiple imputation approach (MI) to account for missing data. Children's age and calcium intake were significant predictors of blood lead levels in both analyses whereas the number of smokers in the household was significant only in the complete data set (without imputation). Breastfeeding duration and consumption of country foods on the day of the 24-hour recall were not significant predictors of blood lead levels. These models explained about 16% of the variability in the blood lead levels (R^2 corresponds to 0.173 and 0.157 in the complete and imputed data set respectively).

Discussion and conclusions

To our knowledge, this study is the first to assess the dietary intakes and adequacy of preschool Inuit children attending childcare centres in Nunavik. The mean energy intake observed in this study (4843 kJ) was slightly lower than that reported in 1-3 y old children (6174 kJ) enrolled in the Canadian Community Health Survey whose sample included 3.1% Inuit (CCHS 2004). However, it was much lower than the level observed in older Inuit children from Nunavut (3–5 y old; 7840 kJ). The present study identified similar calcium and vitamin D intakes than those reported in Nunavut's children mentioned above even though these Nunavummiut children had higher caloric and protein intakes (Johnson-Down and Egeland 2010). Because our study was carried out in preschool children attending childcare centres, proxy reporting may have affected accuracy, as some meals were provided to the child by other caregivers. Indeed, daycare staff provides care for more than one child, and may not remember the amount of food consumed by a specific child (CCHS 2006). However, although some disparity exists between the results presented above, our data suggest that daycare educators/cooks, but also mothers/caregivers, seem to have adequately reported the dietary intakes of these preschoolers.

Assessment of dietary adequacy was conducted using the Institute of Medicine's Dietary Reference Intakes (IMO 2005; IMO 2010). Based on the first 24-hour diet recall obtained at recruitment, the majority of children met the recommendation for proteins confirming results obtained in Inuit children from Nunavut (Johnson-Down and Egeland 2010). In accordance with the results of other studies, almost a quarter of the children had insufficient calcium intakes (Berti et al. 1999; Johnson-Down and Egeland 2010). Moreover, three-quarters of them had vitamin D intakes below the recommendation which is an agreement with the high prevalence of vitamin D insufficiency (25(OH)D <75 nmol/L) reported in Inuit preschoolers living in Nunavut (El et al. 2010). The current dietary findings indicate that children are not consuming enough vitamin D to meet the recommendation. For Canadian Arctic Indigenous children, even a single portion of local animal or fish food results in higher levels of many nutrients, although the increased vitamin D intake did not reach statistical significance (Kuhnlein and Receveur 2007). This indicates that the addition of healthy market foods such as milk and dairy products to calcium-rich traditional/country foods (kelp, small fish and meat with bones in soups or stew, and fish skin) could help children to satisfy their calcium and vitamin D requirements.

To the best of our knowledge, this is the first study carried out in Canadian preschool children, whether Aboriginal or non-Aboriginal, suggesting that dietary calcium intakes provide a protective effect against lead exposure. Indeed, in multiple regression analyses, calcium intakes were significantly and inversely correlated to blood lead levels while considering other important variables. The positive impact of calcium intakes on blood lead levels was also observed in American infants (Schell et al. 2004), Mexican (Lacasana et al. 2000) and Malay children (Elias et al. 2007). Evidences from studies carried out in animals indicate that calcium and lead compete for the same binding site on the intestinal mucosal protein, which is the most important absorption process (Rabinowitz et al., 1977 cited by Elias et al. 2007). The competition for the binding site could be the reason why insufficient calcium intake could increase lead absorption in the intestine (Elias et al. 2007).

Contrary to calcium intakes, consumption of traditional foods during the day of the recall was not associated with blood lead levels. The main source of lead exposure in the Inuit population comes from wild life species hunted with lead ammunition (Levesque et al. 2003). In spite of the fact that these food items constitute an important source of lead exposure in Nunavik, their consumption is not frequent in Inuit children (Muckle et al. 2008). Nevertheless, the body burden of lead increases with age and this could partly explain the positive and significant association we found between children's age and blood lead levels confirming results obtained in other studies (Gallicchio et al. 2002; Jain and Hu 2006). On the contrary some studies found an inverse relationship between children's age and blood lead levels (Brody et al. 1994; Elias et al. 2007). This could possibly indicate that these children were exposed to different sources of lead such as contaminated soil and lead-based paint chips and flakes. Their impact on blood lead levels would decrease as children get older and abandoned the habit of putting their hands and objects in their mouth. Soil and dust contamination are unlikely to represent significant sources of lead exposure in Nunavik as there are no industrial activities such as smelters, refineries, or battery recycling plants and almost all houses were built after 1972, when lead addition to paint was banned in Canada (Levesque et al. 2003).

Contrary to results obtained in three studies conducted in infants and toddlers (75% were below twelve months of age) (Lozoff et al. 2009) we did not find any association between breastfeeding duration and blood lead levels. Children in the present study were older (24.7 months on average) and as children get older, the effect of breastfeeding duration declines partly because the contribution from the non-breast milk sources increases. Finally, in agreement with other studies (Baghurst et al. 1992; Willers et al. 2005), we found a positive association between children's lead exposure and environmental tobacco smoke, although it remained a tendency in the imputed data set.

In conclusion, our results show that a high proportion of these preschool Inuit children did not meet the recommended intake for vitamin D and to a lesser extent, for calcium. Our results also suggest that calcium intakes may provide a protective effect against lead exposure, reinforcing the necessity of consuming traditional foods rich in calcium as well as milk and dairy products.

After exploring the association between Hg exposure and the consumption of tomato products (a proxy for lycopene intake), and between calcium intakes and blood lead levels, the work to be continued in the 2011–2012 fiscal year will focus on POPs exposure. On a theoretical basis, we will explore the association between POPs exposures and the consumption of other nutrients/food components potentially protective, such as fruits and vegetables. We also plan to describe the consumption of traditional/country and market foods and eating practices of these young preschool Inuit children.

NCP Performance indicators

Number of northerners engaged in our project: Six (6) Inuit were involved during the 2010 data collection, mainly as liaison persons. Over the life of the project 245 children and their caregivers and over 25 Inuit liaison persons participated in this study. As part of the nutrition intervention, we are working in close collaboration with many Inuit and organisations, including among others Kativik Regional Government (Childcare Department), Board of Directors and staff members (directors, cooks, educators) of Nunavik childcare centres, the Kativik School Board and the Nunavik Regional Board of Health and Social Services.

Number of meetings/workshops we held in the North: Several formal and informal meetings took place while our team members traveled to the North. In addition to the data collection in the fall, our team visited Nunavik at least eight times in 2010–2011 and often we visited more than one community per trip. Some of these meetings were organized for research purposes (e.g. data collection), and others for the nutrition intervention (e.g. cooks' training, support to daycare staff members, meetings with daycare boards of directors).

Number of students involved in our NCP work: Five (5) undergraduate students from Université Laval were involved in the Nutrition Program in 2010–2011: two (2) worked on data entry for this study and three (3) did an internship in Nunavik.

Number of citable publications: None but we have three scientific articles in preparation. Results need to be first submitted to the Nunavik Nutrition and Health Committee before being published or communicated otherwise.

Expected Project Completion Date

Most data related to blood contaminant levels will be analysed by March 2012. Communication of the final results will be done in 2012–2013.

Acknowledgements

We would like to thank the parents and the children who participated in the project as well as the staff of childcare centres for their collaboration. We are also grateful to following organizations for their support: Kativik Regional Government; Kativik School Board; Nunavik Regional Board of Health and Social Services; Nunavik Nutrition and Health Committee; Unité de recherche en santé publique (URSP) of the Centre hospitalier universitaire de Québec (CHUQ); Institut national de santé publique du Québec; Inuulitsivik and Tulattavik hospitals; and other laboratories who participated in the laboratory analysis (CHUM-Notre-Dame hospital, CHA-Enfant-Jésus & Laval hospitals, CHUQ-CHUL, University of Guelph). This project is funded by the Kativik Regional Government (intervention component), by Health Canada (research component, 2006–07) and by the Indian and Northern Affairs Canada through the Northern Contaminant Program (research component, since 2007).

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Environmental Monitoring and Research

Temporal Trends of “Legacy” POPs Contaminants in Ringed Seals of Eastern Amundsen Gulf Sampled at Ulukhaktok, NT (M-34)

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Abstract

Twenty ringed seal samples were collected at Ulukhaktok in May 2010 by a local hunter (J. Alikamik) under contract. Age, sex and condition of the 2010 samples have been measured. Blubber samples have been sent to DoE Burlington (D. Muir) and are scheduled for analyses for “legacy” organochlorine pesticides (OCP) by NLET in May 2011. Sub-samples or extracts of these samples will be sent to DFO IOS Sidney (M.G. Ikonomou) for analysis of PCDD/F, PBDE and co-planar PCBs in FY 2011–2012.

A retrospective examination of the QA/QC data for OCP analyses from 1972 onwards is in progress. Since at least three laboratories have undertaken these analyses over the last 35 years or so, this is essential to establishing the comparability of analyses. Results to date show that each laboratory’s analysis of the main OCPs was within 10% of target values in three reference materials: ICES samples 3A and 3B (maize oil) for samples analysed in the 1970’s; NIST 1588 (cod liver oil) for samples analysed in 1980’s and 1990’s; and NIST 1588b (cod liver oil) for samples analysed in the early 2000’s. Analytical data therefore appear to be generally reliable and directly comparable

Résumé

En mai 2010, un chasseur local sous contrat (J. Alikamik) a récolté vingt échantillons de phoques annelés à Ulukhaktok. L’âge, le sexe et l’état des spécimens de 2010 ont été évalués. Des échantillons de petit lard ont été envoyés aux bureaux d’Environnement Canada situés à Burlington (D. Muir) afin que le Laboratoire national des essais environnementaux en analyse la teneur résiduelle en anciens pesticides organochlorés en mai 2011. Des sous-échantillons ou des extraits des échantillons seront envoyés à l’Institut des sciences de la mer de Pêches et Océans Canada à Sidney (M.G. Ikonomou) afin qu’on en analyse la teneur en PCDD F, en EDP et en BPC coplanaires au cours de l’exercice 2011 2012.

Un examen rétrospectif de l’assurance de la qualité et du contrôle de la qualité des analyses des pesticides organochlorés depuis 1972 est en cours. Comme au moins trois laboratoires ont effectué ces analyses depuis les 35 dernières années, cet examen était essentiel pour évaluer la comparabilité des analyses. Les résultats obtenus à ce jour montrent que les valeurs d’analyse des pesticides organochlorés par chacun des laboratoires s’écartaient de moins de 10 % des valeurs cibles indiquées dans les

over the entire sampling interval. Blubber thickness appears to have declined significantly after 1991, probably due to sampling having taken place later in the year, and this will have to be controlled in any estimation of POPs burdens from the concentration data.

trois documents de référence : Conseil international pour l'exploration de la mer 3A et 3B (huile de maïs) pour les échantillons analysés dans les années 1970; National Institute of Standards and Technology 1588 (huile de foie de morue) pour les échantillons analysés dans les années 1980 et 1990; et National Institute of Standards and Technology 1588b (huile de foie de morue) pour les échantillons analysés au début des années 2000. Par conséquent, les données analytiques générales semblent fiables et directement comparables pendant toute la période d'échantillonnage. L'épaisseur du petit lard semble diminuer considérablement après 1991, probablement parce que les échantillons ont été prélevés plus tard dans l'année. Il faudra tenir compte de ce facteur au moment d'évaluer les effets des polluants organiques persistants en fonction de leur concentration.

Key Messages

The aim of the present work is to bring up to date trends in "legacy" POPs contaminants in ringed seals from Ulukhaktok (formerly Holman) NT, which have been sampled and analysed by different laboratories at irregular intervals since 1972. Work undertaken in 2010–11 has achieved the following:

(i) Twenty ringed seal samples were collected at Ulukhaktok in May 2010 and their ages, sex and condition measured. Blubber samples are scheduled for analyses for "legacy" organochlorine pesticides (OCP) by NLET in May 2011 and for analysis of PCDD/F, PBDE and co-planar PCBs by IOS in FY 2011–2012.

(ii) Analyses of "legacy" POPs contaminants in undertaken by three different laboratories at intervals over the last 35y (approx.) are reliable (as judged from each laboratory's performance in analysing standard or certified reference materials; thus, the analytical data accumulated over this interval are directly comparable.

Messages clés

Les présents travaux visent à établir une tendance à jour en ce qui a trait aux anciens polluants organiques persistants chez les phoques annelés à Ulukhaktok, autrefois Holman, dans les Territoires du Nord-Ouest, qui ont été échantillonnés et analysés par différents laboratoires à des intervalles irréguliers depuis 1972. Les travaux entrepris en 2010 2011 se résument ainsi :

(i) Récolte de vingt phoques annelés à Ulukhaktok en mai 2010 et évaluation de leur âge, de leur sexe et de leur état. Les échantillons de petit lard feront l'objet d'une analyse des pesticides organochlorés anciens par le Laboratoire national des essais environnementaux ainsi que d'une analyse de leur teneur en PCDD F, en EDP et en BPC coplanaires par l'Institut des sciences de la mer au cours de l'exercice 2011 2012.

(ii) Les analyses des anciens polluants organiques persistants effectués par trois laboratoires à différents intervalles au cours des 35 dernières années (environ) sont fiables (selon le rendement obtenu par les laboratoires lors de l'analyse de références normalisées ou certifiées. Par conséquent, les données analytiques accumulées pendant cette période sont directement comparables).

(iii) Blubber thickness of the samples appears to have declined over the sampling interval, though at this stage, it seems that this may reflect the later date of spring sampling (May–June in recent years compared to March–April in the 1970's and 1980's).

iii) L'épaisseur du petit lard a diminué au cours de la période d'échantillonnage, même si, pour le moment, on croit que ces résultats sont attribuables à un échantillonnage printanier plus tardif que par le passé (mai juin au cours des dernières années plutôt que mars avril comme dans les années 1970 et 1980).

Project Objectives

a. Update trends in "legacy" POP concentrations, including selected OC pesticides and polychlorinated biphenyls (PCBs) until 2010, using data already gathered but not yet analysed statistically;

b. Analyse existing extracts of POPs, which may have been prepared for other analyses, to extend existing trend data;

c. Confirm reliability of analyses undertaken previously (by assessing the relevant laboratory's performance in analysis of standard or certified reference materials) and so establish the comparability of analytical data; (completed spring 2011).

d. Obtain 20 samples of ringed seal blubber covering a defined range of ages and condition during the subsistence hunt in spring 2010. (Completed spring 2010.)

Introduction

Ringed seals (Phoca hispida) from Ulukhaktok, NT (formerly Holman, NWT) have been analysed for a range of persistent organic pollutants (POPs) at intervals since the early 1970's; the data set is probably the longest available for marine mammals in the Canadian Arctic, and reflects contaminant trends in the habitat and range of these seals, mainly in the SE Amundsen Gulf. The objective of this work is to compile and bring up-to-date (i.e. to 2010) data for:

(i) the DDT-group of insecticides and polychlorinated biphenyls (PCBs) which were last summarised to 1991 by Addison and Smith, 1998, though data are already available for samples from 2001 and 2006 and will be available in FY 2010–11 for 2010 samples;

(ii) miscellaneous other chlorinated pesticides, also last summarised to 1991 by Addison and Smith, 1998, though data are already available for samples from 2001 and 2006 and will be available in FY 2010–11for 2010 samples.

(iii) polybrominated diphenyl ethers (PBDEs), last summarised to 2000 (Ikonomou et al, 2002); data will be available in FY 2011–12 for 2010 samples;

(iv) polychlorinated dibenzo- dioxins and furans (PCDD/F) which have been summarised to 2000 (Addison et al. 2005); data will be available in FY 2011–12 for 2010 samples.

Activities and Results 2010–2011

(i) Compile database of past analyses of "legacy" POP contaminants and supporting biological information.(addresses Objective 7(a) and (b) above).

An MS Excel database has been compiled of relevant data from 1972 to 2006; residue analyses from the 2010 sampling and from other samples will be added during summer 2011. (Analysis of the 2010 samples was planned to have been completed by March 2011, but delays at NLET [the lab. undertaking the analysis} have resulted in the analyses being postponed until May 2011.)

The biological factors other than which have most influence on blubber residue concentrations are sex, age and condition (blubber thickness) (Addison, 1989). A preliminary analysis (within sex) of age and blubber thickness recorded over the 1972–2006 interval shows that the mean ages of the females sampled has risen significantly (by one-way ANOVA) but those of males has stayed fairly constant (Fig. 1). (Data from 2010 have not yet been analysed.) In practice, this may not create problems for statistical analysis of residue trends over time, since age is usually not a factor

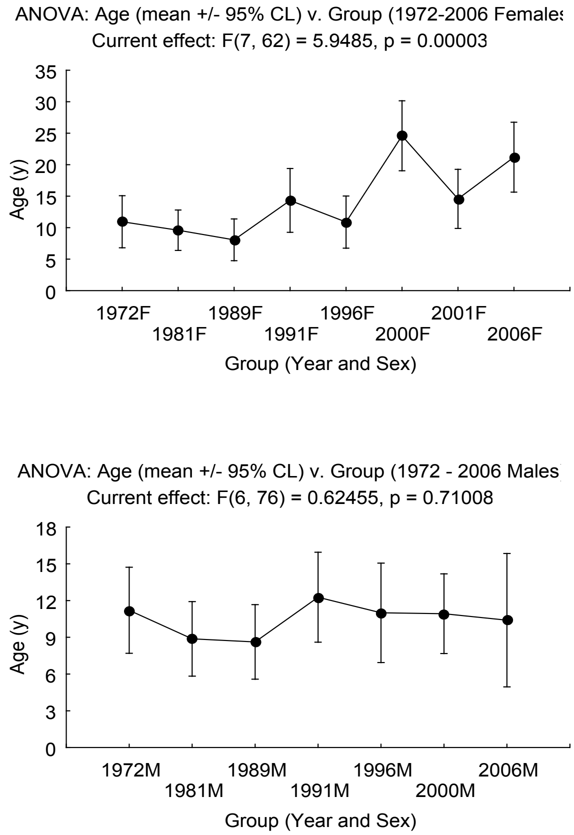

Figure 1: One-way ANOVA of age in female and male ringed seals (Phoca hispida) from Ulukhaktok, NT, between 1972 and 2006

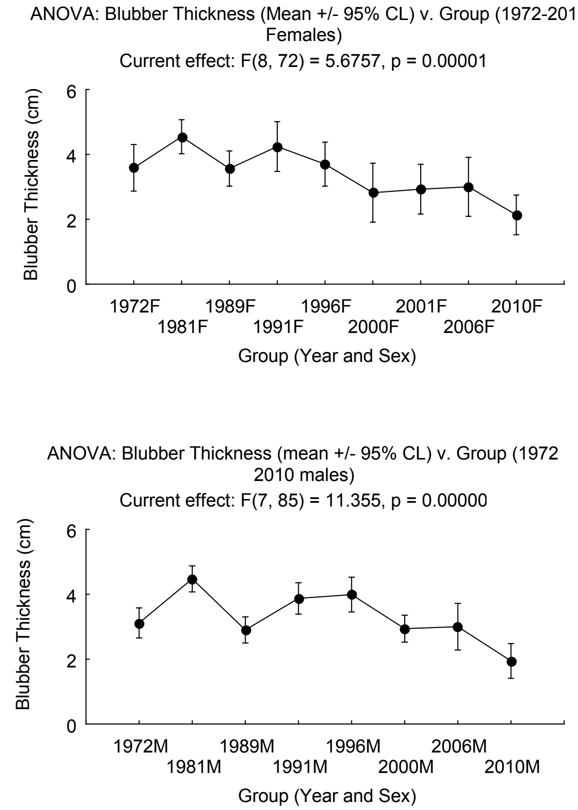

Figure 2: One-way ANOVA of blubber thickness (cm) in female and male ringed seals (Phoca hispida) from Ulukhaktok, NT, between 1972 and 2010

affecting at least DDT-group or PCB concentrations in female seals (Addison and Smith, 1974) since residue loss during lactation usually equals (approximately) residue accumulation during feeding. Since the mean ages of the male seals has been fairly constant (Fig. 1) the samples are directly comparable over the sampling interval.

Condition, as measured by blubber thickness, presents more of a problem. One-way ANOVA of blubber thickness measurements shows (Fig. 2) shows that between 1972 and 2010, condition appears to have been declining steadily. However, this is probably not a "real" trend but a reflection of the fact that sampling has taken place progressively later in the year: in the 1970's and 1980's sampling took place in March –April, whereas the more recent (2006 and 2010) samples have been taken in May–June. A more detailed analysis of these data will be undertaken in summer 2011: Dr. T.G. Smith, who undertook the earlier sampling, will provide information about the month and date of sampling during the 1970's and 1980's from his archived field notebooks.

i. (ii) Examination of the reliability of past analyses of "legacy" contaminants (Objective 7(c) above).

The laboratories which undertook these analyses have participated in "inter-calibration exercises" or have used standard or certified reference materials (S/CRM) to assess the reliability of their analyses. In the early 1970's the Marine Ecology Lab. (MEL) participated in the ICES (International Council for the Exploration of the Sea) inter-calibration exercise (Topping and Holden, 1978) based on analyses of cod liver oils (both "spiked" and "unspiked"); later, Axys Analytical Services, Sidney BC, and Environment Canada labs. (NLET) used cod liver oils 1588 and 1588b, respectively, whose organochlorine contents were certified by the US NIST

(National Institute of Science and Technology, Gaithersburg, MD). The labs' accuracy in analysing these samples is summarised in Tables 1–3.

Table 1 summarises analyses of the DDT group of insecticides. Only the p,p'- isomers are included, because in the ICES inter-calibration no o,p'-isomers were either reported or spiked; in NIST 1588 and 1588b, although values of o,p'-DDT were certified, this isomer was hardly ever found in the seal samples.

The ICES inter-calibration involved two samples, 3A (unspiked) and 3B (spiked). Of the 11 laboratories which participated in the exercise, all used packed column GLC with ECD detection. Analyses of 3A for p,p'-DDE were recorded as "ND" or "less than …" by six labs; of the five sets of usable data, one reported concentrations >10-fold over the other four (Topping and Holden, 1978; Table 18). Usable analyses of p,p'-DDD and p,p'-DDT were reported by only three labs. Statistical analyses of the consensus data for 3A are therefore not very informative, especially as the s.d. of the p,p'-DDT data exceeded the mean. However, the MEL data (Topping and Holden 1978, Table 18 Lab. "A") were within the range reported by the other labs. and in the cases of p,p'-DDE and p,p'-DDD were fairly close to the consensus mean values. DDT-group concentrations in the spiked sample 3B were reported by all eleven participants (though two of these were obvious outliers); data reported by MEL were within 10% of the spiked value for p,p'-DDE, p,p'-DDD and p,p'-DDT (Topping and Holden, 1978; Table 19, Lab. "A"). Data for DDT-group residues in 1972 samples may therefore be considered reliable.

Seal samples from 1981 and 1991 were analysed by Axys by GC-MS, and by GC-ECD, and calibrated with NIST CRM 1588. The variance quoted by NIST in its "Certificate of Analysis" for 1588 is ± 2 s.d.; Axys analysed the samples in six batches, each of which was accompanied by the CRM analysis (three each for 1981 and 1991 samples) and Table 1 shows Axys' variance as ± 1 s.d. Analyses of the CRM yielded data for all the three DDT-group components which were within 10% (and usually < 1 s.d.) of the certified value. Data for DDT-group residues in 1981 and 1991 samples may therefore be considered reliable.

Seal samples from 2001 and 2006 were analysed by NLET by GC-ECD, and calibrated with NIST CRM 1588b. Since only 10 seal samples from each year were analysed, only one CRM for each year was used. In the 2001 batch, both p,p'-DDE and p,p'-DDT were recorded in the CRM at 77%, and p,p'-DDD at close to 100%, of the certified value. In the 2006 samples, p,p'-DDE was recorded in the CRM at 74% of the certified value; both p,p'-DDD and p,p'-DDT were within 10% of the certified value. (Note that NIST lists the variance about its certified values in 1588b as "approx. 95% confidence".) Data for p,p'-DDE and p,p'-DDT in 2001 samples, and for p,p'-DDE in 2006 samples, will therefore have to be used with caution.

Table 2 summarises analyses of miscellaneous organochlorine pesticides between 1981 and 2006. All pesticides were analysed by Axys (for 1981 and 1991 samples) and by NLET (2001 and 2006 samples). Axys results were usually with 10% of the target value, except for dieldrin in 1991, cis-chlordane in 1981, trans-chlordane in 1991 and cis-nonachlor in both 1981 and 1991 where the difference between observed and target values was around 20%. NLET results tended to be lower than target values; the discrepancy was often about 20% except for oxychlordane in 2006 and cis- and trans-nonachlor in 2001 and 2006, where the difference was less than 10%. Data for these pesticides will have to be analysed carefully to establish trends reliably.

Table 3 summarises results for PCB analyses of inter-calibration samples and CRMs. PCBs were analysed during the 1970's by packed column GLC with ECD; PCBs were quantified by comparing major peaks in the chromatogram with a standard PCB mixture, Aroclor 1254. During the 1980's GLC techniques improved and by the 1990's, capillary GLC columns and coupling of GLC with mass spectrometry allowed the detection of (usually) individual PCB congeners (although even now, some co-eluters are separated only with difficulty). Comparison of PCB estimates in (say) 1972 samples with those of (say) 1991 samples presents problems, since (a) the earlier comparisons of PCB distribution in a field sample with standard Aroclor 1254 were necessarily approximate, as they did not allow for selective uptake or degradation of individual congeners,

Table 1: Target v. observed DDT-group residue concentrations in inter-calibration samples or reference materials, 1972–2006

Sample yr	Analyst	Analyte	Inter-calibration or SRM/CRM	Target or consensus value (ng/g) (see text)	Observed value (ng/g) (mean ± s.d.)	Reference and/or Comment
1. 1972	BIO/MEL	p,p'-DDE	ICES 3A	4.75 ± 1.71	4	Consensus; mean ± s.d., n=4; Topping and Holden, 1978
		p,p'-DDD		12.3 ± 8.50	9	Consensus; mean ± s.d., n=3;
		p,p'-DDT		25.3 ± 29.3	11	Consensus; mean ± s.d., n=3;
2. 1972	BIO/MEL	p,p'-DDE	ICES 3B	210	193	Topping and Holden, 1978
		p,p'-DDD		210	236	
		p,p'-DDT		100	98	
3. 1978						DDT group not yet analysed; only HCH data available
4. 1981	Axys	p,p'-DDE	NIST 1588	641 ± 62	603 ± 47.3	NIST variance from unspecified samples;
		p,p'-DDD		277 ± 15	253 ± 20.8	Axys SD from 3 replicates; contract 2894
		p,p'-DDT		529 ± 45	550 ± 43.6	batches 521, 528 and 541.
5. 1989						DDT group not yet analysed; only HCH data available
6. 1991	Axys	p,p'-DDE	NIST 1588	641 ± 62	593 ± 66.6	NIST variance from unspecified samples;
		p,p'-DDD		277 ± 15	260 ± 20.0	Axys SD from 3 replicates; contract 2894
		p,p'-DDT		529 ± 45	523 ± 50.3	batches 550, 556 and 557.
7. 2001	NLET	p,p'-DDE	NIST 1588b	676 ± 36	521	NIST variance from unspecified samples;
		p,p'-DDD		285 ± 37	280	NLET batch 07kgb003.
		p,p'-DDT		570 ± 27	439	
8 2006	NLET	p,p'-DDE	NIST 1588b	676 ± 36	500	NIST variance from unspecified samples
		p,p'-DDD		285 ± 37	292	NLET batch 07kgb002
		p,p'-DDT		570 ± 27	537	

Table 2: Target v. observed concentrations of miscellaneous organochlorine pesticides in certified reference materials, 1981–2006

Sample yr	Analyst	SRM/CRM	Target value (ng/g)	Observed value (ng/g)	Reference and/or Comment
1. HCB					
1981	Axys	NIST 1588	148 ± 21	147 ± 6	Axys contract 2894 batches 521, 528 and 541
1991	Axys	NIST 1588	148 ± 21	137 ± 15	Axys contract 2894 batches 550, 556 and 557
2001	NLET	NIST 1588b	163 ± 16	126	NLET Batch 07kgb003
2006	NLET	NIST 1588b	163 ± 16	126	NLET Batch 07kbg002
2. Dieldrin					
1981	Axys	NIST 1588	150 ± 12	140 ± 20	Axys contract 2894 batches 521, 528 and 541
1991	Axys	NIST 1588	150 ± 12	133 ± 6	Axys contract 2894 batches 550, 556 and 557
2001	NLET	NIST 1588b	156 ± 4	133	NLET Batch 07kgb003
2006	NLET	NIST 1588b	156 ± 4	138	NLET Batch 07kbg002
3. Heptachlor epoxide					
1981	Axys	NIST 1588		NR	No certified value
1991	Axys	NIST 1588		NR	No certified value
2001	NLET	NIST 1588b	30 ± 1.9	20.1	NLET Batch 07kgb003
2006	NLET	NIST 1588b	30 ± 1.9	21.6	NLET Batch 07kbg002
4. Oxychlordane					
1981	Axys	NIST 1588		NR	No certified value
1991	Axys	NIST 1588		NR	No certified value
2001	NLET	NIST 1588b	37.5 ± 4.5	27.8	NLET Batch 07kgb003
2006	NLET	NIST 1588b	37.5 ± 4.5	34.4	NLET Batch 07kbg002

Continued

Sample yr	Analyst	SRM/CRM	Target value (ng/g)	Observed value (ng/g)	Reference and/or Comment
5. Cis-Chlordane					
1981	Axys	NIST 1588	158 ± 8	180 ± 0.0	Axys contract 2894 batches 521, 528 and 541
1991	Axys	NIST 1588	158 ± 8	167 ± 35	Axys contract 2894 batches 550, 556 and 557
2001	NLET	NIST 1588b	186 ± 22	158	NLET Batch 07kgb003 (alpha chlordane)
2006	NLET	NIST 1588b	186 ± 22	167	NLET Batch 07kbg002 (alpha chlordane)
6. Trans-Chlordane					
1981	Axys	NIST 1588	50 ± 13	45.3 ± 5.0	Axys contract 2894 batches 521, 528 and 541
1991	Axys	NIST 1588	50 ± 13	41.3 ± 4.0	Axys contract 2894 batches 550, 556 and 557
2001	NLET	NIST 1588b		50.3	No certified value; NLET batch 07kgb003 (gamma-chlordane)
2006	NLET	NIST 1588b		50.1	No certified value; NLET batch 07kgb002 (gamma-chlordane)
7. Cis-Nonachlor					
1981	Axys	NIST 1588	94 ± 8	73.3 ± 5.0	No certified value but value supplied to Axys from NIST; Axys contract 2894 batches 521, 528 and 541
1991	Axys	NIST 1588	94 ± 8	65	No certified value but value supplied to Axys from NIST; Axys contract 2894 batch 550
2001	NLET	NIST 1588b	92.4 ± 3	83.6	NLET Batch 07kgb003
2006	NLET	NIST 1588b	92.4 ± 3	87.6	NLET Batch 07kbg002
8. Trans-Nonachlor					
1981	Axys	NIST 1588	209 ± 11	223 ± 11.5	Axys contract 2894 batches 521, 528 and 541
1991	Axys	NIST 1588	209 ± 11	213 ± 51	Axys contract 2894 batches 550, 556 and 557
2001	NLET	NIST 1588b	222 ± 10	219	NLET Batch 07kgb003
2006	NLET	NIST 1588b	222 ± 10	214	NLET Batch 07kbg002

Table 3: Target v. observed PCB residue concentrations in Inter-calibration samples or Reference Materials, 1972–2006

Sample yr	Analyst	Analyte	SRM/CRM	Target value (ng/g)	Observed value (ng/g)	Reference and/or Comment
1. Aroclor 1254 (A1254) equivalents						
a. 1972	BIO/MEL	A1254	ICES 3B	1100	1020	Topping and Holden, 1978, ICES Co-op Research Rep. 80; lab. A
b. 1981	Axys	A1254	NIST 1558	1500 ± 500	1430 ± 115	Not certified value, but mean of repeated Axys analyses A1254 calculated from individual congener analyses
c. 1991	Axys	A1254	NIST 1558	1500 ± 500	1430 ± 208	Not certified value, but mean of repeated Axys analyses A1254 calculated from individual congener analyses
2. "ICES PCBs" + CB 170						
a. 1981	Axys	CB 28	NIST 1558			No certified value
		52				No certified value
		101		129 ± 5	130 ± 17.3	Actually CB 90/101; Axys analyses as mean ± s.d. (n=3)
		118				No certified value
		138		261 ± 29	283 ± 15.3	Actually CB 138/163/164; Axys analyses as mean ± s.d. (n=3)
		153		276 ± 40	273 ± 25.2	Actually 132/153; Axys analyses as mean ± s.d. (n=3)
		180		107 ± 4	107 ± 6	
		170		45 ± 5	42 ± 3	
b. 1991	Axys	CB 28	NIST 1558			No certified value
		52				No certified value
		101		129 ± 5	113 ± 5.8	Actually CB 90/101
		118				No certified value
		138		261 ± 29	277 ± 47.3	Actually CB 138/163/164
		153		276 ± 40	273 ± 41.6	Actually CB 132/153
		180		107 ± 4	99 ± 11	
		170		45 ± 5	37 ± 3.5	

Continued

Sample yr	Analyst	Analyte	SRM/CRM	Target value (ng/g)	Observed value (ng/g)	Reference and/or Comment
c. 2001	NLET	CB 28	NIST 1558b	27.8 ± 1.4	29.6	
		52		82.4 ± 1.7	64.8	
		101		127 ± 9	102	
		118		172 ± 7	144	
		138		212 ± 29	193	
		153		275 ± 4	224	
		180		98.5 ± 6.3	88.1	
		170		41.9 ± 3.8	35.9	
d. 2006	NLET	CB 28	NIST 1558b	27.8 ± 1.4	28.2	
		52		82.4 ± 1.7	61.8	
		101		127 ± 9	95.8	
		118		172 ± 7	138	
		138		212 ± 29	185	
		153		275 ± 4	216	
		180		98.5 ± 6.3	84.8	
		170		41.9 ± 3.8	34.6	

and (b) reconstruction of putative PCB sources from individual congener distribution in a field sample is also approximate, for the same reasons.

We will deal later with approaches to making long-term PCB comparison, but for the present we will concentrate on the accuracy of PCB and/or individual congener analysis.

PCBs in samples from 1972 (MEL) and in 1981 and 1991 (Axys) were expressed as Aroclor 1254. MEL analyses were based on comparisons of four main peaks in the packed column chromatogram with those of standard Aroclor 1254; Axys estimates of Aroclor 1254 content were calculated from "marker" congeners characteristic of specific Aroclor mixes, in this case, CBs 99, 97, and 87/115 (Sather et al., 2001). In the ICES unspiked sample 3A, only four labs. reported usable results, but the variance was so high (mean 128 ± s.d. 228 ng/g, n=4) that the consensus value was meaningless. In the spiked sample 3B, MEL's estimate of Aroclor 1254 concentration was within <10% of the spike value (Topping and Holden 1978, Table 19, Lab. "A"). NIST 1588, the CRM used by Axys for its analysis of 1981 and 1991 samples, had no certified value of Aroclor 1254, but repeated previous analyses (by Axys) had led to an estimate of 1500 ng/g; observed values were within 5% of this.

In samples from 1981–2006, Axys and NLET analysed a wide range of congeners in both field samples and in CRMs; only some of these congeners had certified values in the CRMs. I have focussed on the "ICES 7" congeners (CBs 28, 52, 101,118, 138, 153 and 180) plus CB 170; these congeners are usually recorded in field samples, they cover a wide range Cl substitution (tri- to hepta-) and their concentrations were certified in NIST CRM 1588b and to a lesser extent NIST 1588. Axys estimates of these CBs were always within 10% of the certified values except for CBs 101 and 170 which in the 1991 suite of analyses differed from certified values by <20%. NLET analyses of these congeners in CRM 1588b were a little less accurate than those of Axys; estimates were usually within 20% of certified values, except for CBS 101 and 153 which were within about 30% of certified values.

Overall, PCB analyses, whether expressed as Aroclor 1254 equivalents or as CB congeners appear reliable, though the deviation of some NLET estimates from certified values in NIST CRM 1588b means that apparent temporal changes in field samples after 2001 may require careful examination. In addition, some method will have to be developed to produce a “common” basis for reporting and comparing PCB concentrations over the entire sampling interval. The simplest approach might be to consider the data in two overlapping phases: (a) 1972–1991, in which data are reported as Aroclor 1254 (a “calibration curve” derived from replicate analyses of 18 samples by both MEL and Axys is available which will allow re-calculation of these data sets: Addison 1997, Fig. 1), and (b) 1981–2006 (and 2010) in which data are reported as individual CB congeners.

Collection of samples in spring 2010 (addresses Objective 7(d) above)

Twenty samples were collected, as noted above. Blubber samples have been sent for analysis to NLET (D. Muir) and are scheduled for analysis in May 2011. Tooth samples have been aged, and both age and blubber thickness data have been recorded in the cumulative database.

Capacity building

The seal monitor at Ulukhaktok (JA) has decades of experience in the techniques of sampling (tissue dissection, storage and shipping) and recording of relevant morphometric data (T.G. Smith, pers. comm.; cf. Addison and Smith 1998). No specific training was planned, given JA’s experience in this area. However, undertaking the sampling programme described above in spring 2010 has provided an opportunity to continue to exercise and apply these skills.

Communications

Preliminary data have been presented (D. Muir) at the 2010 NCP Results Workshop.

L. Skinner (INAC) presented a summary description of this project to about 40–50 members of the Ulukhaktok community (Aug 12 2010).

Traditional knowledge

Sample collection by the seal monitor (JA) from Ulukhaktok relied on his knowledge and experience, not only of specific aspects of sampling, but also, of his “contextual” ecological knowledge and experience.

Discussion and Conclusions

Overall, this project is going as planned; the only delays are (i) postponement of analysis of 2010 samples by NLET, which is beyond the control of the project team, and (ii) the need to gather detailed data about sampling dates in the 1970’s and 1980’s to explain the apparent trends in condition which have emerged from preliminary analysis of the data (noted above). However, we expect that both data sets will be available in summer 2011.

The analysis of past residue analysis, and of biological variables shows that most of the data are comparable over the entire sampling interval. Some statistical approach will have to be applied to “correct” for the apparent trends in condition, and some common approach to reporting PCB data (whose analyses have evolved significantly over the years) will have to be devised, but these problems are not insuperable.

Expected completion date.

March 31, 2012.

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Production and Loss of Methylmercury, and its Uptake in Lake Food Webs of the High Arctic

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Abstract

A study was initiated in 2010 on processes regulating the standing pool of methylmercury (MeHg) in lakes and wetlands on Cornwallis Island and thaw ponds on Bylot Island. Concentrations of total mercury (THg) and MeHg were generally low in lake and wetland sediments on Cornwallis Island, ranging from 3.5–67.9 ng THg g^{-1} and 0.01–1.79 ng MeHg g^{-1}. Rates of production and breakdown of MeHg in sediments were measured using a mercury (Hg) stable isotope method applied to collected cores. Methylation potentials were low in lake sediments (0.11–1.33% per day) but higher in the wetlands (0.34–3.87% per day), and demethylation potentials were low at all sites. Novel DGT (Diffusive Gradient in Thin film) sentinels were tested for their capacity to retain labile (and therefore bioavailable) species of MeHg migrating into a gel. The DGT technique successfully retained measureable concentrations of labile

Résumé

En 2010, on a entrepris une étude sur les processus régulant le bassin de méthylmercure (MeHg) dans les lacs et les terres humide de l'île Cornwallis et dans les étangs thermokarstique de l'île Bylot. Les concentrations de mercure total (THg) et de MeHg étaient généralement faibles dans les sédiments des lacs et les des terres humides de l'île Cornwallis, allant de 3,5 à 67,9 ng de THg g^{-1} et de 0,01 à 1,79 ng de MeHg g^{-1}. Les vitesses de production et de décomposition du MeHg dans les sédiments ont été mesurées grâce à une méthode basée sur l'isotope stable du mercure (Hg) appliquée à des carottes collectées. Les potentiels de méthylation étaient faibles dans les sédiments des lacs (0,11–1,33 % par jour), mais plus élevés dans les terres humides (0,34–3,87 % par jour), et les potentiels de déméthylation étaient faibles sur tous les sites. On a testé la capacité de nouvelles sentinelles de type DGT (gradient de diffusion dans une couche mince)

MeHg from sediment (pore water), indicating its utility for low-level Arctic conditions. Molecular techniques were used to characterize the microbial community that may be involved in sediment methylation of Hg. Evidence from RNA transcripts at a wetland site indicated that sediment conditions were conducive to both sulfate reduction and methanogenesis below 3 cm depth. While no methanogen transcripts could be detected in sediments from Char Lake, markers for sulphate reduction were detected at 3 cm suggesting anoxic conditions below that depth. Sulphate reduction may be the dominant anaerobic metabolism in Char Lake. On Bylot Island, water THg and MeHg concentrations in permafrost thaw ponds ranged from 0.55−13.44 ng L-1 and 0.04−2.81 ng L-1, respectively. Photodemethylation of water MeHg was observed in spiked and unamended samples after a 9–day incubation period in the field, with losses ranging from 61−82%, whereas dark controls did not vary significantly over time. Mechanistic experiments showed that radical hydroxyl producers and scavengers did not significantly change photodemethylation losses compared to unamended controls. However, singlet oxygen producers, glutathione and chlorides increased photodemethylation losses by 11−33% compared to controls. Further research will be conducted in 2011–2012 to build on these initial findings.

à retenir des espèces labiles (et donc biodisponibles) de MeHg migrant dans un gel. La technique de DGT a permis de retenir des concentrations mesurables de MeHg labile provenant des sédiments (eau interstitielle), montrant ainsi son utilité dans des conditions de faibles concentrations dans l'Arctique. On a utilisé des techniques moléculaires pour caractériser la communauté microbienne pouvant participer à la méthylation du Hg dans les sédiments. Des résultats de transcripts d'ARN sur une terre humide ont montré que les conditions des sédiments étaient favorables à une réduction des sulfates et à une méthanogenèse à plus de 3 cm de profondeur. Bien qu'aucun transcript méthanogène n'ait pu être détecté dans les sédiments du lac Char, des marqueurs de la réduction des sulfates ont été détectés à 3 cm, suggérant des conditions anoxiques sous ce niveau. La réduction des sulfates peut être le métabolisme anaérobie dominant dans le lac Char. Sur l'île Bylot, les concentrations de THg et de MeHg dans l'eau des étangs themokarstiques allaient respectivement de 0,55 à 13,44 ng L-1 et de 0,04 à 2,81 ng L-1. La photodéméthylation du MeHg aqueux a été observée dans des échantillons dopés et non modifiés après une période d'incubation de 9 jours sur le terrain, avec des pertes allant de 61 à 82 %, alors que pour des échantillons de contrôle gardés au noir elle ne variait pas de manière significative. Des expériences mécanistes ont montré que les producteurs et les piégeurs de radicaux hydroxyles ne modifiaient pas de manière significative les pertes par photodéméthylation, comparativement à celles des échantillons de contrôle non modifiés. Toutefois, les producteurs d'oxygène singulet, glutathione et chlorures, faisaient augmenter les pertes par photodéméthylation de 11−33 %, comparativement à des échantillons de contrôle. D'autres travaux seront réalisés en 2011–2012 afin de compléter ces résultats initiaux.

Key Messages

- The production of MeHg was measured in aquatic sediments on Cornwallis Island, at low rates in lakes and at higher rates in wetlands. Demethylation rates were low at all sites.
- Sulphate-reducing bacteria were present and active in sediments of Char Lake and a wetland on Cornwallis Island while methanogens

Messages clés

- La vitesse de production de MeHg a été mesurée dans des sédiments aquatiques sur l'île de Cornwallis, elle était faible dans les lacs et plus élevée dans les terres humides. Les vitesses de déméthylation étaient faibles sur tous les sites.
- Des bactéries réduisant le soufre étaient présentes et actives dans les sédiments du lac Char et d'une terre humide de l'île de Cornwallis, alors que des méthanogènes ont aussi été détectés, mais uniquement dans

were also found in the wetland only. Sulphate reduction may be the dominant anaerobic metabolism in Char Lake sediments.

- Water concentrations of THg and MeHg were high in thaw ponds on Bylot Island. Photodemethylation of water MeHg was rapid, and the presence of certain chemicals altered its rate of breakdown in water.

des terres humides. La réduction du sulfate peut être le métabolisme anaérobie dominant dans les sédiments du lac Char.

- Les concentrations de THg et de MeHg dans l'eau étaient élevées dans les étangs thermokarstiques de l'île Bylot. La photodéméthylation du MeHg aqueux était rapide, et la présence de certains composés chimiques modifiait sa vitesse de décomposition dans l'eau.

Objectives

The main purpose of this two-year project is to investigate sources and losses of MeHg in Arctic freshwater ecosystems and its uptake in food webs. This research is focusing on two study areas: NCP-monitored lakes at Resolute Bay (Cornwallis Island) and non-focal ecosystems at Bylot Island. Cornwallis Island is a barren polar desert with little terrestrial plant cover whereas Bylot Island is more biologically productive with extensive tundra vegetation. In the first year of this project (2010–2011), the main objectives were to:

- Measure sediment methylation and demethylation rates in lakes and wetlands
- Characterize the microbial community involved in methylation and demethylation
- Measure photodemethylation rates in the water column and investigate the associated mechanisms;
- Measure bioavailable MeHg in sediment pore water

Introduction

Most Hg in the environment is in an inorganic form whereas organic MeHg is the much more toxic species that biomagnifies through food webs. Processes regulating the standing pool of MeHg such as inorganic Hg methylation and MeHg degradation are therefore critical in controlling how much enters aquatic food webs. Information on these key processes is currently lacking for freshwater ecosystems in the High Arctic. Specifically, it remains unclear: 1) where MeHg is produced; 2) what groups of bacteria are methylating inorganic Hg; 3) how much MeHg is lost by sunlight-induced breakdown (photodemethylation); and 4) how these processes relate to bioaccumulation in lake food webs. Although these processes have been investigated in lakes at more southern latitudes such as in Alaska (Hammerschmidt et al. 2006) and temperate Canada (Sellers et al. 2001, Harris et al. 2007), environmental conditions in the High Arctic are severe, making it difficult to extrapolate from other studies.

MeHg production may occur within the watershed in wetlands (Loseto et al. 2004b) or thermokarst ponds (standing waters formed from permafrost thaw). These shallow standing waters typically contain abundant organic matter and may have warmer temperatures than lakes in summer, providing favourable conditions for methylation (St. Louis et al. 2005). Water draining from wetlands and ponds may then transport MeHg to lakes where it could enter the food web. Production in the sediment of lakes may also be an important source of MeHg, as observed in lakes at lower latitudes (Sellers et al. 2001). Snowmelt is another possible source of MeHg to lakes (Loseto et al. 2004a, St. Louis et al. 2005).

The production of MeHg in aquatic environments is primarily mediated by microbes, and they are also involved in MeHg degradation. The types of microbial organisms involved in these processes have not been identified in the Arctic (Barkay and Poulain 2007), but low abundance of sulfate-reducing bacteria in soil samples from Cornwallis Island put into question the importance of these microbes in the High Arctic (Loseto et al. 2004b). The role of methanogens or iron reducing bacteria remains unclear.

Arctic lakes have very transparent water, resulting in high light penetration and the potential for efficient photochemical breakdown of MeHg in the water column (Hammerschmidt and Fitzgerald 2006). Photodemethylation counteracts MeHg production by breaking it down before it enters the food web. Estimates of photodemethylation rates and the mechanisms controlling this loss process are needed to better constrain its role in the movement of MeHg in the High Arctic.

Factors that control the uptake of MeHg at the base of lake food webs remain poorly constrained. Specifically, the role of watershed versus lake production of MeHg, and its bioavailability and photodecomposition have not been determined for High Arctic lakes. This information is important to interpret NCP monitoring of Hg in lake populations of Arctic char.

Activities in 2010–2011

This project incorporates multiple approaches, specifically rate measurements in the field of key production and loss processes, mechanistic studies of MeHg cycling (i.e., investigation of the microbial community, photodemethylation experiments), and measurements of MeHg bioaccumulation at a low trophic level in lake food webs. Rates are being measured to identify the influence of specific processes, mechanistic studies are being conducted to provide information on factors driving the processes, and a food web analysis in the second year of the project will examine the net transfer to biota.

Resolute Bay— In August 2010, sediment cores were collected in duplicate to measure sediment methylation and demethylation rates in Resolute, Char and Meretta lakes and three wetlands. Each core was assayed for Hg methylation and MeHg demethylation potential at 1, 3 and 10 cm depth by injecting isotope enriched Hg(II) (200Hg) and MeHgCl (199Hg). Cores were incubated for 9−10 hours in the PCSP laboratory, sliced and individually frozen slices were transported back to the lab at Trent University for analysis of ambient concentrations and Hg species transformation rates by ICP-MS.

Sediments were also collected with a corer from Char and Resolute lakes and two wetlands to characterize the microbial community and quantify targeted microbes potentially involved in MeHg cycling. Sediments were sampled every 2 cm from the surface down to 12 cm and were immediately frozen at $-20^{o}C$. Samples from depths at which mercury isotopes were added (1, 3 and 10 cm) were collected in cryovials and immediately frozen in a dry shipper at about $-180^{o}C$ to prevent nucleic acids from being degraded during transport to the University of Ottawa. Once at the university, both DNA and RNA were analyzed using qRT-PCR approaches, cloning and library analyses combined with gel electrophoresis techniques.

Three MeHg photodemethylation experiments were performed, during which water samples were incubated in the field. Two of them were conducted in Char and Resolute lakes over a period of 13 days, and included the following treatments: (1) filtered samples kept in dark bottles; (2) filtered samples kept in clear bottles (receiving visible + UVB radiation); (3) unfiltered samples kept in clear bottles (receiving visible + UVB radiation); (4) filtered samples amended with 5 ng L-1 of MeHg kept in clear bottles (receiving visible + UVB radiation); (5) filtered samples amended with 5 ng L-1 of MeHg kept in clear bottles covered with light filters (receiving visible only, cut off of 50% of radiation $<$410 nm). Bottles from each treatment were retrieved every three days for analysis, in order to obtain a time series. The last experiment aimed at further exploring processes involved in photodemethylation by adding complexing agents such as thiols or scavengers of different reactive species, roughly following the approach of Zhang and Hsu-Kim (2010). All samples were filtered unless otherwise indicated. Water samples were incubated in situ for 50 h in clear bottles, and the following treatments were conducted (final concentrations in incubation bottles are indicated): additions of (1) 10 nM of glutathione (GSH); (2) 3 mM NaN3; (3) 3 mM NaN3 in unfiltered water; (4) 0.1 mM β-carotene; (5) 15 μM rose bengal; (6) 15 μM eosin-Y; (7) 0.01% v/v 1-hexyne; (8) 0.01% v/v benzene; (9) 0.01% v/v isoprene; and (10) 28 g L-1 Cl.

Filtered and unfiltered water samples were collected in triplicate for MeHg analysis and in duplicate for thiol analysis in three lakes and their inflows near Resolute Bay (Char, Meretta and Resolute lakes). Ambient and experimental samples of water MeHg were distilled and analyzed by CVAFS.

The feasibility of using novel DGT (Diffusive Gradient in Thin film) sentinels to measure concentrations of labile (and therefore bioavailable) species of MeHg in water and pore water and estimate diffusive fluxes of MeHg from sediment to the overlying water was explored. The DGT device is comprised of an ion-exchange resin immobilized in a resin gel, which is separated from the test solution by an ion-permeable gel (diffusive gel). Concentration gradients develop across the diffusive gel and the contaminants are transported to the resin gel where they are fixed and accumulate during the deployment time. DGT devices concentrate MeHg in situ and yield time-averaged concentrations over the length of the deployment period. During the first field season, the DGTs were inserted in sediment cores and set in the water column to test for optimization in the extreme environmental conditions of High Arctic lakes.

Bylot Island—In July 2010, water samples were collected from six low-center polygons, eight runnels, one lake and one coastal site for THg, MeHg and thiol analyses in water, and for THg analyses in sediments. Also, the same three photodemethylation experiments described above for Resolute Bay were performed. The first two experiments were conducted in one polygon and one runnel (BYL22 and BYL24). The final experiment with thiol and radical scavenger additions was performed in BYL 22.

DNA and RNA analyses were also completed on sediment collected at Bylot Island to characterize the microbial community using the methods described above.

Capacity Building/Communications/ Traditional Knowledge

Local assistance was provided by Pilipoosie Iqaluk for the field program at Resolute Bay in August 2010. Pilipoosie participated in the field sampling and assisted with the testing of DGT samplers as a monitoring tool for labile MeHg concentrations in High Arctic fresh waters. In the second year of the field program, the plan is for Pilipoosie to deploy and retrieve samplers in local lakes during the open water season. In addition, he will participate in the August 2011 field collection of sediment, water and chironomids.

The Resolute Bay HTA was consulted for permission to conduct the project activities at local lakes and wetlands. An update on the project was provided to the HTA in February 2011, and future communication is planned to provide additional information on the progress and outcome of the research.

There was no direct use of traditional knowledge due to the specialized nature of the project.

Results and Discussion

A) Sediment methylation and demethylation
THg concentrations in lake sediments ranged from 11.1–67.9 ng g^{-1} and were on average 25.0, 36.5 and 36.9 ng g^{-1} in Char, Resolute and Meretta lakes, respectively. No specific trends with depth were observed. While within-lake variations were small in Char and Meretta lakes, two (out of seven) cores in Resolute Lake showed significantly higher levels of up to 67 ng g^{-1}. THg in wetland sediments was significantly lower, typically from 3.5–12.2 ng g^{-1} (with two outliers up to 28.2 ng g^{-1}).

MeHg concentrations in lake sediments ranged from 0.01–1.79 ng g^{-1} and were on average 0.12, 0.22 and 0.12 ng g^{-1} in Char, Resolute and Meretta lakes, respectively. Frequently, highest concentrations were observed in the top sediment layer, with significantly lower concentrations in deeper sections of the core. MeHg concentrations in wetland sediments were less variable, ranging from 0.02–0.45 ng g^{-1} (average 0.11 ng g^{-1}).

Rates of Hg methylation varied from 0.11–1.33% per day in lake sediments. The largest variations were observed in Resolute Lake, while Meretta Lake showed uniformly (low) methylation rates from 0.15–0.40%. On average 0.39, 0.33 and 0.26% of the added inorganic Hg spike was methylated over 24 hours. Wetland sediments showed the greatest variation and highest potential for methylation. Values ranged from 0.34–3.87% per day, with an average of 1.40%.

Table 1: Concentrations of THg and MeHg, and methylation and demethylation potentials in top surface sediments

	Char Lake 1	Char Lake 2	Resolute Lake	Meretta Lake	Wetland
THg (ng g^{-1})	22.1	30.4	43.0	36.7	12.4
MeHg (ng g^{-1})	0.09	1.1	0.38	0.12	0.66
M (% per hour)	0.007	0.030	0.010	0.012	0.075
D (%)	31.0	24.0	15.4	9.2	14.5

M: proportion of the inorganic Hg spike methylated per hour
D: proportion of MeHg spike demethylated during incubation

Demethylation potentials were variable. Particularly in Resolute Lake, some sediments only showed a very small decline of the added MeHg spike, suggesting a low potential for demethylation. Char Lake, on the other hand, exhibited the highest rate of MeHg degradation with on average 29% of the injected MeHg spike being demethylated over the incubation period.

Since the top sediment layer is probably most important for MeHg production and export to the overlying water, Table 1 shows characteristic data obtained in the top 1 cm slice of sediments. The two sites in Char Lake showed distinct differences and are presented separately. More frequent sampling might be warranted in this lake. Other locations showed less site-to-site variation.

Concentrations of ambient MeHg in surface sediment varied greatly among locations. The highest and lowest levels were found in Char Lake, suggesting that site specific parameters are important in controlling standing pools of MeHg. Potential for MeHg formation was highest in the wetland location (Table 1). The potential for MeHg formation in all study lakes was relatively low. Even the highest rate observed in Char Lake is low compared to methylation potentials measured in southern lakes. The wetland rate was in the range of what one would expect from a “typical” wetland, and consistent with the observed higher level of ambient MeHg concentration in the wetland sediment. Likewise, highest methylation rates in surface lake sediments correlated reasonable well with standing pools of ambient MeHg (except for Char Lake). Demethylation potentials were low across the board for sediments, both in lakes and the wetland. Previous studies have often found degradation rates of up to 80%. In comparison, losses of 9–31% suggest low activity or low a bundance of demethylating microbes. However,

Table 2: Ambient and isotope enriched MeHg measured in sediment DGTs (pg of MeHg accumulated per 24 hours)

	Char Lake	Resolute Lake	Wetland
Ambient MeHg			
Overlying water	6.8	7.0	5.9
Sediment (0–6 cm)	7.7	11.4	27.1
Sediment (6–12 cm)	15.0	13.1	20.7
Isotope enriched MeHg			
Overlying water	3.45	1.89	5.80
Sediment (0–6 cm)	3.15	2.68	2.84
Sediment (6–12 cm)	8.34	5.83	4.00

Table 3. Genes targeted to characterize the microbial community of Char Lake and a wetland near Small Lake.

Gene	Function	Relevance to this project
16S rRNA bacteria: Ribosomal subunit specific to bacteria	Protein synthesis	Proxy for bacteria presence and abundance
16S rRNA archaea: Ribosomal subunit specific to archaea	Protein synthesis	Proxy for archaea presence and abundance
glnA: Glutamine synthetase	Nitrogen metabolism	Gene involved in core nitrogen metabolism; proxy for bacteria activity; protein-encoding gene transcript control
mcrA: Methyl coenzyme M reductase alpha-subunit	Methane production	Catabolic gene; indicates presence of methanogens and anaerobic conditions
dsrAB: dissimilatory sulfate reductase genes	Sulfate reduction	Catabolic gene; indicates presence of sulfate reducers (involved in Hg methylation); indicates anaerobic conditions
merA: mercuric reductase	Hg resistance	Resistance gene; inorganic Hg reduction and potential oxidative demethylation

combined with the even lower rate of methylation, resulting MeHg concentrations are still lower than those typically found in southern locations.

Several DGT pistons were deployed in Resolute Lake, but due to adverse weather conditions at the time of planned retrieval, we were unable to recover the devices. During the field trip, sediment DGTs were inserted into (spiked) sediment cores on-site for 24 hours. In the lab, the DGT strip was cut into three pieces: sections exposed to overlying water (3 cm), 0–6 cm sediment depth and 6–12 cm sediment depth. The amounts of accumulated ambient MeHg and accumulated isotope enriched MeHg spike are shown in Table 2.

The DGT technique was successful in measuring labile MeHg species in sediment (pore water) migrating into the gel. Highest levels in sediments were found in the wetland location, which is consistent with the observations made for MeHg concentrations in sediments. The isotope enriched MeHg spike was also measured at detectable levels in the DGT device. Some of the methylated spike was even detected in the overlying water. Lower concentrations in the top surface layer represent a higher rate of MeHg demethylation, which appears to be more pronounced at the surface relative to deeper segments in the core. No methylated inorganic spike was detected in the DGT gel.

Table 4. DNA concentrations (μg DNA g^{-1} sediment) from Char Lake and the Small Lake wetland.

Depth	Lake	Wetland
2 cm	2.32	2.8
5 cm	4.18	3.12
7 cm	3.58	1.84
9 cm	2.38	1.60
11 cm	1.72	1.28
14 cm	1.60	1.44

B) Sediment microbial community

DNA and RNA were extracted from sediment collected in Char Lake, Resolute Lake and a wetland near Small Lake. DNA extraction was performed on core samples from the lakes and wetland at depths of 2, 5, 7, 9, 11 and 14 cm. RNA extractions were performed at depths of 1, 3 and 10 cm at which stable isotopes were added. We report results for Char Lake and the Small Lake wetland only. The results here focus on six genes and their transcripts (Table 3) to characterize the microbial

Table 5. Presence "+" or absence "-" of a PCR amplicon for the six genes of interest at various depths from the lake and wetland sediment. (+) denotes a very faint band. n/a denotes not available. See also Figure 1.)

Depth – lake	*16S* bacteria	*16S* archaea	*glnA*	*mcrA*	*dsrAB*	*merA*
2 cm	+	-	+	(+)	+	+
5 cm	+	-	+	+	+	+
7 cm	+	-	+	+	+	+
9 cm	+	-	+	+	+	+
11 cm	+	-	+	+	+	+
14 cm	+	-	+	+	+	+
Depth - wetland	***16S* bacteria**	***16S* archaea**	***glnA***	***mcrA***	***dsrAB***	***merA***
2 cm	+	+	+	+	n/a	n/a
5 cm	+	+	+	+	n/a	n/a
7 cm	+	+	+	+	n/a	n/a
9 cm	+	-	+	+	n/a	n/a
11 cm	+	-	+	+	n/a	n/a
14 cm	+	-	+	+	n/a	n/a

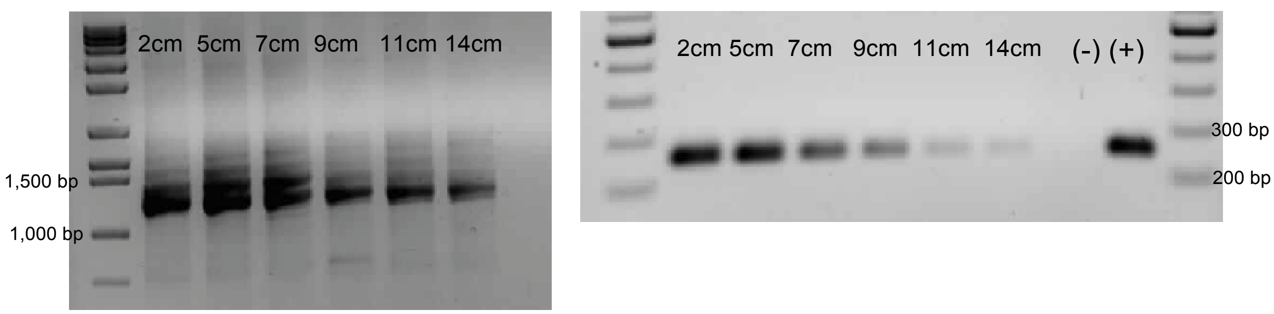

Figure 1. Left panel: dsrAB PCR on a lake sediment core. Expected band size is 1,300 bp. Right panel: glnA PCR on a lake sediment core. Expected band size is 280 bp.

Table 6. RNA concentrations (µg RNA g^{-1} sediment) from Char Lake and the Small Lake wetland.

Depth	Lake	Wetland
1 cm	2.15	6.01
3 cm	0.49	2.41
10 cm	0.27	1.05

community present and active in two contrasting aquatic ecosystems of a polar desert (a lake and a wetland).

Sediment DNA

DNA was successfully extracted from sediments at all depths. The highest DNA concentrations were observed within the first 5 cm and decreased with depth (Table 4). All genes tested, except for archaeal 16S rRNA, were amplified from all depths (Table 5). Markers of general metabolism (glnA) and of anaerobic environments, such as genes involved in sulphate reduction (dsrAB) or methanogenesis (mcrA), were found throughout the profile from 2–14 cm suggesting that both the lake and wetlands sediments are anoxic (Table 5, Figure 1). Note that the marker for methanogenesis was very faint at a depth of 2 cm in the lake, suggesting suboxic conditions from the surface down to 2 cm. We did not perform DNA extraction on samples from 0–2 cm.

Table 7. Presence "+" or absence "-" of transcripts detected by PCR from cDNA for the six genes of interest at various depths for the lake and the wetland. (+) denotes a very faint band and "++" a strong signal. n/a denotes not available. See also Figures 2–4.

Depth - lake	*16S* bacteria	*16S* archaea	*glnA*	*mcrA*	*dsrAB*	*merA*
1 cm	+	-	++	-	-	n/a
3 cm	+	+	+	-	+	n/a
10 cm	+	-	(+)	-	-	n/a
Depth - wetland	***16S* bacteria**	***16S* archaea**	***glnA***	***mcrA***	***dsrAB***	***merA***
1 cm	+	-	+	-	+	n/a
3 cm	+	+	++	+	+	n/a
10 cm	+	+	++	(+)	+	n/a

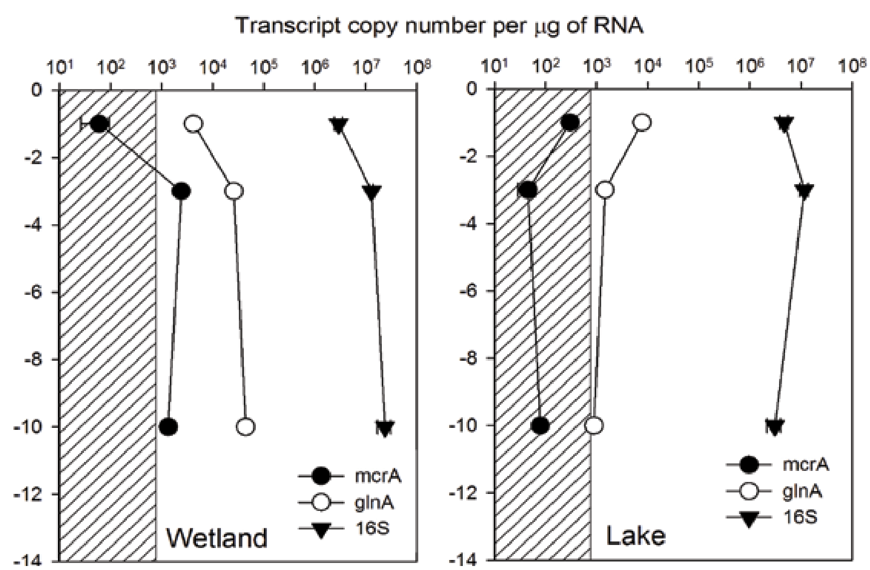

Figure 2. Transcript copy number of target genes normalized to RNA amount as function of depth. The hatched area represents our limit of quantification.

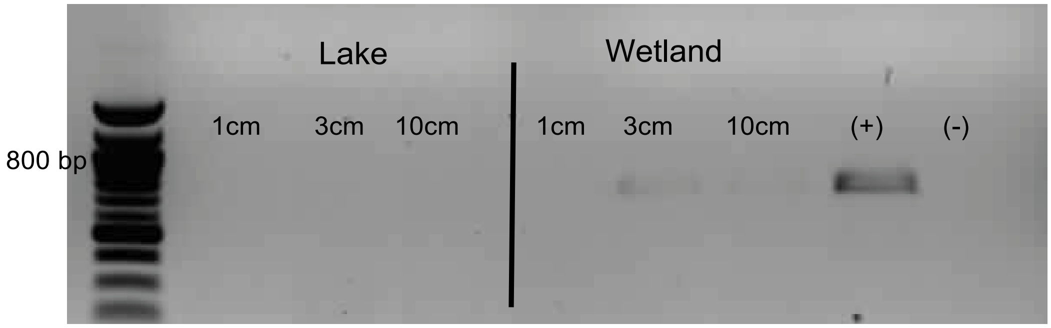

Figure 3. mcrA PCR performed on cDNA from lake and wetland samples. Expected band size is 760 bp.

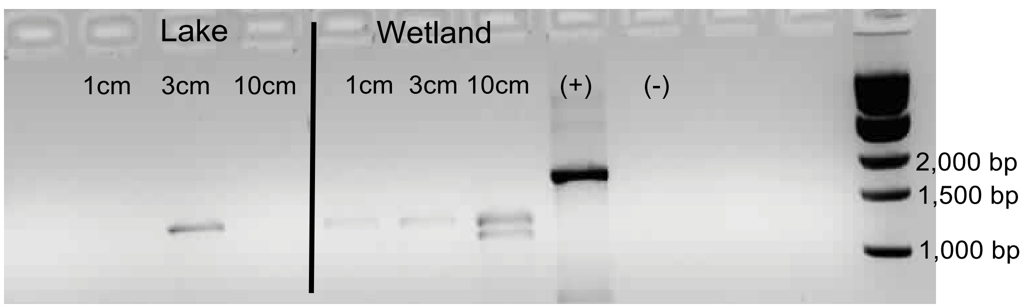

Figure 4. dsrAB nested PCR performed on cDNA from lake and wetland samples. Expected band size is 1,300 bp. Positive control (+) is from the first round of PCR and expected size is 1,900 bp.

Sediment RNA

The presence of DNA does not necessarily imply that the microbes were active, and therefore, we extracted RNA and performed transcript analyses of the genes of interest. RNA was successfully extracted from sediments at all depths. The highest RNA concentrations were observed at the surface and decreased with depth (Table 6). Markers of bacterial activity such as transcripts for 16S rRNA and glnA were found at all three depths (Table 7, Figure 2) supporting the presence of active microbial populations down to 10 cm within the sediment of both Char Lake and the Small Lake wetland.

Markers of methanogenesis (mcrA transcripts) could not be detected by regular PCR in the lake and only at depths of 3 cm and 10 cm in the wetland (Table 7, Figure 2). McrA transcripts could be detected by quantitative PCR at 1, 3 and 10 cm (Figure 2) in both the lake and the wetland, but at very low levels and only above our limit of quantification at depths of 3 and 10 cm in the wetland, supporting the information provided by the gel (Figure 3).

Markers of sulfate-reduction (dsrAB transcripts) were detected at all depths in the wetland and only at a depth of 3 cm in the lake (Figure 4). A method is currently being developed in our lab to detected long fragments such as those produced by dsrAB amplification using quantitative PCR.

Conclusions for the microbial community characterization

Together these results suggest that the wetland and lake sediments were mostly anoxic below a depth of 2 cm. These environments exhibited conditions conducive to both sulfate reduction (dsrAB) and methanogenesis (mcrA) below 3 cm. Because some sulphate reducers can be tolerant to low oxygen levels, the presence of dsrAB and the absence of mcrA at a depth of 1 cm may suggest micro-oxic conditions or the succession of oxic and anoxic conditions that can be expected from a wetland fed by seasonal snow melt. While no mcrA transcripts could be detected in the lake sediments, markers for sulphate reduction were detected at a depth of 3 cm suggesting anoxic conditions below 3 cm. Sulphate reduction may be the dominant anaerobic metabolism in Char Lake. These results also suggest that wetlands from polar deserts, more than lakes, are likely sources of methane to the atmosphere.

C) Photodemethylation studies

Studies on MeHg levels and MeHg photodemethylation were conducted near Resolute and on Bylot Island. Here, we focus on preliminary results from Bylot Island, for which the data set has been more fully analyzed.

THg and MeHg levels on Bylot Island

THg and MeHg concentrations in permafrost thaw ponds on Bylot Island ranged from 0.55−13.44 ng L-1, and from 0.04−2.81 ng L-1, respectively. Runnels were more contaminated than lakes and polygon ponds with respect to THg, MeHg and %MeHg/THg (ANOVA; $p<0.001$). In runnels, we observed that dissolved oxygen and dissolved organic carbon (DOC) levels were correlated to THg ($R2adj=0.292$; $p<0.05$) and MeHg concentrations ($R2adj=0.219$; $p<0.05$). In polygons, MeHg depended more on pH ($R2adj=0.484$; $p<0.05$) and DOC ($R2adj=0.219$ ($p<0.05$)).

MeHg levels in runnels are high compared to those reported in the Arctic and at lower latitudes, and we therefore suggest that runnels represent potential hotspots of MeHg contamination in the Arctic landscape. The fact that runnels are much more contaminated in total mercury can be explained by the geomorphology of the sites. Runnels are deeply entrenched into the ground and receive large amounts of seeping permafrost thaw water that is high in organic matter, ions and Hg (Klaminder et al. 2008). MeHg contamination in runnels may result from high methylation rates, since these systems are also often lined with thick biofilms.

Photodemethylation of MeHg

Photodemethylation of MeHg was observed in spiked (5 ng L-1) and unamended samples after a 9–day incubation period in the field, with losses

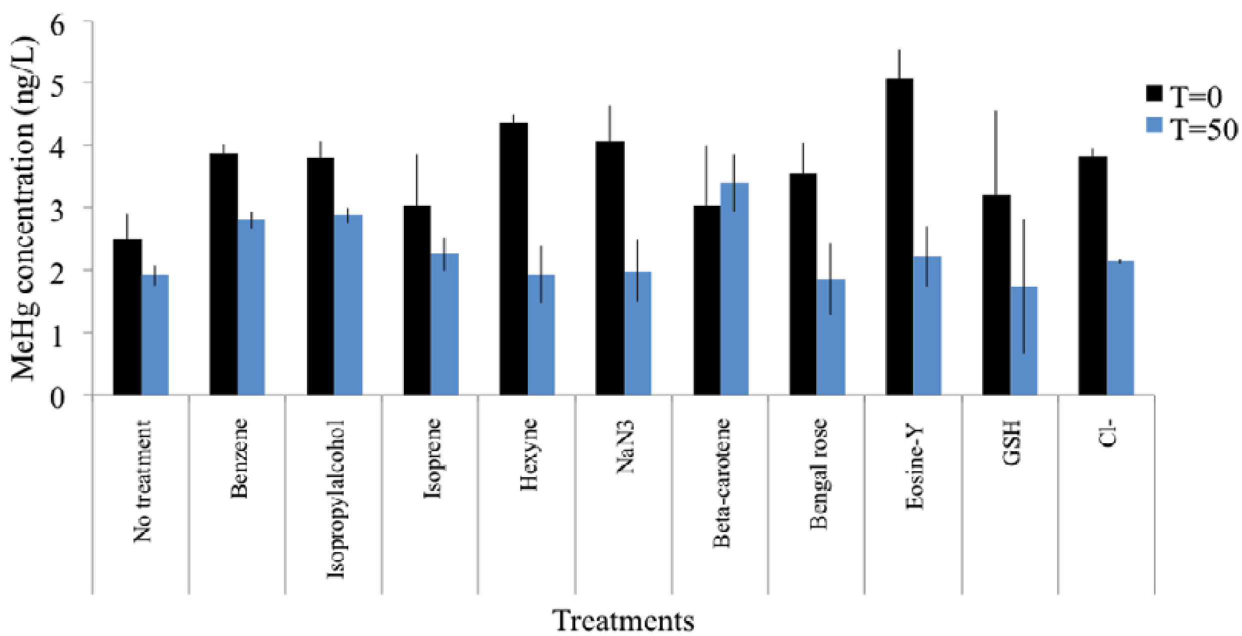

Figure 6. Mechanistic photodemethylation experiments conducted in the field on Bylot Island at site BYL22. All samples were filtered (online filters, 0.45 μm), amended with a 5 ng L-1 spike of MeHg and preserved in situ following a 50 hour incubation period with 500 μL of ultra-pure HCl. Treatments: benzene (0.01% v/v), isopropylalcohol (0.01% v/v), isoprene (0.01% v/v), 1-hexyne (0.01% v/v), NaN3 (3 mM), beta-carotene (0.1 mM), Bengale rose (15 μM),eosine-Y (15 μM), GSH (10 nM), and Cl- (28 g L-1).

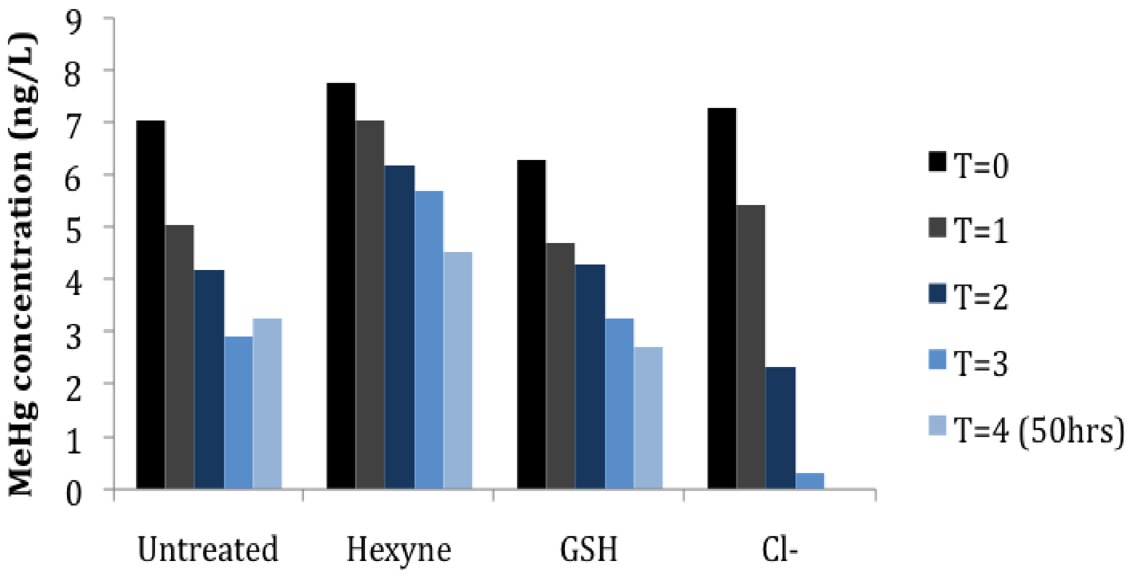

Figure 7. Mechanistic photodemethylation experiments repeated in the lab using natural waters incubated in the Suntest CPS+. All samples were filtered (online filters, 0.45μm) and amended with 5 ng L-1 spike of MeHg. Total incubation time was 14 hours at 750 w m-2 to simulate solar irradiance received during 50 hours of exposition in the field. Samples were removed every 3.5 hours (T=1–4) and acidified using 340 μL of ultra-pure HCl. Treatments: 1-hexyne (0.01% v/v), GSH (10 nM), and Cl- (28 g L-1).

ranging from 61–82%, whereas dark controls did not vary significantly over time. Mechanistic experiments showed that radical OH producers (benzene, isopropylalcohol) and scavengers (isoprene) did not significantly change photodemethylation losses compared to the unamended control series (Figure 6). This concurs with laboratory results previously obtained by Zhang and Hsu-Kim (2010) that showed radical OH did not play a major role in photodemethylation in synthetic water. However, singlet oxygen producers yielded losses 24–33% greater than those obtained in the control series (Figure 6). The addition of GSH accelerated photodemethylation-related losses by 22% (Figure 6), as was observed by Zhang and Hsu-Kim (2010). Our results differ from those found in previous papers in the case of chlorides: indeed, the addition of 28 g L-1 of NaCl accelerated photodemethylation by 11% (Figure 6).

Hexyne, GSH and chloride treatments were repeated in natural waters exposed in a solar simulator at the Université de Montréal. The lab results confirmed what was observed in the field, with hexyne slowing photodemethylation by 13%, GSH accelerating it by 4% and chlorides by 46% (with total losses of 99% over the incubation period) (Figure 7). Further research will be conducted in 2011 to better define the role of different radicals and thiols in MeHg degradation.

Conclusions

Preliminary results from the first year of this project showed measureable MeHg production in High Arctic fresh waters, at low rates in sediments of polar desert lakes and at higher rates in wetland sediments. Demethylation rates were low in sediments from both the lakes and wetlands. DGT sentinels retained labile MeHg from sediment porewater, indicating its potential applicability for Arctic conditions. Sulphate-reducing bacteria were present and active in sediments of a polar desert lake and wetland while methanogens were also found in the wetland only. Sulphate reduction, which is associated with Hg methylation, may be the dominant anaerobic metabolism in sediments of the lake. Water concentrations of THg and MeHg were high in thaw ponds on

Bylot Island. Photodemethylation of water MeHg was rapid, and the presence of certain chemicals altered its rate of breakdown in water.

During the field program of 2011, additional measures of sediment methylation and demethylation, and water photodemethylation will be conducted. Photodemethylation experiments will be continued to identify chemicals that alter the rate of this process. Sediment slurry experiments will be conducted in the laboratory to further characterize the microbial community involved in Hg methylation. Food web uptake will be linked with the processes of MeHg cycling by measuring MeHg in benthic invertebrates (chironomids) at the study sites. Together, findings from this study will provide important information on processes regulating the standing pool of MeHg and its uptake in lakes of the High Arctic. This information will support the interpretation of long-term Hg trends from NCP monitoring of lake populations of Arctic char.

NCP Performance Indicators

Number of northerners engaged in this project: 1

Number of meetings/workshops held in the North: 0

Number of students involved in this project: 2

Number of citable publications: 2 conference presentations

Girard, C., M. Amyot, and I. Laurion. 2010. Aqueous concentrations and degradation pathway of methylmercury in Arctic lakes and thaw ponds. 37th Aquatic Toxicology Workshop, Toronto, ON, October 3–6, 2010.

Girard, C., M. Amyot, and I. Laurion. 2011. Aqueous concentrations and degradation pathway of methylmercury in Arctic lakes and thaw ponds. XXIe symposium annuel du Groupe de recherche interuniversitaire en limnologie et en environnement aquatique (GRIL), St. Hippolyte, QC, March 3–5, 2011.

Expected Project Completion Date

This project will end March 31, 2012.

Acknowledgements

We thank the NCP for funding to support this project. Additional funding was provided by an NSERC Northern Supplement to MA and an FQRNT Équipe grant to MA and AP. Field logistic support was provided by the Polar Continental Shelf Program. We thank the HTA of Resolute Bay for permission to conduct this research in local lakes.

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

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Abstract

Our study is investigating whether mercury and persistent organochlorine contaminants are changing in lake trout and burbot in Great Slave Lake. The primary monitoring began in 1999 but earlier data exist from our more limited studies conducted in over 1993–1996 and from periodic mercury measurements made in the commercial fisheries. We are investigating lake trout in the West Basin (near Hay River) and East Arm (near Lutsel K'). We also are investigating burbot from the Fort Resolution area of the West Basin; burbot sampling at Lutsel K'e was discontinued in 2004 but was resumed in 2007 under our companion Great Slave Lake project and findings presented in that report. Mercury concentrations are increasing in lake trout harvested from the West Basin and East Arm and burbot from the West Basin possibly due to a combination of a warming trend and increased Asian emissions. Average mercury concentrations remain below 0.5 $\mu g/g$ and well below the high concentrations observed in smaller lakes along the Mackenzie

Résumé

Nous avons réalisé des études poussées au Lac Great Slave afin de mieux comprendre les facteurs qui touchent les différents profils de concentration des contaminants que nous observons dans le touladi et la lotte. En 2010, nous nous sommes efforcés d'obtenir plus d'information sur les concentrations de mercure et les tendances temporelles dans les espèces et les lieux qui ne sont pas visés par notre étude de base sur le Grand lac des Esclaves. Cette accentuation était fondée sur le fait qu'une série de recommandations ont été formulées en juin 2010 au sujet de la consommation de poisson provenant de certains des lacs faisant l'objet de notre étude. Comme prévu, nous avons évalué les concentrations de mercure dans la lotte de Lutsel K'e (East Arm) et le grand brochet, ou brochet du Nord, de Fort Resolution (West Basin) du Grand lac des Esclaves. La lotte de Lutsel K'e montre une tendance considérable à l'augmentation du mercure, comme la lotte prise à Resolution Bay. Aucune tendance temporelle n'est apparente pour le grand brochet pour la période de 1998 à 2010, et ce, peut-être parce que d'autres

River. HCH and DDT concentrations are declining in lake trout and burbot as global usage of these compounds is reduced. PCBs are declining in West Basin burbot, but not in West Basin and East Arm lake trout.

facteurs comme la croissance accrue masquent l'augmentation de la charge corporelle de mercure. Nos enquêtes sur le touladi ont confirmé que les concentrations de mercure corrigées en fonction de la longueur ont tendance à être plus élevées chez les poissons qui vivent dans des petits ou moyens lacs que chez ceux des lacs de grandes dimensions. Dans l'ensemble, il y a une tendance constante à l'augmentation des concentrations de mercure au cours de périodes successives, cette augmentation étant plus prononcée pour les petits et les moyens lacs. Les concentrations de mercure ont augmenté également chez les brochets et les dorés jaunes du lac Deep, tandis que pour le lac McGill, les concentrations de mercure étaient moins élevées dans le brochet du Nord et il y avait peu de changement pour le doré jaune; quoi qu'il en soit, les concentrations moyennes continuent de dépasser 0,5 μg/g. Nous avons obtenu de nouveaux renseignements sur les concentrations de mercure dans le brochet, le doré jaune et le touladi dans le lac Fish; les concentrations moyennes de mercure étaient de $<$0,5 μg/g seulement pour le touladi. Les concentrations de mercure ont été évaluées chez le touladi dans le lac Nonacho, où il n'y avait qu'une faible augmentation de la concentration observée au cours de la période de 2003 à 2011; les concentrations de mercure étaient plus élevées au milieu des années 1970, quelques années après la construction d'un barrage sur le lac et la montée du niveau de l'eau. Nous avons soumis pour évaluation l'information découlant des études sur les concentrations de mercure dans le poisson des petits et moyens lacs avec des recommandations pour les lacs Stark et Nonacho.

Key Messages

- There a trend for mercury concentrations to be increasing in lake trout harvested from the East Arm and West Basin and burbot from the West Basin. Trends may be driven by global warming and/or an increase in mercury emissions.
- Average mercury levels are below 0.5 μg/g for both species harvested from both locations in contrast to higher mercury concentrations observed in lake trout, pike, and walleye in the smaller lakes along the Mackenzie River where advisories were issued in June 2010.

Messages clés

1. Les niveaux de mercure augmentent dans la lotte de la région Lutsel K'e, comme on l'observe pour la lotte de la région de Resolution Bay du lac Great Slave; par conséquent, l'augmentation à Resolution Bay ne peut pas être attribuée à des influences directes de la rivière des Esclaves.
2. Il n'y a pas de tendance à l'augmentation du mercure chez le brochet du Nord de Resolution Bay pour la période allant de 1998 à 2010; il est possible que la croissance accrue influe sur les tendances en ce qui concerne la charge corporelle de mercure.

- Among the legacy persistent organic contaminants, HCH is showing a strong trend of decline as is DDT in lake trout from both basins and burbot from the West Basin. In contrast PCBs are declining in West Basin burbot but not lake trout.
- Mercury concentrations tend to be higher in West Basin lake trout and burbot while the converse is observed for persistent organochlorine contaminants although differences are not large.
- Lake trout harvested from the West Basin are faster growing, more lipid rich and more predaceous that lake trout harvested from the East Arm.
- Burbot harvested from the East Arm are smaller, younger and more littoral in their feeding than burbot harvested from the West Basin.

3. Les concentrations de mercure corrigées en fonction de la longueur chez le touladi sont le plus élevées dans les petits et moyens lacs et le moins élevées dans les lacs de grandes dimensions. Les concentrations de mercure ont augmenté à des intervalles consécutifs, les augmentations les plus importantes étant généralement observées dans les petits et moyens lacs.
4. Les concentrations de mercure demeurent élevées dans le brochet et le doré jaune du lac Deep et le grand brochet, ou brochet du Nord, ainsi que le doré jaune du lac McGill. À l'exception du grand brochet du lac McGill, les concentrations de mercure étaient plus élevées en 2011 qu'en 2000.
5. Nous avons obtenu de nouvelles données sur les concentrations de mercure dans le brochet, le doré jaune et le touladi du lac Fish; les concentrations moyennes de mercure dépassaient 0,5 μg/g pour le doré jaune et le grand brochet seulement.
6. Des concentrations de mercure ont été déterminées dans le touladi du lac Nonacho et comparées aux données antérieures. Les concentrations ont augmenté de 2003 à 2010, mais l'augmentation était moindre après correction en fonction de la longueur des poissons. Les concentrations de mercure étaient plus élevées au milieu des années 1970, après la construction d'un barrage qui a fait monter le niveau de l'eau; elles ont diminué en 1985 et elles étaient à leur plus bas en 2003.
7. Des recommandations fondées sur nos constatations ont été formulées au sujet de la consommation de touladi pour les lacs Nonacho et Stark.

Objectives

1. Determine temporal trends in persistent organic contaminants, mercury, and other metals in lake trout at two locations (West Basin near Hay River, East Arm at Lutsel K'e) and burbot in the West Basin (offshore of Fort Resolution) through annual sampling, extending the 1993–2008 data sets to 2010 and beyond.
2. Investigate factors affecting temporal variability in contaminants in lake trout and burbot including length, age, trophic feeding, and lipid levels.

3. Participate in and contribute information to AMAP and CACAR expert work groups for trend monitoring for POPs and mercury.
4. Communicate results to the communities and the commercial fisheries in a timely manner, including through the Northwest Territories Regional Contaminants Committee.

Introduction

Great Slave Lake, located in the Northwest Territories, is part of the Northern Contaminant Program's (NCP) long-term biomonitoring program which includes lake trout and burbot. The first measurements of contaminants (persistent organic pollutants) in these 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). Since 1999, lake trout and burbot have been monitored for contaminant trends annually with two exceptions: monitoring was not conducted in 2003 and burbot sampling at Lutsel K'e was discontinued in 2004 as part of the core biomonitoring program. With eleven years of high quality biomonitoring data (1999–2010) and less rigorous NCP data going back to 1993, temporal trends are now beginning to be detected.

Great Slave Lake 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). The West Basin is profoundly affected by the Slave River inflow. Early monitoring considered lake trout and burbot both in the West Basin and East Arm. While the original rationale for studying two locations was to consider the influence of the Slave River on contaminant loading and biomagnification in Great Slave Lake, the rationale has taken on new dimensions in recent years. This is because the basic features of the two regions of the lake will affect contaminant pathways in a number of ways regardless of Slave River contaminant inputs from the south. For example, persistent organic contaminant concentrations are likely to be higher in biota in the low productivity waters of the East Arm than the higher productivity waters of the West Basin (Larsson et al. 1998; Berglund et al. 2001; Houde et al. 2008). In contrast mercury levels are likely to be higher in the West Basin than the East Arm because of temperature, watershed, and productivity effects (Bodaly et al. 1993; Evans et al 2005b). Differences in fish growth and feeding characteristics between the two basins will also be influential in affecting contaminant levels in fish.

Lake trout (*Salvelinus namaycush*) and burbot (*Lota lota*) were selected for study because the former is important in the domestic, sport and commercial fisheries (West Basin) while burbot is more important in the domestic fishery. Lake trout is an omnivorous, cold-water stenotherm with a thermal optimum of ca. 10°C; as such it is confined to cold, deep and well-oxygenated waters during summer although it does venture into the littoral zone where the lake edge is steep-sided and deep (Rawson 1951; Scott and Crossman 1998). Burbot also is a predatory fish and while it resides in the hypolimnion, in addition to large northern rivers, its thermal optimum is 15.6°–18.3°C (Scott and Crossman 1998). In Great Slave Lake, burbot is found both in shallow waters and deep waters down to depths of 100 m (Rawson 1951). Burbot are more commonly captured by hook and line suggesting that they are an "ambush" predator whereas lake trout are more traditional "search" predators. Burbot liver, which is prized, is lipid-rich and hence high in persistent organic contaminants (Kidd et al. 1995; Evans et al. 2005a; Ryan et al. 2005). Studies of the two species and in the two ecological regions of Great Slave Lake provide for an improved scientific understanding of the factors affecting contaminant levels which can then be generalized to the other broader regions of the Arctic.

This Great Slave Lake burbot and lake trout monitoring study is tracking trends in persistent organic contaminants such as HCH, DDT, and PCB which are expected to decline in concentration as usage diminishes and as these compounds degrade and are buried in lake sediments. However, it has been hypothesized that global 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 and increased productivity result in atmospherically-transported contaminants being captured in organic matter within the lake and more effectively retained, including in the sediments (Outridge et al.

2007). Global warming also has been attributed to enhanced mercury fluxes to lake sediments and increased levels in burbot (Outridge et al. 2007; Carrie et al. 2010). However, for mercury, it is also possible that increased Asian emissions are driving mercury time trends including Great Slave Lake. Certainly, the issue of time trends in mercury fluxes to lakes is complex, varying with the lake and location within the lake (Muir et al. 2008; Evans and Muir 2010a, b; Kirk et al. 2011).

Activities in 2010–2011

Great Slave Lake—collections and biological measurements

In 2010–2011, 20 lake trout were collected from the Lutsel K'e area (East Basin) and northwest of Hay River (West Basin). In addition, 20 burbot were collected in the Fort Resolution area (near the Slave River inflow, West Basin). Collections were done by community members or by a commercial fisherman (Hay River). Fish were frozen and shipped whole to Environment Canada (Saskatoon) for processing. Total length, fork length (lake trout only), round weight, liver weight, gonad weight, and gender were determined for all fish; features such as the presence of parasites, discolored liver, skinniness, and crude measures of stomach contents were noted. Aging structures (otoliths) were removed from all fish and age later determined for all fish. Approximately 100 gm of dorsal fillet, the liver and stomach were removed from all fish for analyses and/or archiving. A subsample of fillet was freeze-dried, percent moisture determined, and analyzed for carbon and nitrogen stable isotopes for all 20 fish from each location. Ten fish from each location were selected for persistent organic contaminant and metal analyses. With the exception of persistent organic contaminants, all analyses have been completed.

Communications

Various communications and reporting were given on this study in 2010–2011. A scientific paper reporting mercury trends in lake trout and burbot and our sediment core studies (Evans and Muir 2010 a, b) was submitted to a scientific journal and is now in revision. Contributions were made to the mercury and persistent organic contaminant chapters of the CACAR report on spatial and temporal trends in contaminants in lake trout and burbot in Great Slave Lake. In addition the NCP workshop, an invited presentation on contaminants trends was given at the IPY 2010 Conference in Oslo and a Managing Risks in Aquatic Systems: Effects of Climate Change and Anthropogenic Activity in Niagara Falls. An invited abstract was submitted to the Mercury 2011 Conference.

The most important communications in 2010–2011 centered on the mercury Public Health advisory issued in June by the Chief Public Health Officer, the Government of the Northwest Territories recommending that people limit their consumption of lake trout from Cli, Kelly and Trout Lakes and lake trout, walleye and northern pike from Lac Ste. Therese. These recommendations were issued based on the findings of our periodic assessments of mercury levels in fish in smaller lakes along the Mackenzie River (Evans and Muir 2010a). However, people consuming fish from other lakes, including Great Slave Lake, were concerned with this issue. Thus, there were various radio and other interviews were held in the following weeks and, on July 19, a panel consisting of J. Stow (INAC), K. Kandola (Chief Public Health Officer), M. Evans (Environment Canada), and M. Feeley (Health Canada) met with Tulita to discuss the findings and recommendations. Other presentations were given by L. Skinner (INAC-Yellowknife) in Fort Simpson and Trout Lake. In late February and early March 2011, M. Evans gave a series of presentations on the findings of the mercury assessments to Lutsel K'e, Fort Resolution, Hay River and Yellowknife with L. Skinner and D. Leonard (Fisheries and Oceans Canada) also part of the panel and available to answer questions on the NCP program and fish ecology in general.

While not a formal part of the NCP program, funding was obtained under the Cumulative Impact Monitoring Program for the study "Community monitoring of the Great Slave Lake ecosystem: second steps". This study was based on the desire to develop a community based limnological monitoring program for the Fort Resolution and Lutsel K'e areas and to provide information of the seasonal and year to year variability in water quality features of the lake. Ideally this information would assist in interpreting the factors affecting changes in mercury levels in fish, e.g., changing lake productivity. There were various challenges to this study but a series of temperature and water clarity measurements were made at a number of sites in late July and August while, later in the year, weekly data were collected from the water intake at Fort Resolution and a several week survey conducted of the domestic fisheries. A traditional knowledge survey also was conducted asking what was known about changes in the water quality, climate and fish populations of Great Slave Lake. This CIMP project was renewed in 2011.

Results and Discussion

Biological features of fish populations

As part of our investigation of temporal trends in mercury and persistent organochlorine contaminant concentrations in lake trout and burbot, we have been focussing on differences and similarities in their biological features at their West Basin and East Arm collection sites. Earlier in our study (Evans 1994, 1995), we reported that persistent organochlorine concentrations tended to be higher in the East Arm which we related to the lower productivity of these waters which provided for less biodilution of organic contaminants. Later studies have shown that organic contaminants tend to be higher in oligotrophic than less productive water (Berglund et al. 2000; Houde et al. 2010). As mercury determinations were incorporated into the biomonitoring in 1999, it was thought that higher mercury levels would be observed in fish caught near the Slave River, where watershed influences are substantial and the waters themselves warmer than in the East Arm where waters are colder and watershed influences weaker. However, before locations can be compared, one first must understand differences in the biological feature of fish by location and species.

Biological data collected for burbot and lake trout from the Hay River area, Fort Resolution, and Lutsel K'e have been combined and examined for regional and species differences (Table 1). Burbot from the West Basin tended to be larger, older, and with more lipid-rich liver than burbot from the East Arm; furthermore, they were more pelagic in their feeding (more negative carbon isotope) and more predaceous. It is not known why smaller burbot were collected from Lutsel K'e than Fort Resolution; possibly larger fish were in deeper waters where they were less readily caught. Mercury levels were higher in West Basin than East Arm burbot due either to their greater age and/or limnological influences of the basin (warm waters, strong watershed inputs).

Lake trout were similar in size in the West Basin and East Arm but West Basin trout were younger and with more lipid in their fillet; such differences indicate a faster growth rate and suggest a more

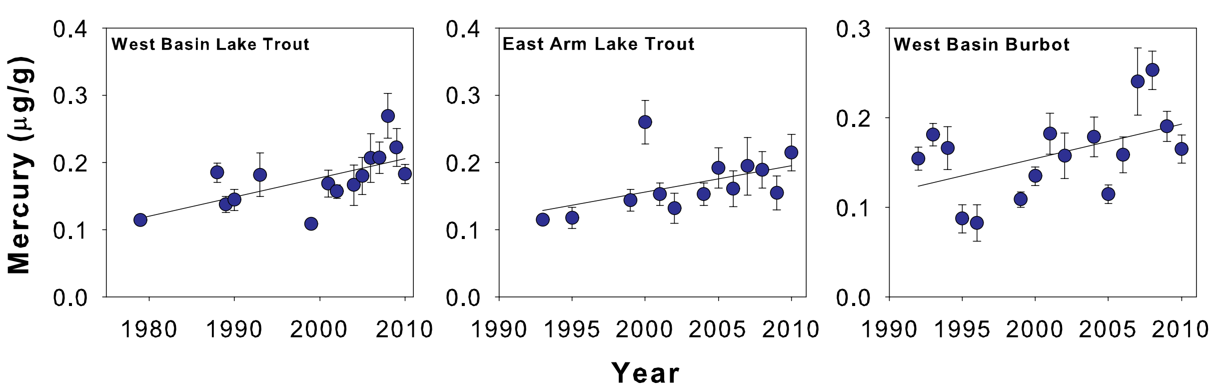

Figure 1. Time trends in mercury concentrations and length for burbot collected near Lutsel K'e. The blue line is the linear regression and the red line the Lowess smoother.

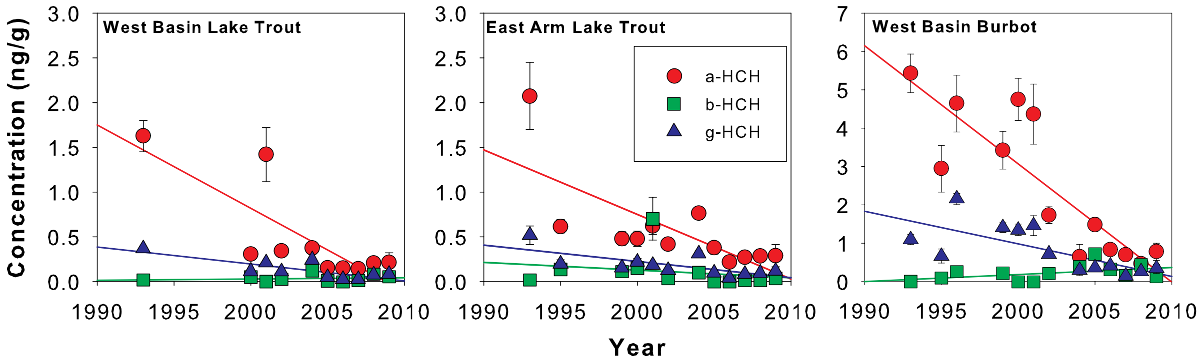

Figure 2. Time trends in mercury concentrations and fish length in northern pike caught near Fort Resolution over 1996–2009. Also shown is the linear regression (blue line) and a Lowess smoother (red line; *f*=0.5).

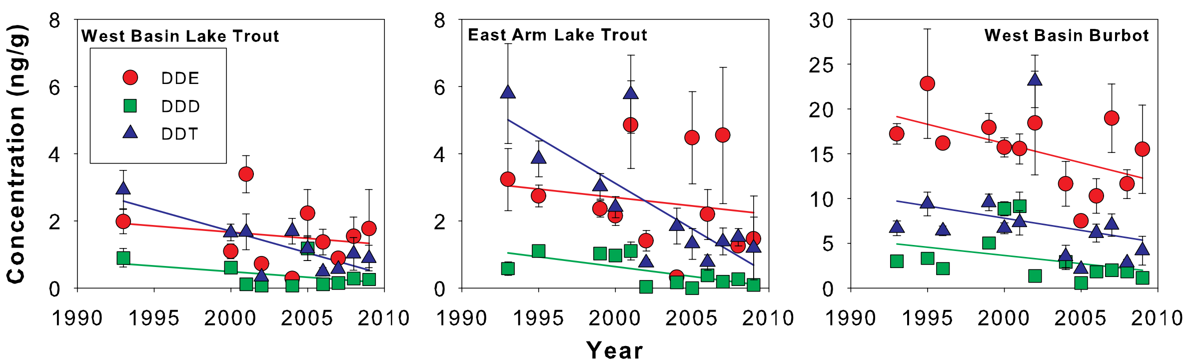

Figure 3. Temporal changes in length-adjusted mercury concentrations in lake trout collected from lakes along the Mackenzie River; lakes are arranged in order of increasing surface area. The sampling years for each lake are identified in the text. Total length adjustments are based on 555 mm (Trout Lake), 600 mm (Kelly, Ste. Therese) or 650 mm (Colville, Great Bear, Cli, Stark) fish depending on the size range of fish caught in each lake.

rich food supply for West Basin than East Arm trout. Lake trout were somewhat more predaceous and pelagic in their feeding in the West Basin than East Arm an observation also made decades earlier by Rawson (1951). Despite their younger age, mercury levels are higher in West Basin than East Arm lake trout. Again, such differences may be related to the warmer and more productive waters of the West Basin which allow for more mercury to be methylated than in the colder, less productive East Arm: Slave River inputs and transformations with the Slave River delta may also be important.

Mercury trend monitoring

Mercury time trends in lake trout and burbot have been examined in various ways including using the full NCP data sets (1993–2009) and the more limited data from the commercial fishery from the West Basin where only length and weight are available as additional explanatory variables, i.e., in addition to time (Evans et al. in revision). In the West Basin, where the lake trout record can be extended back to the lake 1970s with the inclusion of commercial fish record, there is a statistically significant trend of increase in mercury concentrations. This trend also is significant when data are limited to the more recent NCP record (Fig. 1). The record of mercury levels in lake trout in the East Arm is more limited but here also mercury levels are showing a significant trend of increase over the NCP record. Burbot collected from the West Basin have had lower mercury concentrations in 2009 and 2010 than 2007 and 2008; nevertheless, the trend of increase remains. Similarly, Carrie et al. (2010) have observed a significant trend of increase in mercury concentrations in burbot collected from the Mackenzie River at Fort Good Hope. Mercury levels are lower in burbot from Great Slave Lake than the Mackenzie River. Mean concentrations of lake trout and burbot remain well below the 0.5 μg/g commercial sale guideline. The factors affecting these trends is under investigation is hypothesized to be due to a combination of a warming trend, decreasing winds, and increased Asia emissions with the relative role of these three factors unknown (Carrie et al. 2010; Evans and Muir 2010 a, b).

Persistent organic contaminants trend monitoring

In contrast to mercury, HCH is showing a significant trend of decline in lake trout (West Basin and East Arm) and burbot (West Basin); the steepest time trend is being observed for burbot. The greatest rate of decline is being observed in α-HCH which is the predominant isomer followed by δ-HCH. Similarly, declining HCH concentrations are being observed in burbot at Fort Good Hope (Stern 2010) and lake trout from Lake Laberge and Kusawa Lake in the Yukon (Stern et al. 2010). Such declines are anticipated given the reduced usage of HCH globally. HCH concentrations average 0.86 ±1.18 ng/g West Basin lake trout and 0.81 ± 0.76 ng/g in East Arm lake trout fillet versus 3.29 ± 2.62 ng/g in West Basin burbot liver and 5.37 ±3.82 ng/g in East Arm burbot liver.

Total DDT also is showing a significant trend of decrease in lake trout and burbot although the trends differ with the species and location (Fig. 3). Lake trout in the West Basin are showing a steep decline in DDT and a somewhat less steep decline in DDE as DDE becomes the predominant isomer in more recent years. The decline in total DDT is steeper for East Arm lake trout. Similar declines in total DDT are being observed in lake trout from Lake Laberge and Kusawa Lake in the Yukon (Stern et al. 2010). DDT concentrations average 3.34 ±3.07 ng/g in West Basin lake trout and 5.42 ±5.06 ng/g in East Arm lake trout fillet. West Basin burbot also are showing a decline in total DDT concentrations although DDT rates are not declining as fast as in lake trout; DDE has and continues to predominate over DDT possibly because analyses are conducted on the liver and parent DDT may be rapidly more rapidly metabolized to DDE than in the muscle. In contrast total DDTs are showing no evidence of a decline in burbot at Fort Good Hope with concentrations in more recent years higher than in the 1990s (Stern 2010). DDT

Table 1. Mean biological attributes of burbot collected from the West Basin (Fort Resolution) and East Arm (Lutsel K'e) and lake trout collected from the West Basin (Hay River) and East Arm (Lutsel K'e) over 1993–2008. Data are shown as mean ± one standard deviation. Lipid (fat content) is based on the liver for burbot and fillet for lake trout; mercury measurements are on fillet.

Location	Total length (mm)	Weight (g)	Age (yr)	% Lipid	δ^{13}C (‰)	δ^{15}N (‰)	Hg (µg/g)
Burbot							
West Basin	654 ± 73	2096 ± 704	13.2 ± 3.4	36 ± 12	-28.6 ± 0.7	12.1 ± 0.6	0.17 ± 0.08
East Arm	523 ± 75	1095 ± 501	10.2 ± 2.6	30 ± 12	-23.6 ± 2.0	11.3 ± 0.8	0.13 ± 0.06
Lake trout							
West Basin	668 ± 101	3278 ± 1647	9.3 ± 4.8	9 ± 4	-29.6 ± 1.0	12.6 ± 0.6	0.19 ± 0.10
East Arm	655 ± 72	2659 ± 1000	15.9 ± 4.9	5 ± 4	-28.2 ± 2.0	11.8 ± 0.6	0.17 ± 0.09

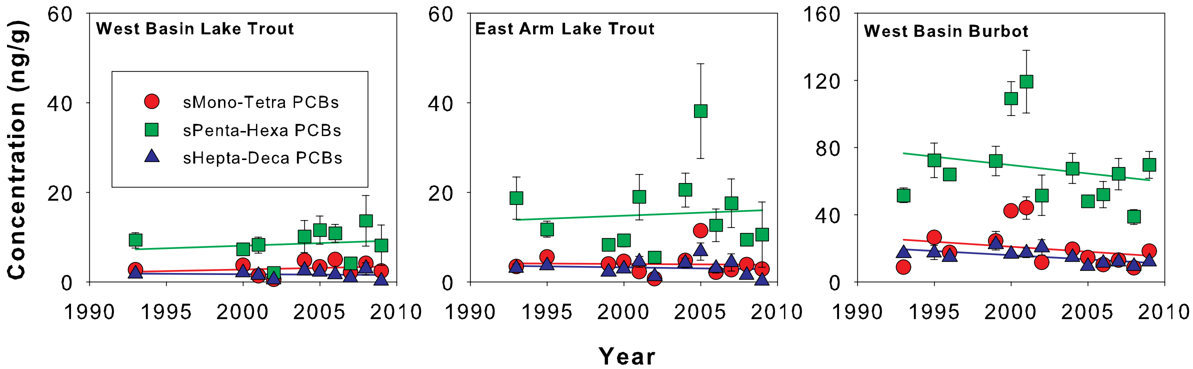

Figure 4. Time trends in mercury concentrations in lake trout from Nonacho Lake; length adjustments are based on 600 mm total length. Water level data are from the Water Survey of Canada.

concentrations average 25.7 ± 15.5 ng/g in West Basin burbot liver and 29.5 ±19.4 ng/g in East Arm burbot liver.

In contrast to HCH, PCBs in lake trout are showing no trend or at either locations kin Great Slave Lake; there is a weak positive slope (although not significant) for penta and hexa PCBs which also are the predominant congeners (Fig. 4). In contrast PCBs are showing a pronounced decline in lake trout at Lake Laberge and Kusawa Lake, where levels were very high in the early 1990s with higher levels associated with local contamination (Jensen et al. 1997; Rawn et al. 2001). Such a situation does not apply to Great Slave Lake where PCB concentrations in sediments are low with only limited evidence of a time trend which appears reflective of long-range atmospheric transport (Evans et al. 1996). In contrast to lake trout, PCB concentrations show a more pronounced trend of decline in West Basin burbot. The reasons for these differing responses for the two species are under consideration. Burbot trends differ from that observed at Fort Good Hope where higher PCB concentrations have been observed over the late 2000s than the early 2000s (Stern 2010). PCB concentrations average 14.6 ± 13.3 ng/g in West Basin lake trout and 21.5 ± 19.4 ng/g in East Arm lake trout fillet versus 104.6 ± 55.3 ng/g in West Basin burbot liver and 115.0 ± 62.8 ng/g in East Arm burbot liver.

Conclusions

There is a distinct trend for mercury concentrations to be increasing in lake trout harvested from the West Basin and East Arm of Great Slave Lake although average concentrations remain below 0.5 μg/g and substantially lower than in the smaller lakes along the Mackenzie River where advisories were issued in June 2010. Mercury concentrations also are increasing in burbot from the West Basin but again remain relatively low. Trends may be driven by global warming and/or an increase in mercury emissions. Among the legacy persistent organic contaminants, HCH is showing a strong trend of decline as is DDT for lake trout from both basins and burbot. In contrast PCBs are declining in West Basin burbot but not lake trout. Overall, mercury concentrations are slightly higher in West basin burbot and lake trout that East Arm fish while the converse is observed for persistent organochlorine contaminants.

NCP Performance Indicators

Number of northerners engaged in your project: We work with Fort Resolution and Lutsel K'e with two-three people in each community involved in this study. At Hay River, we work directly with Shawn Buckley with the commercial fisheries. Minimally, there were 5–7 northerners involved in this study.

Number of meetings/workshops held in the north: NCP Annual meeting at Whitehorse. Tulita Workshop and presentations in Trout Lake and Fort Simpson regarding the mercury advisories issued in June 2010. Workshops in late February and early March 2011 at Yellowknife, Hay River, Fort Resolution and Lutsel K'e regarding this and the core mercury trend monitoring.

Number of students involved in the project: 0

Number of citable publications: 1 (Riget et al. in press), CACAR and AMAP reports; submitted scientific paper in revision.

Expected Project Completion Date

This project is a core NCP biomonitoring study with an indeterminate date.

Acknowledgements

Special appreciation is extended to Gab Lafferty at Fort Resolution and Ernest Boucher at Lutsel K'e for collecting the pike and burbot respectively and Shawn Buckley for collecting lake trout at Hay River.

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Bay 1993–2010 with commercial fish data from 1992 and 1994. Data are presented as the means (± 1 standard error) and as a linear regression.

Figure 2. HCH isomer time trends in lake trout (fillet) collected from the West Basin (Hay River) and East Arm (Lutsel K'e) of Great Slave Lake. Also shown are burbot (liver) from Fort Resolution. Data are presented as the means (± 1 standard error) and as a linear regression.

Figure 3. DDT isomer time trends in lake trout (fillet) collected from the West Basin (Hay River) and East Arm (Lutsel K'e) of Great Slave Lake. Also shown are burbot (liver) from Fort Resolution. Data are presented as the means (± 1 standard error) and as a linear regression.

Figure 4. PCB congener time trends in lake trout (fillet) collected from the West Basin (Hay River) and East Arm (Lutsel K'e) of Great Slave Lake. Also shown are burbot (liver) from Fort Resolution. Data are presented as the individual data points with a linear regression.

Temporal Trends and Spatial Variations in Persistent Organic Pollutants and Metals in Sea-Run Char from the Canadian Arctic

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Abstract

Our study is investigating metal and organic contaminant levels in sea-run char as they return from feeding in the ocean. In 2010, sea-run char were collected from Cambridge Bay and Pond Inlet for the full suite of chemical analyses and from Nain for mercury analyses only. Pond Inlet was visited as part of a study investigating factors affecting differences in mercury concentrations between resident and sea-run char; sea-run char were collected at this time. Mercury analyses have been completed for 2010 caught sea-run char while persistent organochlorine analyses are ongoing. Mercury concentrations in char are showing a significant trend of increase at Cambridge Bay and a weaker trend of increase at Pond Inlet although mercury levels remain very low (<0.2 $\mu g/g$). This increase in mercury concentrations potentially is related to a warming trend being observed in this region of the Arctic. Mercury concentrations are exhibiting a decline at Nain which is not experiencing a warming trend. Persistent organochlorine concentrations remain

Résumé

Notre étude porte sur les degrés de contaminants métalliques et organiques qui se trouvent dans l'omble anadrome qui revient de son séjour dans l'océan, où il s'est nourri. En 2010, on a prélevé des ombles anadromes à Cambridge Bay et à Pond Inlet pour procéder à une gamme approfondie d'analyses chimiques. D'autres ont été prélevés à Nain, lesquels ont seulement fait l'objet d'une analyse des concentrations de mercure. On a prélevé les ombles anadromes lors d'une visite à Pond Inlet dans le cadre d'une étude au sujet des facteurs qui entraînent des différences dans les concentrations de mercure entre les ombles résidents et les ombles anadromes. Les analyses des concentrations de mercure présentes dans les ombles anadromes prélevés en 2010 sont terminées, tandis que les analyses des contaminants organochlorés persistants sont en cours. On a observé une importante tendance à la hausse dans les concentrations de mercure des ombles prélevés à Cambridge Bay et une tendance à la hausse plus faible dans les ombles de Pond Inlet, bien que ces niveaux de mercure demeurent très

low in char with concentrations over 2004–2009 at Cambridge substantially lower than in 1987; a trend of increase in recent years may be related to higher lipid content of the fish in successive years. PBDEs occurred in low concentrations with no trends evident.

Key Messages

- Mercury concentrations were very low in sea-run char caught in 2010, i.e., well below the 0.5 µg/g guideline for the commercial sale of fish.
- There was a trend of increase in mercury at Cambridge Bay (1977–2010) and a weaker trend of increase at Pond Inlet (2004–2010), while mercury concentrations declined at Nain (1997–2010) when fish length and weight also were considered.
- Concentrations of legacy contaminants (PCBs, DDT, CBz, HCH, and chlordane) were low with trends of decline most evident at Cambridge Bay from historic highs in 1987. Toxaphene and PBDE concentrations also were low.
- Fish appear healthy.

bas (<0,2 µg/g). Cette hausse est possiblement liée aux tendances de réchauffement observées dans cette région de l'Arctique. Les concentrations de mercure sont en baisse à Nain, où l'on ne constate pas de tendance de réchauffement. Les concentrations de contaminants d'organochloré persistants demeurent basses chez l'omble. Les concentrations de 2004 à 2009 présentes dans les échantillons prélevés à Cambridge Bay sont nettement inférieures à celles de 1987; on pourrait expliquer la tendance à la hausse des dernières années du fait que le contenu lipidique des poissons est plus élevé depuis plusieurs années. On ne décèle aucune tendance évidente concernant les faibles concentrations de PBDE.à Cambridge Bay et une tendance à la hausse plus faible dans les ombles de Pond Inlet, bien que ces niveaux de mercure demeurent très bas (<0,2 µg/g). Cette hausse est possiblement liée aux tendances de réchauffement observées dans cette région de l'Arctique. Les concentrations de mercure sont en baisse à Nain, où l'on ne constate pas de tendance de réchauffement. Les concentrations de contaminants d'organochloré persistants demeurent basses chez l'omble. Les concentrations de 2004 à 2009 présentes dans les échantillons prélevés à Cambridge Bay sont nettement inférieures à celles de 1987; on pourrait expliquer la tendance à la hausse des dernières années du fait que le contenu lipidique des poissons est plus élevé depuis plusieurs années. On ne décèle aucune tendance évidente concernant les faibles concentrations de PBDE.

Messages clés

- Les concentrations de mercure présentes dans l'omble anadrome prélevé en 2010 sont très faibles, soit bien inférieures à la ligne directrice de 0,5 µg/g pour les poissons destinés à la vente commerciale.
- On a remarqué une tendance à la hausse des concentrations de mercure à Cambridge Bay (de 1977 à 2010) et une tendance à la hausse moins importante à Pond Inlet (de 2004 à 2010), tandis que les concentrations de mercure ont baissé à Nain (de 1997 à 2010), où la longueur et le poids des poissons ont aussi été pris en compte.
- Les concentrations de contaminants classiques (BPC, DDT, CBz, HCH et chlordane) étaient faibles, et les tendances à la baisse les plus remarquables ont été constatées à Cambridge

Bay, où des sommets inégalés ont été atteints en 1987. Les concentrations de toxaphène et de PBDE étaient également faibles.

- Les poissons semblent en santé.

Objectives

1. Determine levels of persistent organic pollutants (POPs) and metals (including mercury) as well as "new" POPs from sea-run char which are harvested by Arctic communities.
2. Investigate the role of factors such as fish age, trophic feeding, climate, and location in affecting contaminant body burdens and trends.
3. Contribute to AMAP's and CACAR's assessment of long-term trends in metals and POPs in the Arctic and subarctic and the factors affecting such trends.
4. Provide and explain data to Arctic environmental contaminant committees, health committees, and local communities in a timely manner so that appropriate advice can be given on consuming sea-run char, a country food which is particularly low in contaminant concentration.

Introduction

Sea-run Arctic char (Salvelinus alpinus) are a member of the Salmonidae family (which includes lake trout (S. namaycush)). They inhabit Arctic and subarctic waters and spend the majority of their lives in freshwater lakes and rivers (Scott and Crossman 1998). Char have a wide variety of life history forms which only recently has been appreciated (Gantner et al. 2010 a, b; Swanson and Kidd 2010; Swanson et al. 2010). Some live in fresh waters all their lives while others migrate to the sea in late spring, spending a few weeks feeding on benthos and forage fish before returning inland in the fall. This migratory pattern is believed to confer a growth benefit to these fish by providing them access to abundant and large marine prey in contrast to smaller and less abundant prey that are characteristic of many but not all of inland waters. Higher growth rates provide for contaminant biodilution (assuming that contaminant concentrations are the same in marine and freshwater prey). Thus, mercury and persistent organochlorine contaminant concentrations in sea-run char tend to be substantially lower than in landlocked and resident char (Fisk et al. 2003; Lockhart et al. 2005); concentrations are even lower than in marine mammals which tend to consume larger prey (i.e., higher up on the food chain) and, as warm blooded mammals, have higher consumption rates.

Sea-run char are important in the diets of many coastal communities with fish harvested from migratory rivers in late spring and early fall and the ocean itself during summer. Prior to 2004, contaminant levels were measured on only a few occasions in sea-run char including mercury in fish from the domestic and commercial fisheries (summarized in Lockhart et al. (2005)), a toxaphene study conducted by Muir et al. (1990), and an unpublished study conducted by Muir in 1987 (including Cambridge Bay) and later work under NCP in the eastern Arctic (Muir et al. 1999, 2000). However, measurements were infrequent with other metrics such as fish age and carbon and nitrogen isotopes not always run. Thus, while it was known that contaminant concentrations were low in sea-run char, NCP was concerned that the data base was insufficient in terms of spatial coverage. Thus, over 2004–2009, mercury and persistent organic contaminant levels were investigated in sea-run char at 17 communities across the subarctic and Arctic from as far east as the Rat River (west of Inuvik) and as far west as east as Labrador, as far north as Resolute and as far south as Sanikiluaq. While spatial variations in contaminant concentrations in sea-run char were observed (appearing to be due mainly to differences in fish size and age at the various communities), contaminant concentrations at all locations were all very low (Evans and Muir 2005; 2006; 2007; 2008; 2009; 2010) thus confirming the recommendation that char were a good food item for those seeking to enjoy a country food diet while reducing contaminant intake.

As part of this spatial trend monitoring study, some communities were visited more than once in order to begin to establish a long-term monitoring program for char in subarctic and Arctic waters. Four locations were targeted. Pond Inlet was selected as the northerly most location as char were readily caught in the community. Resolute Bay, located further north, was less suitable as an aircraft charter was required to reach the char harvest area. Cambridge Bay was selected in the central Arctic based on its location, the fact that a commercial fishery operates out of this community, and a relatively good historic record exists for mercury levels in these fish. Attempts were made to establish a monitoring program in the eastern Arctic at Paulatuk where warming trends are particularly intense (ACIA 2005) and where fish potentially could be exposed to a Mackenzie River influence. Char are uncommon in this area and communities were reluctant to part with the few fish that they collected. The fourth location was Nain off the Labrador coast, which also has a commercial fishery and some historic data. This region is not experiencing a strong warming trend as in the wetern and central Arctic.

In 2010, NCP scaled back the sea-run study to temporal trend monitoring only, and then at only two sites, Pond Inlet and Cambridge Bay. While Nain was not included, funds were provided to collect these fish for mercury trend monitoring. The rationale for this sampling is science based, mercury time trends could be driven by a combination of warming trends and/or increased Asian emissions (Pacyna et al. 2006; Weiss-Penzias et al. 2007). Nain, by virtue of its location, may show different trends than Cambridge Bay and Pond Inlet. This study contributes to the overall assessment of mercury trends in Arctic biota as recently synthesized by Riget et al. (2011).

Activities in 2010–2011

In late winter 2010, Cambridge Bay, Pond Inlet and Nain were contacted about the proposed collections; the study was discussed with them and they were sent a copy of the plain language summary and the consultation forms. They also asked to see a copy of the full proposal and the 2009–2010 report and these were sent. This was followed by telephone conversation and emails to arrange for the 2010 collections.

Twenty sea-run char were successfully collected at Cambridge Bay and Nain and shipped to Saskatoon; fish arrived in excellent condition. In the case of Pond Inlet, a scientific party (Power, Keating, Dorn) visited the community in Aug 2010 to process sea-run char collected by the HTO, and to collect landlocked char. The landlocked char were for an ArcticNet project with Michael Power and Shannon Dorn at the University of Waterloo; this study is investigating factors affecting difference in mercury concentrations in sea run and resident char along a latitudinal gradient (Dorn et al. 2010). Arrangements were made for a local boat to assist with food web sampling in the ocean. Unfortunately (for the scientific party), the bowhead whale hunt was ongoing at the time the scientific party visited Pond Inlet and the boat charter was cancelled. The landlocked lakes were accessed by helicopter.

Length, weight, age, and gender were determined on all fish from each location along with liver and gonad weight; notations were made of the presence of parasites and/or disease where appropriate. A fillet sample, the liver and stomach were retained from each fish. Carbon and nitrogen isotope (fillet) and percent moisture (fillet) analyses were performed on all fish. Ten of the 20 fish from each location were selected for metals, legacy organic contaminants and PDBE and PFA analyses, with our sample archive consisting of various tissue samples from all 20 fish per location. Archived samples are maintained at -40^{o}C in a walk-in freezer at the National Hydrology Research Centre which has a monitoring system overseen by commissionaires 24-hours a day, 365 days a year.

Fish age, stable isotope ratios, and mercury concentration data have been provided by the analytical laboratories. Metal scans and organochlorine contaminant analyses are ongoing. Highlights of our findings to date are presented under the results section.

Results of our research to date were reported at the September 2009 NCP workshop in Whitehorse. Bryan Simonee with the Mittimatalik HTO and Brenda Sitatak with the Ekaluktutiak HTO were able to attend the NCP workshop and meet with us, other researchers, agencies, and community members involved with NCP. We contributed to

CACAR reports including sections on spatial and temporal trends in persistent organic contaminants and metals in sea-run char.

Results and Discussion

The largest char were from Cambridge Bay followed by Pond Inlet and then Nain, a pattern observed in previous sampling years (Table 1).

Pond Inlet char, while slightly smaller on average than Cambridge Bay char were older, indicating a slower growth rate in this more northerly environment. Pond Inlet char also had more enriched carbon isotope ratios suggesting a greater reliance on benthic carbon sources.

Temporal variations in mercury levels

Cambridge Bay has the longest record for investigating mercury time trends in sea-run char with fish measured for mercury in 1977, 1978, 1992, and 1993 as part of fish inspection studies of the commercial fishery (Lockhart et al. 2005). Weight was measured in all years and length in all but 1978. Fish caught in 1978 were substantially smaller (455–660 g) than fish caught in earlier and later years and hence were not used in trend analyses. Fish length was not distinguished between fork and total length; therefore, fork and total length were plotted against fish weight using 2004–2010 NCP data and the two regression lines calculated. Then fish inspection length and weight data were plotted as a

Table 1. Mean (± standard deviation) fork length, age, weight, and carbon and nitrogen isotope ratios for sea-run char caught in 2010.

Location	Fork length (mm)	Weight (gm)	Age (yr)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Cambridge Bay	681 ± 106	4,216 ± 1,643	12.4 ± 2.0	-24.1 ± 1.3	14.6 ± 0.7
Pond Inlet	654 ± 40	3,050 ± 774	14.5 ± 2.0	-21.1± 0.7	14.3 ± 0.3
Nain	533 ± 47	2,199 ± 580	6.9 ±0.7	-25.3 ± 3.3	13.8 ± 1.3

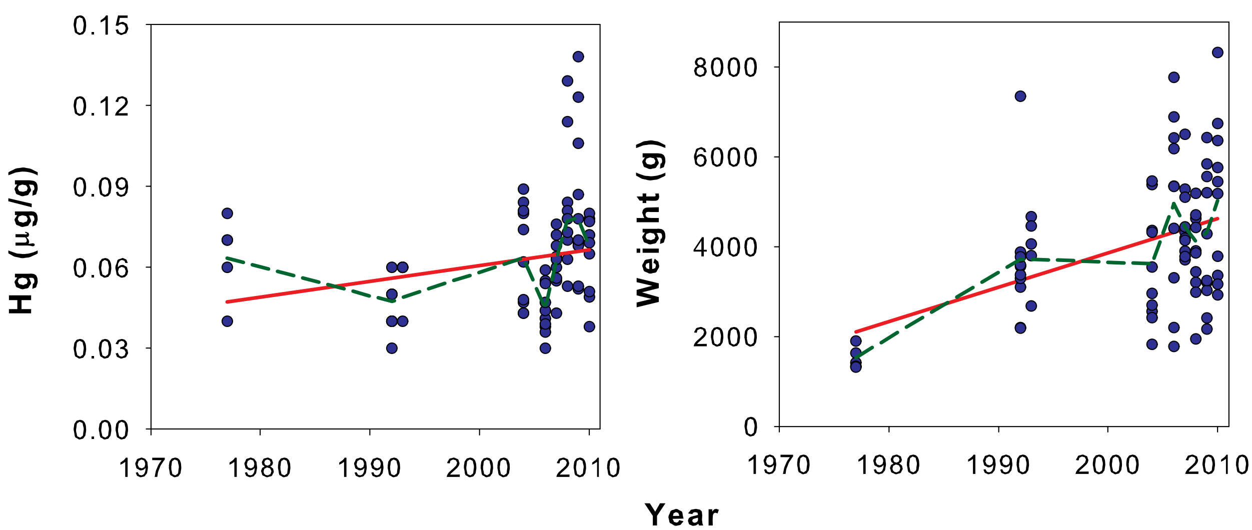

Figure 1. Time trends in mercury concentrations (µg/g) and round weight (g) in sea-run char collected at Cambridge Bay. A Lowess smoother (dashed line) has been run through the data.

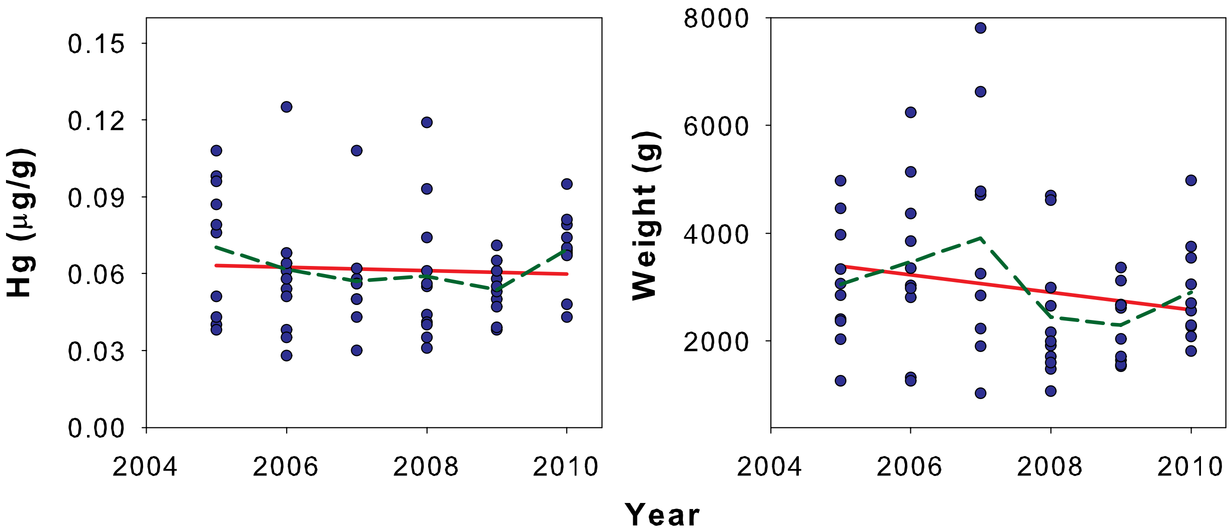

Figure 2. Time trends in mercury concentrations (µg/g) and round weight (g) in sea-run char collected at Pond Inlet. A Lowess smoother (dashed line) has been run through the data.

third regression and compared to the fork length and total length regression lines. Based on these regressions it appeared that fish inspection length was total length. We then conducted analyses of variance (General Linear Model (GLM)) using log mercury as the dependent variable and total length, weight and year as independent variables to assess the factors affecting variations in mercury concentrations. We also plotted mercury concentrations and fish weight against time and calculated the linear regression for these data; a Lowess smoother also a calculated to reveal general trends (Fig. 1).

Mercury concentrations in Cambridge Bay char exhibited a general trend of increase over 1977–2010 (Fig. 1). However, fish weight (and length) showed a similar trend of increase. Using year, length and weight as variables in the GLM analyses, variations in log mercury level were described by length and weight with year significant only at $p=0.07$. It is interesting to note that higher mercury levels were measured in char in 1977, when fish were small, than in 1992 and 1993 when they tended to be larger. If 1977 fish are excluded from the analyses, then year is a significant variable ($p<0.001$) explaining mercury concentrations over 1992–2010. Similarly, if analyses are limited to 2004–2010, year again emerges as a significant variable ($p=0.006$), along with fish length and weight in explaining variations in mercury concentration.

Mercury concentrations were not measured in Pond Inlet char until 2004. Mean mercury concentrations have varied little over the years of the study with no trend apparent while mean fish weight has varied more with a weak trend for smaller fish to have been analyzed in later than earlier years (Fig. 2). Since mercury concentrations tend to increase with fish size, lower mercury concentrations may have been expected in later years. Variations in mercury concentration were explained by fish length, weight, nitrogen isotope ratios with year, a positive coefficient, significant at $p=0.09$. Thus, there is the suggestion that mercury concentrations may be exhibiting a weak trend of increase at Pond Inlet although the trend is not as apparent as at Cambridge Bay.

Time trends in mercury in char at Nain are of interest because unlike Cambridge Bay and Pond Inlet which are in a region where a warming trend is being experienced, the northern Quebec and Labrador coast may be experiencing a cooling trend. Therefore, if climate warming is driving some of the trends observed in char at Cambridge Bay and Pond Inlet, a converse trend may be expected to be occurring at Nain. Mercury levels were measured in char at Nain in 1998 and 1999

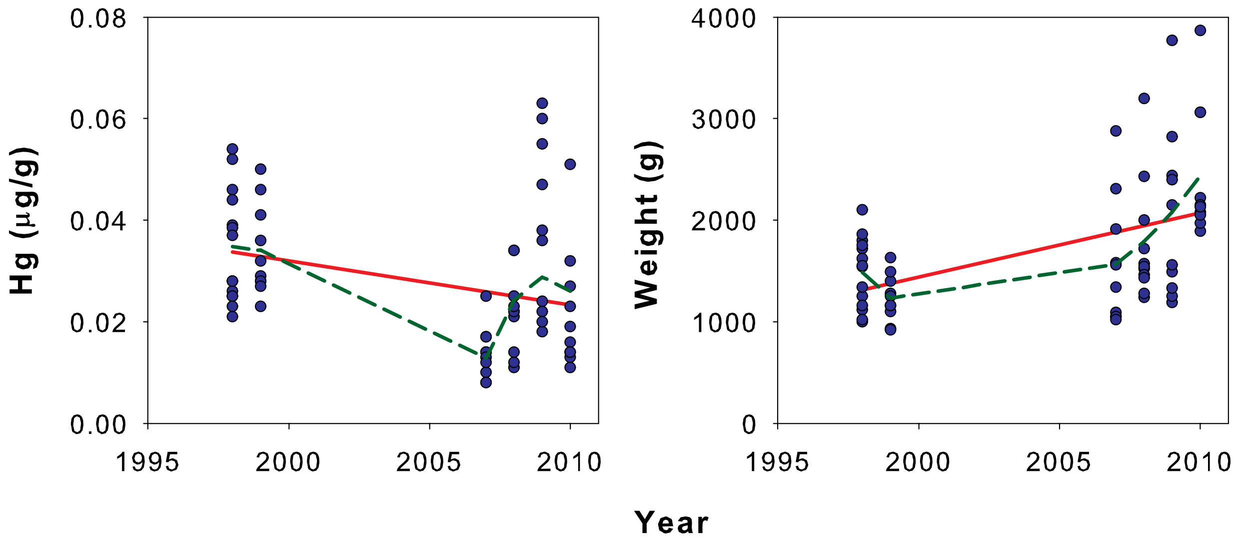

Figure 3. Time trends in mercury concentrations (µg/g) and round weight (g) in sea-run char collected at Nain. A Lowess smoother (dashed line) has been run through the data.

and over 2007–2010 (Fig. 3). Overall, there was a strong trend for mercury concentrations to decline over the study period while fish weight increased. Variations in mercury concentration were explained by fish length, weight and year with year significant at $p<0.001$. It is not evident why mercury concentrations are declining but changes in the operation of the coal-fired power plants in the northeastern United States may be an influencing factor.

Temporal variations in POPs

Persistent organic contaminant concentrations first were measured in char at Cambridge Bay and Pond Inlet in 1987 and Nain in 1998 with NCP sampling beginning in 2004 (Cambridge Bay), 2005 (Pond Inlet) and 2007 (Nain). Comparisons of 1987 data with more recent data are problematic because early measurements were made on whole body samples, whereas more recent measurements have been made on fillet; in addition, analytical methods have changed. Lipid concentration varied between locations and showed a recent trend of increase in Nain and Cambridge Bay char; this increase may have been associated with heavier fish being collected in later years (Fig. 4); lipid levels tended to be lower for Nain char possibly because fish were younger and putting more energy into growth.

Overall CBz concentrations were highest in Cambridge Bay char and lowest in Nain char; concentrations in 1987 were particularly high and greater than for Pond Inlet fish, also measured in 1987. CBz concentrations showed a trend of increase in recent years at Nain and Cambridge Bay, possibly associated with the larger and more lipid-rich fish collected over successive years. HCH concentrations were substantially higher in Cambridge Bay and Pond Inlet char in 1987 than later years and in Nain char in 1998 than later years. As with CBz and most other persistent organic contaminants, concentrations tended to be highest at Cambridge Bay.

Chlordane concentrations were higher at Cambridge Bay than in later years whereas there was little change in concentrations at Pond Inlet and Nain over the study periods. DDT concentrations were substantially higher at Cambridge Bay in 1987 than later years, although DDT concentrations in Pond Inlet char in 1987 were similar to those measured in later years. For Nain char, highest DDT concentrations were observed in 2009.

PCB concentrations in Cambridge Bay char were similar in 1987 as in 2004 and then showed a general trend of increase while a declining trend was observed at Pond Inlet. Nain char had their highest PCB concentrations in 1997 with substantially lower concentrations in 2007 and 2008 with high concentrations observed again in 2009.

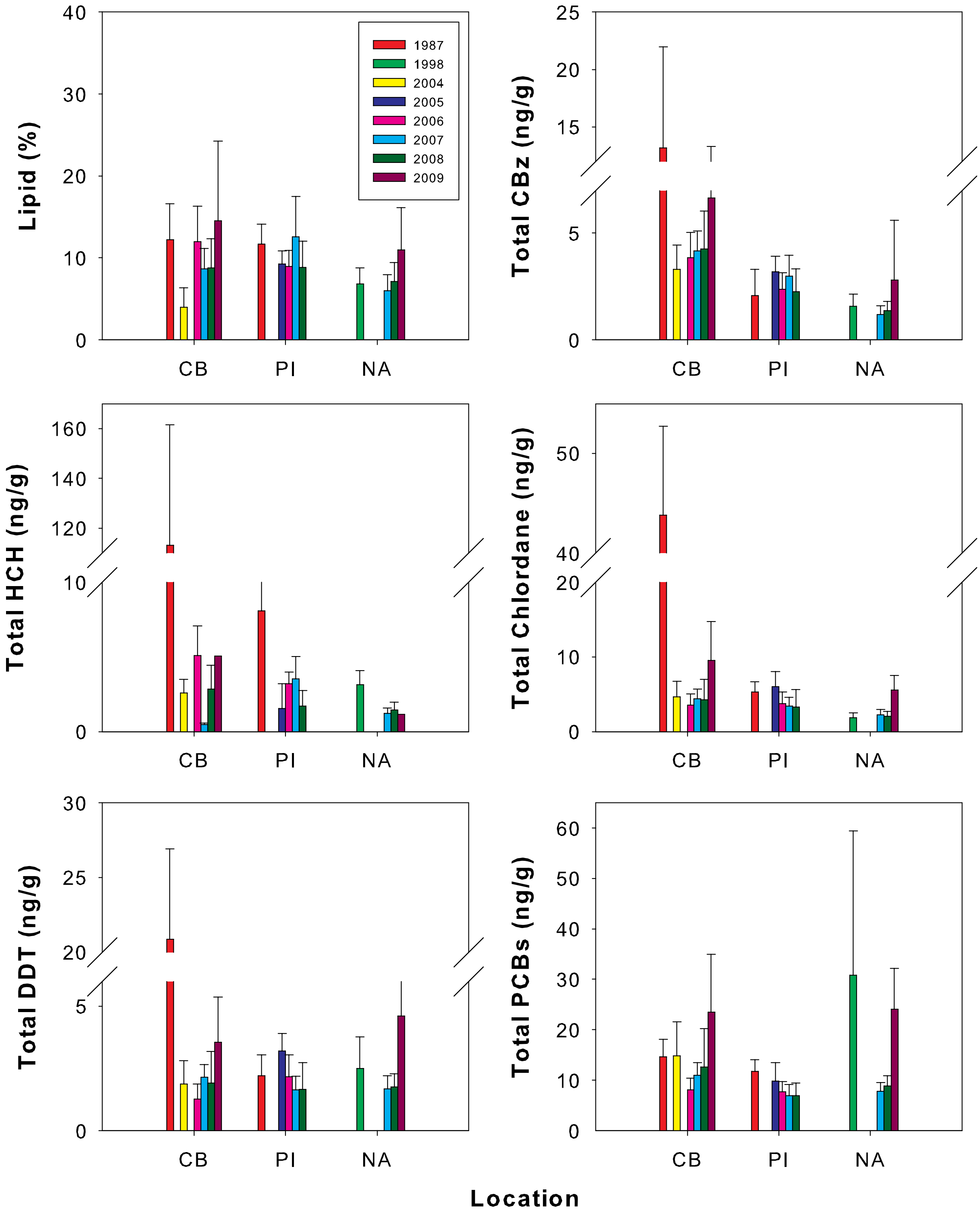

Figure 4. Time trends in lipids and persistent organic contaminants in sea-run char at Cambridge Bay (CB), Pond Inlet (PI), and Nain (NA).

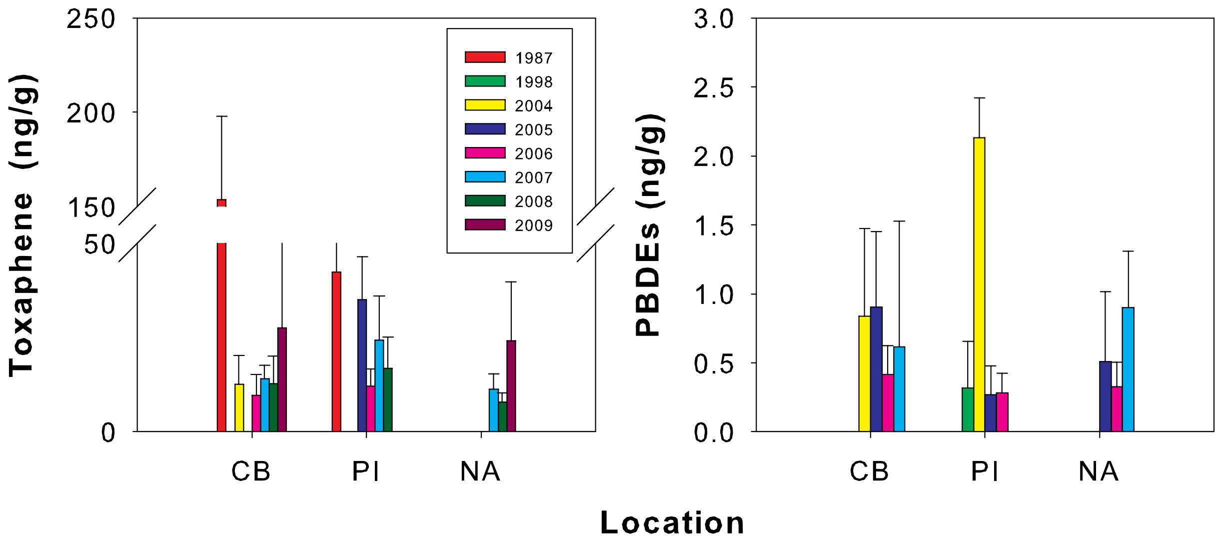

Figure 5. Temporal variability in toxaphene and PBDEs (ng/g wet weight) in sea-run char from Cambridge Bay (CB), Pond Inlet (PI), and Nain (NA).

Overall, persistent organochlorine concentrations were very low in sea-run char at all three locations. The more recent data record is too short to infer trends for these highly persistent compounds with long half lives. The higher concentrations of most legacy persistent organochlorine contaminant concentrations (PCBs are the exception) observed at Cambridge Bay in 1987 were not observed in later years.

Toxaphene and PDBEs

Toxaphene concentrations were moderately high in Cambridge Bay char in 1987 and substantially lower in later years; a similar pattern was observed for toxaphene in Pond Inlet char (Fig. 5). Lowest concentrations were observed at Nain. PBDEs occurred in low concentrations in sea-run char from Cambridge Bay, Pond Inlet, and Nain with no trends evident.

Conclusions

Mercury and persistent organic contaminant concentrations are low in sea-run char with lowest concentrations at Nain where fish are smallest and youngest with similar concentrations at Pond Inlet and Cambridge Bay. There appears to be a trend of increasing mercury concentrations in char at Cambridge Bay and Pond Inlet although a longer record is needed to establish this with certainty. This increase could be driven by a warming trend which could be enhancing productivity and the mercury methylation and/or increased mercury emissions from Asia (Stern et al. 2005; Outridge et al. 2007; Muir et al. 2009). Mercury concentrations appear to be decreasing at Nain, possibly because this is in a region that is experiencing a cooling trend and/or because of reduced mercury releases from coal fired power plants in the northeastern United States. Legacy organic contaminant concentrations have declined markedly at Cambridge Bay since the higher measurements made in 1987.

NCP Performance Indicators

Number of northerners engaged in your project: We rely on the HTO's or their equivalent to arrange for the harvest of the fish and more than one fisherperson could be involved at each community. Minimally, there are seven northerners involved in this study.

Number of meetings/workshops held in the north: NCP Annual meeting at Whitehorse.

Number of students involved in the project: 1 M. Sc. Student

Number of citable publications: 1 (Riget et al. in press), CACAR and AMAP reports.

Expected Project Completion Date

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

Acknowledgements

We thank Brenda Sitatak with the Ekaluktutiak (Cambridge Bay) Hunters and Trappers Organization; Bryan Simonee with the Mittimatalik (Pond Inlet) Hunters and Trappers Organization; and Mary Denniston and John Lampe (Nunavsiavut Government) for their support and participation in this study.

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Spatial and Long-Term Trends in Persistent Organic Contaminants and Metals in Lake Trout and Burbot from the Northwest Territories

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Abstract

Our study is investigating whether mercury and persistent organochlorine contaminants are changing in lake trout and burbot in Great Slave Lake. The primary monitoring began in 1999 but earlier data exist from our more limited studies conducted in over 1993–1996 and from periodic mercury measurements made in the commercial fisheries. We are investigating lake trout in the West Basin (near Hay River) and East Arm (near Lutsel K'). We also are investigating burbot from the Fort Resolution area of the West Basin; burbot sampling at Lutsel K'e was discontinued in 2004 but was resumed in 2007 under our companion Great Slave Lake project and findings presented in that report. Mercury concentrations are increasing in lake trout harvested from the West Basin and East Arm and burbot from the West Basin possibly due to a combination of a warming trend and increased Asian emissions. Average mercury concentrations remain below

Résumé

Notre étude consiste à déterminer si des changements se sont produits dans les concentrations de mercure et de contaminants d'organochloré persistants qui se trouvent dans le touladi et dans la lotte du Grand lac des Esclaves. Les principales activités de surveillance ont commencé en 1999, mais les premières données proviennent d'études restreintes menées de 1993 à 1996 et de mesures périodiques de mercure effectuées dans le cadre de la pêche commerciale. Nous nous penchons sur le touladi de West Basin (principalement près de Hay River) et d'East Arm (près de Lutsel K'e). Nous étudions aussi la lotte du secteur de Fort Resolution (West Basin); l'échantillonnage de la lotte à Lutsel K'e a cessé en 2004 et repris en 2007, dans le cadre de notre projet connexe sur le Grand lac des Esclaves, et les résultats sont exposés dans le présent rapport. Les concentrations de mercure ont augmenté dans le touladi de West Basin et d'East Arm, de même que dans la lotte de West Basin, augmentation qui

0.5 $\mu g/g$ and well below the high concentrations observed in smaller lakes along the Mackenzie River. HCH and DDT concentrations are declining in lake trout and burbot as global usage of these compounds is reduced. PCBs are declining in West Basin burbot, but not in West Basin and East Arm lake trout. lakes. Mercury levels also have increased in pike and walleye in Deep Lake while for McGill Lake, mercury concentrations were lower in northern pike with little change for walleye; nevertheless mean concentrations continue to be greater than 0.5 $\mu g/g$. New information was obtained on mercury levels in pike, walleye and lake trout in Fish Lake; mean mercury levels were <0.5 $\mu g/g$ only for lake trout. Mercury levels were assessed in lake trout in Nonacho Lake with only a small increase in concentration observed over 2003–2011; mercury levels were higher in the mid 1970s a few years after a dam was placed on the lake and water levels rose. Information on mercury levels in fish in the small to medium-size lake studies was submitted for assessment with recommendations issued for Stark and Nonacho lakes.

Key Messages

- There a trend for mercury concentrations to be increasing in lake trout harvested from the East Arm and West Basin and burbot from the West Basin. Trends may be driven by global warming and/or an increase in mercury emissions.
- Average mercury levels are below 0.5 $\mu g/g$ for both species harvested from both locations in contrast to higher mercury concentrations observed in lake trout, pike, and walleye in the smaller lakes along the Mackenzie River where advisories were issued in June 2010.
- Among the legacy persistent organic contaminants, HCH is showing a strong trend of decline as is DDT in lake trout from both basins and burbot from the West Basin. In contrast PCBs are declining in West Basin burbot but not lake trout.
- Mercury concentrations tend to be higher in West Basin lake trout and burbot while the converse is observed for persistent organochlorine contaminants although differences are not large.

découle possiblement du réchauffement climatique et des émissions accrues en Asie. La moyenne des concentrations de mercure demeure inférieure à 0,5 $\mu g/g$ et bien en dessous des fortes concentrations observées dans des lacs plus petits le long du fleuve Mackenzie.

On remarque actuellement une diminution des concentrations de HCH et de DDT dans le touladi et dans la lotte, parce que ces composés sont moins utilisés à l'échelle mondiale. On note une diminution de la concentration de BPC dans la lotte de West Basin, mais pas dans le touladi de West Basin et d'East Arm.

Messages clés

- Les concentrations de mercure ont tendance à augmenter dans le touladi d'East Arm et de West Basin et dans la lotte de West Basin. Le réchauffement planétaire ou l'augmentation des émissions de mercure ont peut-être influé sur ces tendances.
- Les concentrations moyennes de mercure sont inférieures à 0,5 $\mu g/g$ chez les deux espèces prélevées dans les deux milieux. Par contre, dans les lacs de moins grande superficie le long du fleuve Mackenzie où des avis ont été émis en juin 2010, le touladi, le brochet et le doré jaune présentaient des concentrations de mercure plus élevées.
- Parmi les anciens contaminants organiques persistants, le HCH, tout comme le DDT, est fortement à la baisse chez le touladi des deux bassins et chez la lotte de West Basin. Par contre, les concentrations de BPC sont à la baisse chez la lotte de West Basin, mais non chez le touladi.
- Les concentrations de mercure ont tendance à être plus élevées chez le touladi et la lotte de West Basin, tandis que l'on observe le

- Lake trout harvested from the West Basin are faster growing, more lipid rich and more predaceous that lake trout harvested from the East Arm.
- Burbot harvested from the East Arm are smaller, younger and more littoral in their feeding than burbot harvested from the West Basin.

contraire en ce qui concerne les contaminants d'organochloré persistants, bien que les différences ne soient pas grandes.

- Le touladi du West Basin croît plus rapidement, contient plus de lipides et est davantage carnassier que le touladi d'East Arm.
- La lotte prélevée à East Arm est plus petite, plus jeune et s'alimente davantage près du littoral que la lotte prélevée à West Basin.

Objectives

1. Determine temporal trends in persistent organic contaminants, mercury, and other metals in lake trout at two locations (West Basin near Hay River, East Arm at Lutsel K'e) and burbot in the West Basin (offshore of Fort Resolution) through annual sampling, extending the 1993–2008 data sets to 2010 and beyond.
2. Investigate factors affecting temporal variability in contaminants in lake trout and burbot including length, age, trophic feeding, and lipid levels.
3. Participate in and contribute information to AMAP and CACAR expert work groups for trend monitoring for POPs and mercury.
4. Communicate results to the communities and the commercial fisheries in a timely manner, including through the Northwest Territories Regional Contaminants Committee.

Introduction

Great Slave Lake, located in the Northwest Territories, is part of the Northern Contaminant Program's (NCP) long-term biomonitoring program which includes lake trout and burbot. The first measurements of contaminants (persistent organic pollutants) in these 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). Since 1999, lake trout and burbot have been monitored for contaminant trends annually with two exceptions: monitoring was not conducted in 2003 and burbot sampling at Lutsel K'e was discontinued in 2004 as part of the core biomonitoring program. With eleven years of high quality biomonitoring data (1999–2010) and less rigorous NCP data going back to 1993, temporal trends are now beginning to be detected.

Great Slave Lake 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). The West Basin is profoundly affected by the Slave River inflow. Early monitoring considered lake trout and burbot both in the West Basin and East Arm. While the original rationale for studying two locations was to consider the influence of the Slave River on contaminant loading and biomagnification in Great Slave Lake, the rationale has taken on new dimensions in recent years. This is because the basic features of the two regions of the lake will affect contaminant pathways in a number of ways regardless of Slave River contaminant inputs from the south. For example, persistent organic contaminant concentrations are likely to be higher in biota in the low productivity waters of the East Arm than the higher productivity waters of the West Basin (Larsson et al. 1998; Berglund et al. 2001; Houde et al. 2008). In contrast mercury levels are likely to be higher in the West Basin than the East Arm because of temperature, watershed, and productivity effects (Bodaly et al. 1993; Evans et al 2005b). Differences in fish growth and feeding characteristics between the two basins will also be influential in affecting contaminant levels in fish.

Lake trout (Salvelinus namaycush) and burbot (Lota lota) were selected for study because the former is important in the domestic, sport and commercial fisheries (West Basin) while burbot is more important in the domestic fishery. Lake trout is an omnivorous, cold-water stenotherm with a thermal optimum of ca. 10oC; as such it is confined to cold, deep and well-oxygenated waters during summer although it does venture into the littoral zone where the lake edge is steep-sided and deep (Rawson 1951; Scott and Crossman 1998). Burbot also is a predatory fish and while it resides in the hypolimnion, in addition to large northern rivers, its thermal optimum is 15.6o–18.3°C (Scott and Crossman 1998). In Great Slave Lake, burbot is found both in shallow waters and deep waters down to depths of 100 m (Rawson 1951). Burbot are more commonly captured by hook and line suggesting that they are an "ambush" predator whereas lake trout are more traditional "search" predators. Burbot liver, which is prized, is lipid-rich and hence high in persistent organic contaminants (Kidd et al. 1995; Evans et al. 2005a; Ryan et al. 2005). Studies of the two species and in the two ecological regions of Great Slave Lake provide for an improved scientific understanding of the factors affecting contaminant levels which can then be generalized to the other broader regions of the Arctic.

This Great Slave Lake burbot and lake trout monitoring study is tracking trends in persistent organic contaminants such as HCH, DDT, and PCB which are expected to decline in concentration as usage diminishes and as these compounds degrade and are buried in lake sediments. However, it has been hypothesized that global 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 and increased productivity result in atmospherically-transported contaminants being captured in organic matter within the lake and more effectively retained, including in the sediments (Outridge et al. 2007). Global warming also has been attributed to enhanced mercury fluxes to lake sediments and increased levels in burbot (Outridge et al. 2007; Carrie et al. 2010). However, for mercury, it is also possible that increased Asian emissions are driving mercury time trends including Great Slave Lake. Certainly, the issue of time trends in mercury fluxes to lakes is complex, varying with the lake and location within the lake (Muir et al. 2008; Evans and Muir 2010a, b; Kirk et al. 2011).

Activities in 2010–2011

Great Slave Lake—collections and biological measurements

In 2010–2011, 20 lake trout were collected from the Lutsel K'e area (East Basin) and northwest of Hay River (West Basin). In addition, 20 burbot were collected in the Fort Resolution area (near the Slave River inflow, West Basin). Collections were done by community members or by a commercial fisherman (Hay River). Fish were frozen and shipped whole to Environment Canada (Saskatoon) for processing. Total length, fork length (lake trout only), round weight, liver weight, gonad weight, and gender were determined for all fish; features such as the presence of parasites, discolored liver, skinniness, and crude measures of stomach contents were noted. Aging structures (otoliths) were removed from all fish and age later determined for all fish. Approximately 100 gm of dorsal fillet, the liver and stomach were removed from all fish for analyses and/or archiving. A subsample of fillet was freeze-dried, percent moisture determined, and analyzed for carbon and nitrogen stable isotopes for all 20 fish from each location. Ten fish from each location were selected for persistent organic contaminant and metal analyses. With the exception of persistent organic contaminants, all analyses have been completed.

Communications

Various communications and reporting were given on this study in 2010–2011. A scientific paper reporting mercury trends in lake trout and burbot and our sediment core studies (Evans and Muir 2010 a, b) was submitted to a scientific journal and is now in revision. Contributions were made to the mercury and persistent organic contaminant chapters of the CACAR report on spatial and temporal trends in contaminants in lake trout and burbot in Great Slave Lake. In addition the NCP workshop, an invited presentation on contaminants trends was given at the IPY 2010 Conference in Oslo and a Managing Risks in Aquatic Systems: Effects of Climate Change and Anthropogenic Activity in Niagara Falls. An invited abstract was submitted to the Mercury 2011 Conference.

The most important communications in 2010–2011 centered on the mercury Public Health advisory issued in June by the Chief Public Health Officer, the Government of the Northwest Territories recommending that people limit their consumption of lake trout from Cli, Kelly and Trout Lakes and lake trout, walleye and northern pike from Lac Ste. Therese. These recommendations were issued based on the findings of our periodic assessments of mercury levels in fish in smaller lakes along the Mackenzie River (Evans and Muir 2010a). However, people consuming fish from other lakes, including Great Slave Lake, were concerned with this issue. Thus, there were various radio and other interviews were held in the following weeks and, on July 19, a panel consisting of J. Stow (INAC), K. Kandola (Chief Public Health Officer), M. Evans (Environment Canada), and M. Feeley (Health Canada) met with Tulita to discuss the findings and recommendations. Other presentations were given by L. Skinner (INAC-Yellowknife) in Fort Simpson and Trout Lake. In late February and early March 2011, M. Evans gave a series of presentations on the findings of the mercury assessments to Lutsel K'e, Fort Resolution, Hay River and Yellowknife with L. Skinner and D. Leonard (Fisheries and Oceans Canada) also part of the panel and available to answer questions on the NCP program and fish ecology in general.

While not a formal part of the NCP program, funding was obtained under the Cumulative Impact Monitoring Program for the study "Community monitoring of the Great Slave Lake ecosystem: second steps". This study was based on the desire to develop a community based limnological monitoring program for the Fort Resolution and Lutsel K'e areas and to provide information of the seasonal and year to year variability in water quality features of the lake. Ideally this information would assist in interpreting the factors affecting changes in mercury levels in fish, e.g., changing lake productivity. There were various challenges to this study but a series of temperature and water clarity measurements were made at a number of sites in late July and August while, later in the year, weekly data were collected from the water intake at Fort Resolution and a several week survey conducted of the domestic fisheries. A traditional knowledge survey also was conducted asking what was known about changes in the water quality, climate and fish populations of Great Slave Lake. This CIMP project was renewed in 2011.

Results and Discussion

Biological features of fish populations

As part of our investigation of temporal trends in mercury and persistent organochlorine contaminant concentrations in lake trout and burbot, we have been focussing on differences and similarities in their biological features at their West Basin and East Arm collection sites. Earlier in our study (Evans 1994, 1995), we reported that persistent organochlorine concentrations tended to be higher in the East Arm which we related to the lower productivity of these waters which provided for less biodilution of organic contaminants. Later studies have shown that organic contaminants tend to be higher in oligotrophic than less productive water (Berglund et al. 2000; Houde et al. 2010). As mercury determinations were incorporated into the biomonitoring in 1999, it was thought that higher mercury levels would be observed in fish caught near the Slave River, where watershed influences are substantial and the waters themselves warmer than in the East Arm where waters are colder and watershed influences weaker. However, before locations can be compared, one first must understand differences in the biological feature of fish by location and species.

Biological data collected for burbot and lake trout from the Hay River area, Fort Resolution, and Lutsel K'e have been combined and examined for regional and species differences (Table 1). Burbot from the West Basin tended to be larger, older, and with more lipid-rich liver than burbot from the East Arm; furthermore, they were more pelagic in their feeding (more negative carbon isotope) and more predaceous. It is not known why smaller burbot were collected from Lutsel K'e than Fort Resolution; possibly larger fish were in deeper waters where they were less readily caught. Mercury levels were higher in West Basin than East Arm burbot due either to their greater age and/or limnological influences of the basin (warm waters, strong watershed inputs).

Lake trout were similar in size in the West Basin and East Arm but West Basin trout were younger and with more lipid in their fillet; such differences indicate a faster growth rate and suggest a more rich food supply for West Basin than East Arm trout. Lake trout were somewhat more predaceous and pelagic in their feeding in the West Basin than East Arm an observation also made decades earlier by Rawson (1951). Despite their younger age, mercury levels are higher in West Basin than East Arm lake trout. Again, such differences may be related to the warmer and more productive waters of the West Basin which allow for more mercury to be methylated than in the colder, less productive East Arm: Slave River inputs and transformations with the Slave River delta may also be important.

Mercury trend monitoring

Mercury time trends in lake trout and burbot have been examined in various ways including using the full NCP data sets (1993–2009) and the more limited data from the commercial fishery from the West Basin where only length and weight are available as additional explanatory variables, i.e., in addition to time (Evans et al. in revision). In the West Basin, where the lake trout record can be extended back to the lake 1970s with the inclusion of commercial fish record, there is a statistically significant trend of increase in mercury concentrations. This trend also is significant when data are limited to the more recent NCP record (Fig. 1). The record of mercury levels in lake trout in the East Arm is more limited but here also mercury levels are showing a significant trend of increase over the NCP record. Burbot collected from the West Basin have had lower mercury concentrations in 2009 and 2010 than 2007 and 2008; nevertheless, the trend of increase remains. Similarly, Carrie et al. (2010) have observed a significant trend of increase in mercury concentrations in burbot collected from the Mackenzie River at Fort Good Hope. Mercury levels are lower in burbot from Great Slave Lake than the Mackenzie River. Mean concentrations of lake trout and burbot remain well below the 0.5 μg/g commercial sale guideline. The factors affecting these trends is under investigation is hypothesized to be due to a combination of a warming trend, decreasing winds, and increased Asia emissions with the relative role of these three factors unknown (Carrie et al. 2010; Evans and Muir 2010 a, b).

Persistent organic contaminants trend monitoring

In contrast to mercury, HCH is showing a significant trend of decline in lake trout (West Basin and East Arm) and burbot (West Basin); the steepest time trend is being observed for burbot. The greatest rate of decline is being observed in α-HCH which is the predominant isomer followed by δ-HCH. Similarly, declining HCH concentrations are being observed in burbot at Fort Good Hope (Stern 2010) and lake trout from Lake Laberge and Kusawa Lake in the Yukon (Stern et al. 2010). Such declines are anticipated given the reduced usage of HCH globally. HCH

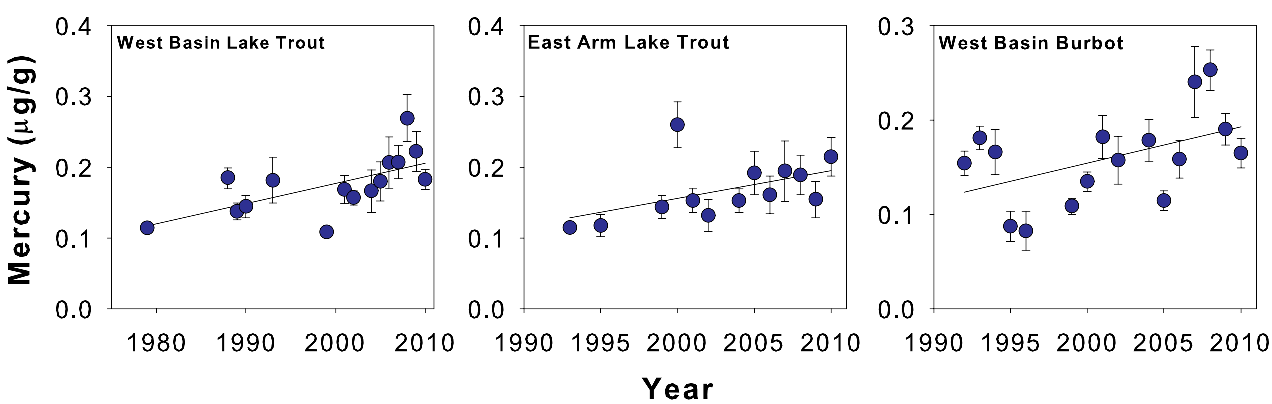

Figure 1. Mercury time trends in lake trout collected from the West Basin (Hay River) and East Arm (Lutsel K'e) of Great Slave Lake, 1993–2010 and earlier data from the commercial fish records for the West Basin. Also shown are burbot collected from Resolution Bay 1993–2010 with commercial fish data from 1992 and 1994. Data are presented as the means (± 1 standard error) and as a linear regression.

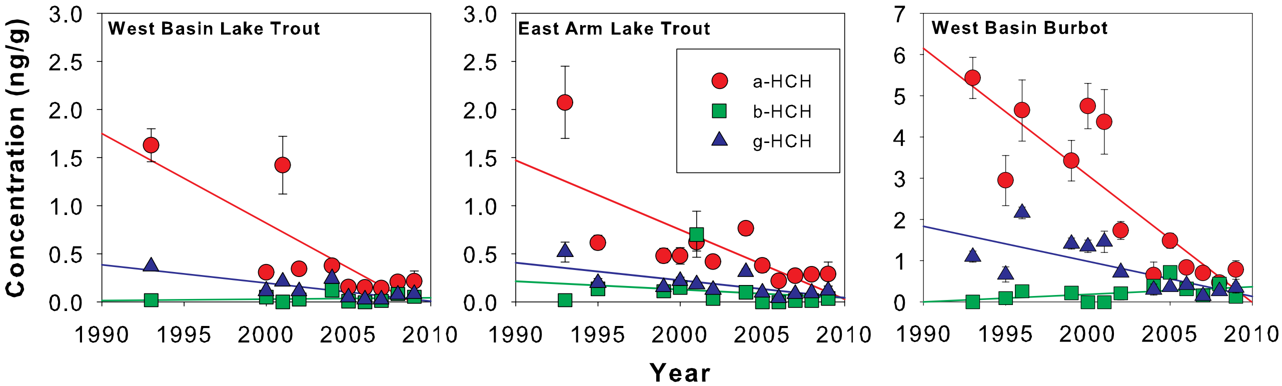

Figure 2. HCH isomer time trends in lake trout (fillet) collected from the West Basin (Hay River) and East Arm (Lutsel K'e) of Great Slave Lake. Also shown are burbot (liver) from Fort Resolution. Data are presented as the means (± 1 standard error) and as a linear regression.

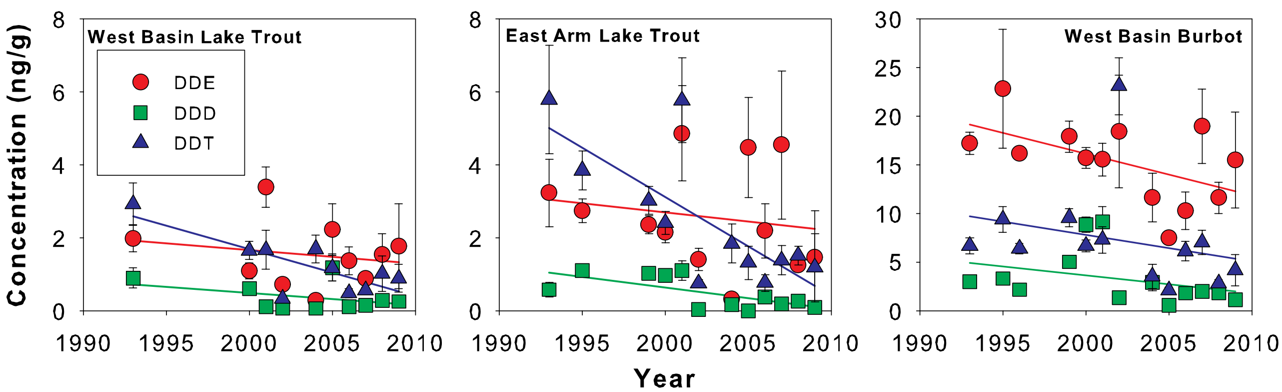

Figure 3. DDT isomer time trends in lake trout (fillet) collected from the West Basin (Hay River) and East Arm (Lutsel K'e) of Great Slave Lake. Also shown are burbot (liver) from Fort Resolution. Data are presented as the means (± 1 standard error) and as a linear regression.

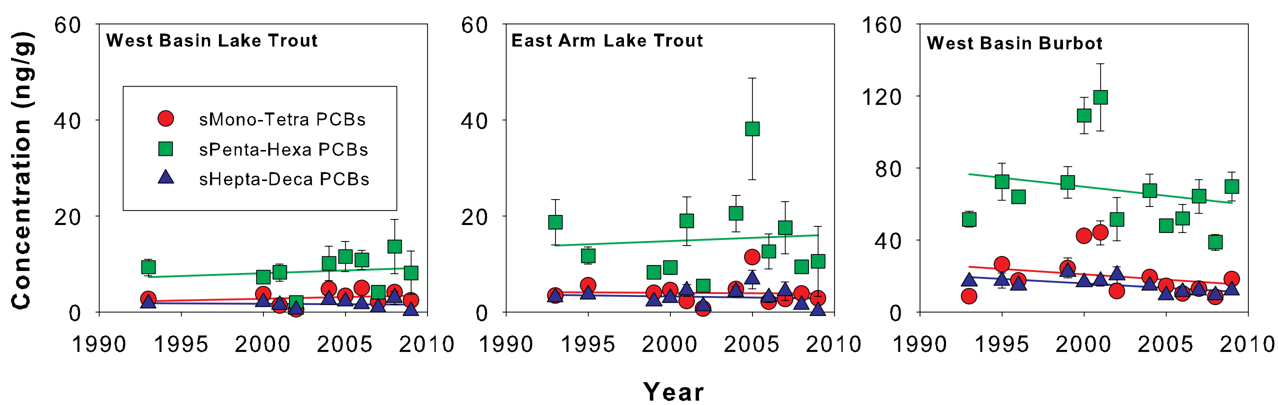

Figure 4. PCB congener time trends in lake trout (fillet) collected from the West Basin (Hay River) and East Arm (Lutsel K'e) of Great Slave Lake. Also shown are burbot (liver) from Fort Resolution. Data are presented as the individual data points with a linear regression.

concentrations average 0.86 ±1.18 ng/g West Basin lake trout and 0.81 ± 0.76 ng/g in East Arm lake trout fillet versus 3.29 ± 2.62 ng/g in West Basin burbot liver and 5.37 ±3.82 ng/g in East Arm burbot liver.

Total DDT also is showing a significant trend of decrease in lake trout and burbot although the trends differ with the species and location (Fig. 3). Lake trout in the West Basin are showing a steep decline in DDT and a somewhat less steep decline in DDE as DDE becomes the predominant isomer in more recent years. The decline in total DDT is steeper for East Arm lake trout. Similar declines in total DDT are being observed in lake trout from Lake Laberge and Kusawa Lake in the Yukon (Stern et al. 2010). DDT concentrations average 3.34 ±3.07 ng/g in West Basin lake trout and 5.42 ±5.06 ng/g in East Arm lake trout fillet. West Basin burbot also are showing a decline in total DDT concentrations although DDT rates are not declining as fast as in lake trout; DDE has and continues to predominate over DDT possibly because analyses are conducted on the liver and parent DDT may be rapidly more rapidly metabolized to DDE than in the muscle. In contrast total DDTs are showing no evidence of a decline in burbot at Fort Good Hope with concentrations in more recent years higher than in the 1990s (Stern 2010). DDT concentrations average 25.7 ± 15.5 ng/g in West Basin burbot liver and 29.5 ±19.4 ng/g in East Arm burbot liver.

In contrast to HCH, PCBs in lake trout are showing no trend or at either locations kin Great Slave Lake; there is a weak positive slope (although not significant) for penta and hexa PCBs which also are the predominant congeners (Fig. 4). In contrast PCBs are showing a pronounced decline in lake trout at Lake Laberge and Kusawa Lake, where levels were very high in the early 1990s with higher levels associated with local contamination (Jensen et al. 1997; Rawn et al. 2001). Such a situation does not apply to Great Slave Lake where PCB concentrations in sediments are low with only limited evidence of a time trend which appears reflective of long-range atmospheric transport (Evans et al. 1996). In contrast to lake trout, PCB concentrations show a more pronounced trend of decline in West Basin burbot. The reasons for these differing responses for the two species are under consideration. Burbot trends differ from that observed at Fort Good Hope where higher PCB concentrations have been observed over the late 2000s than the early 2000s (Stern 2010). PCB concentrations average 14.6 ± 13.3 ng/g in West Basin lake trout and 21.5 ± 19.4 ng/g in East Arm lake trout fillet versus 104.6 ± 55.3 ng/g in West Basin burbot liver and 115.0 ± 62.8 ng/g in East Arm burbot liver.

Conclusions

There is a distinct trend for mercury concentrations to be increasing in lake trout harvested from the West Basin and East Arm of Great Slave Lake although average concentrations remain below 0.5 μg/g and substantially lower than in the smaller lakes along the Mackenzie River where advisories were issued in June 2010. Mercury concentrations also are increasing in burbot from the West Basin but again remain relatively low. Trends may be driven by global warming and/or an increase in mercury emissions. Among the legacy persistent organic contaminants, HCH is showing a strong trend of decline as is DDT for lake trout from both basins and burbot. In contrast PCBs are declining in West Basin burbot but not lake trout. Overall, mercury concentrations are slightly higher in West basin burbot and lake trout that East Arm fish while the converse is observed for persistent organochlorine contaminants.

NCP Performance Indicators

Number of northerners engaged in your project: We work with Fort Resolution and Lutsel K'e with two–three people in each community involved in this study. At Hay River, we work directly with Shawn Buckley with the commercial fisheries. Minimally, there were 5–7 northerners involved in this study.

Number of meetings/workshops held in the north: NCP Annual meeting at Whitehorse. Tulita Workshop and presentations in Trout Lake and Fort Simpson regarding the mercury advisories issued in June 2010. Workshops in late February and early March 2011 at Yellowknife, Hay River, Fort Resolution and Lutsel K'e regarding this and the core mercury trend monitoring.

Number of students involved in the project: 0

Number of citable publications: 1 (Riget et al. in press), CACAR and AMAP reports; submitted scientific paper in revision.

Expected Project Completion Date

This project is a core NCP biomonitoring study with an indeterminate date.

Acknowledgements

Special appreciation is extended to Gab Lafferty at Fort Resolution and Ernest Boucher at Lutsel K'e for collecting the pike and burbot respectively and Shawn Buckley for collecting lake trout at Hay River.

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Arctic Caribou Contaminant Monitoring Program

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Abstract

The objective of this project is to determine contaminant levels in caribou in the Canadian Arctic to determine if the animal populations remain healthy (in terms of contaminant loads), whether these important resources remain safe and healthy food choices for northerners and to see if contaminant levels are changing over time. In 2010/11 collections of the Porcupine and Qamanirjuaq herds were unsuccessful. A new sampling strategy is being devised for the future. Results from the previous year's collections were analyzed. Arsenic, lead and selenium were lower in the 2010 Tay herd collection (males) as compared with the 1993 collection (females) while mercury and zinc were higher. These differences may be due differences between years or between genders. Magnesium concentrations found in the Tay caribou are higher than seen in other caribou herds. Arsenic and lead are decreasing slightly over time in male fall-collected Porcupine caribou, while zinc is increasing. Neither cadmium nor mercury are increasing or decreasing significantly over time in Porcupine caribou. While cadmium and zinc increase with the age of both genders of caribou, mercury increases with age in female caribou but decreases with age in males. This is likely due to the greater relative intake of food, and hence mercury, by

Résumé

L'objectif du projet est de connaître les concentrations de contaminants chez les caribous du Nord canadien afin de déterminer si les populations animales sont en santé (pour ce qui est des concentrations en contaminants), de décider si ces importantes ressources demeurent des choix alimentaires sains et sécuritaires pour les résidants du Nord et de voir si les concentrations de contaminants varient au fil du temps. En 2010 2011, les collectes dans les hardes de Porcupine et Qamanirjuaq se sont soldées par un échec. On élabore actuellement une nouvelle stratégie de collecte de données. Les résultats de l'année précédente ont été analysés. Lors de la collecte de 2010 dans la harde de Tay (mâles), on a remarqué que les concentrations d'arsenic, de plomb et de sélénium étaient plus faibles que celles enregistrées lors de la collecte de 1993 (femelles), alors que les concentrations de mercure et de zinc étaient plus élevées en 2010 qu'en 1993. Ces différences pourraient être attribuables au temps ou au sexe. Les concentrations de magnésium chez les caribous de Tay sont plus élevées que ce qui a été trouvé dans d'autres hardes de caribous. Les concentrations d'arsenic et de plomb baissent légèrement au fil du temps dans les échantillons prélevés à l'automne chez les mâles de la harde de Porcupine alors que les concentrations de zinc

female caribou. Contaminants of concern in the Porcupine caribou are generally stable over time, although the increase in zinc should continue to be monitored. Levels of most elements measured in both the Porcupine and Tay caribou herds were not of concern toxicologically, although renal mercury and cadmium concentrations may cause some concern for human health depending on the quantity of organs consumed. Yukon Health has advised restricting intake of kidney and liver from Yukon caribou, the recommended maximum varying depending on herd. The health advisory confirms that heavy metals are very low in the meat (muscle) from caribou and this remains a healthy food choice.

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.
- Zinc appears to be increasing in the Porcupine caribou and although is not of concern toxicologically at this time, should continue to be monitored.
- Over the long term, mercury in the Porcupine caribou is stable, but does undergo a cycle. More research is required to determine causes of the cycle and mercury dynamics within the caribou food chain.

augmentent. Ni les concentrations de cadmium ni celles de mercure n'augmentent ou ne baissent de manière importante en fonction du temps chez le caribou de Porcupine. Si les concentrations de cadmium et de zinc augmentent avec l'âge chez les deux sexes, les concentrations de mercure augmentent en fonction de l'âge des femelles alors qu'elles diminuent chez les mâles, ce qui s'explique probablement par la plus grande ingestion de nourriture, et donc de mercure, chez les femelles. Les contaminants préoccupants chez la harde de Porcupine présentent généralement des concentrations stables au fil du temps, bien qu'il soit nécessaire de continuer à surveiller les concentrations de zinc. Les concentrations de la plupart des éléments mesurés dans les hardes de Tay et de Porcupine ne soulevaient aucune préoccupation d'ordre toxicologique même si les concentrations de mercure et de cadmium présentes dans les reins pourraient poser un risque pour la santé humaine selon la quantité d'organes consommés. Le ministère de la Santé du Yukon a publié un avis restreignant la consommation des reins et du foie des caribous. Le maximum recommandé varie selon la harde concernée. L'avis sanitaire confirme que les concentrations de métaux lourds sont très faibles dans la viande (muscle) de caribou et que cette dernière demeure donc un aliment sain.

Messages clés

- Les concentrations de la plupart des éléments mesurés ne sont pas préoccupantes, même si les concentrations de mercure et de cadmium présentes dans les reins pourraient poser un risque pour la santé humaine selon la quantité d'organes consommés. La viande de caribou (le muscle) accumule peu de métaux lourds et constitue un aliment sain.
- La concentration de zinc semble augmenter dans la harde de porc-épic et doit faire l'objet d'un suivi même si elle ne soulève aucune préoccupation d'ordre toxicologique pour le moment.
- À long terme, les concentrations de mercure dans la harde de Porcupine demeurent stables, mais sont soumises à des variations cycliques. Il faudra mener davantage de recherches afin de déterminer l'origine de ce cycle ainsi que le comportement 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 2010–2011

No samples were collected from the Porcupine caribou herd during this sampling year. A combination of changes to hunting regulations (reducing the licensed harvest from two caribou to one bull per licensed hunter), changes in the migration of the caribou (few crossed the only accessible highway this year) and cold temperatures during the hunting season resulted in this unfortunate lack of samples. Since there was such a lack of licensed hunter effort this year, an attempt was made to engage First Nations hunters from Old Crow and Aklavik (NWT) to provide samples, but since these were very much last minute and few caribou were available, these attempts were unsuccessful.

No samples were collected from the Qamanirjuaq caribou herd either this year, due to an unfortunate misunderstanding with the local biologist. Once this misunderstanding was discovered, an attempt was made to conduct a spring collection of samples, but since there were no caribou in the area at that time, this was unsuccessful.

Analyses of samples from the fall 2009 collection of the Porcupine caribou and the spring 2010 collection of the Tay caribou have been completed and data are presented. Analysis of samples from the fall 2009 collection of the Qamanirjuaq caribou are waiting upon receiving collection data for these animals (as some of the samples submitted may actually be from 2008). Although kidneys were analyzed for 31 elements, only results for 7 elements of concern were analyzed in detail (arsenic, cadmium, copper, lead, mercury, selenium and zinc). Methylmercury concentrations in caribou muscle tissue are also available and are presented.

Although the intent of this project was to compare element concentrations in the Tay caribou herd from 1993 and 2010, it is difficult since all the animals sampled in 1993 were female and all those sampled in 2010 were male. Therefore, differences could be a result of changes over time or due to differences between the genders. Nonetheless, a comparison between the two collections was made and some interpretation of the data was attempted. It should be noted that differences between years do not necessarily indicate an increase or decrease in a particular element over time, since some elements tend to be cyclic in nature (eg. mercury). Temporal trends were assessed for Porcupine caribou using a general linear model. 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 and Training:

This year provided few opportunities for capacity building and training, since the project was limited to collections from the two caribou herds that were both unsuccessful. However, results of past years of this project were presented to several classes at Yukon College involved in the Renewable Resource program, and the project leader served as a mentor to a Directed Studies student at Yukon College who conducted an associated project on mercury in caribou forage.

Traditional Knowledge:

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. In Arviat, all samples are collected from the Qamanirjuaq herd by one local hunter who uses traditional knowledge on a daily basis, as well as when hunting for food for his community and providing samples for this project.

Communications:

The program was advertised in the fall of 2010 in newspapers and through posters. Several lectures were presented at Yukon College (including the Renewable Resource Program) discussing the results of this program. A radio interview (CBC) was given about results of the program in February 2011.

Results of this project are communicated to the YCC and NAC by this report and will be presented at the NCP symposium anticipated for the fall of 2011. 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. Special presentations may be made as the results dictate, or upon request, in cooperation with the Regional Contaminants Committees. Results of this (and other NCP projects) will be presented at the 2011 International Mercury Conference in Halifax, in July, 2011.

Yukon: The project coordinator is a member of the Yukon Contaminants Committee (YCC), and provides updates on this project at each meeting of the YCC. Each hunter submitting samples to the program is sent a letter informing them about the Hunter Survey Program and the results to date. This form of communication has been in place for the duration of this project in the Yukon (16 years) and is supported by the YCC. The project leader normally arranges at least one radio interview regarding the program, (and often newspaper articles as well), and is available to attend public meetings or health fairs upon request, or to give presentations to local groups (high school or college classes, Yukon Science Institute, Government biologists) to discuss the program and the current status of contaminants in wildlife in the Yukon. Data collected through this program were included in the most recent updates of the CACAR and AMAP reports. Data from this program were also provided to a local consulting group that were assessing contaminant levels in wildlife in a mining area in the Yukon, to provide context for their survey data. A public meeting is planned for Ross River, in cooperation with Yukon Environment and the Ross River Dena Council to present results and answer questions about the program. Informational materials for the meeting will be developed in cooperation with Yukon Environment and the Ross River Dena Council.

Nunavut: Participating Government of Nunavut biologist (Mitch Campbell) includes project results in their ongoing communications with local communities and HTOs. This involves regularly scheduled community meetings, meetings with specific groups and newsletters. An article on contaminants in the Qamanirjuaq caribou herd was included in the fall 2009 issue of Wildlife Tracks, a publication of the Government of Nunavut. The NAC has requested that brochures be produced summarizing the contaminant work done on the Qamanirjuaq and Dolphin and Union caribou herds. Drafts of the brochures were sent to local biologists for comment and input.

Nunatsiavut: At their request, an article was submitted to the Government of Nunatsiavut (Mary Denniston) summarizing the results of research on contaminants in the George River caribou herd, for inclusion in the Government Newsletter.

General: 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.

Table 1. Renal element concentrations (Mean + Standard deviation) in Tay caribou $\mu g \cdot g^{-1}$ dry weight). * indicates a significant difference between the two collections.

	1993 Females			2010 Males		
N	20			7		
Arsenic	0.07	±	0.06	0.02	±	0.01
Cadmium	118.0	±	91.3	183.5	±	78.3
Copper	22.4	±	2.0	24.1	±	1.6
Lead	1.47	±	0.64	0.06	±	0.06
Mercury	3.26	±	0.87	4.23	±	0.95
Selenium	7.62	±	1.05	5.96	±	0.75
Zinc	126.2	±	16.6	163.8	±	20.2

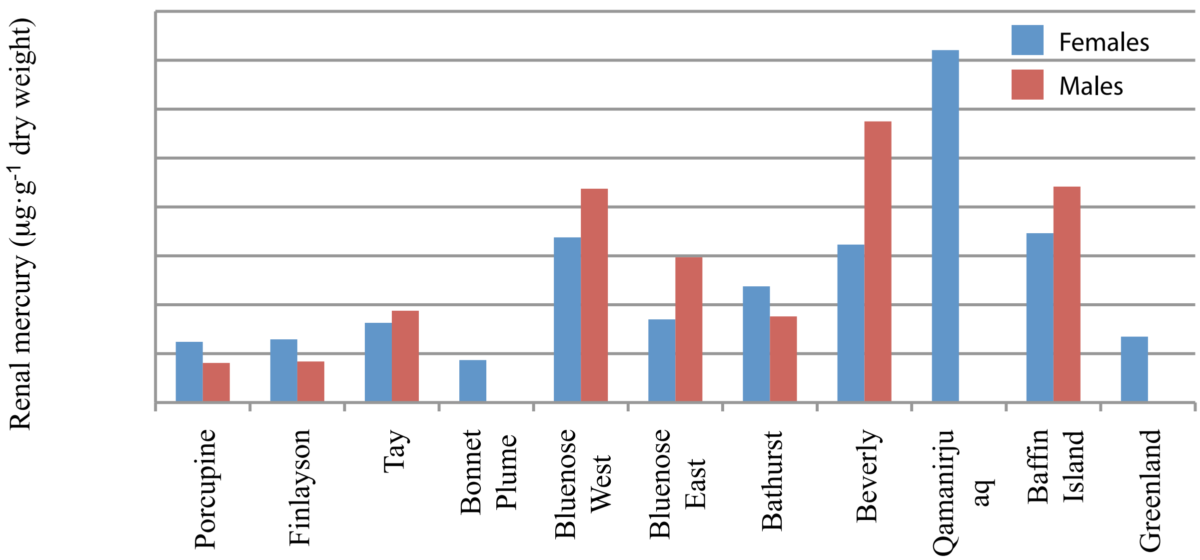
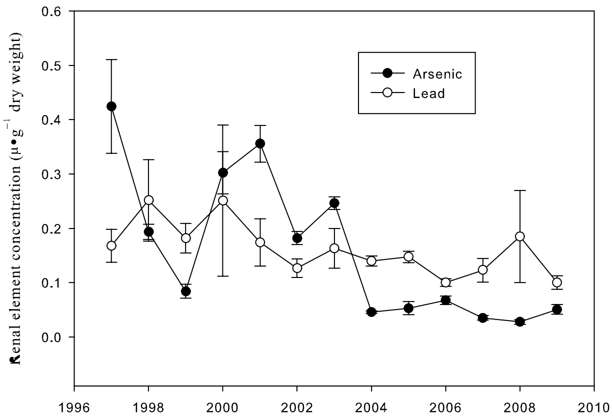


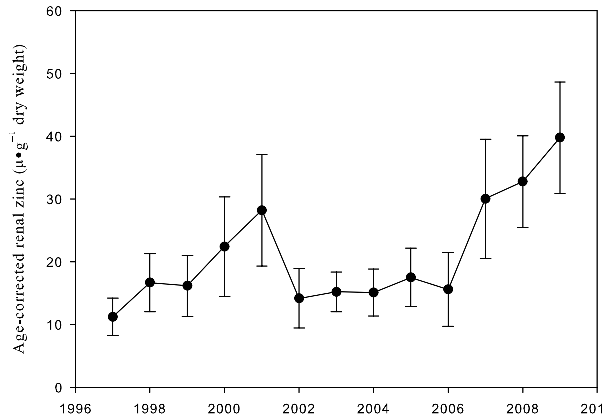
Figure 1. Comparative data for renal mercury in spring-collected caribou. Data from Gamberg (unpublished data) and MacDonald et al. (2002).

Results and Discussion

Although cadmium concentrations in the Tay caribou (Table 1) are higher than would be considered normal for domestic cattle, concentrations did not differ between the two years of collection and previous research has concluded that high levels of cadmium occur naturally in this geographical area and are not caused by anthropogenic sources (Braune et al. 1994).

Significant differences between years of collection in renal levels of arsenic, lead, mercury, selenium and zinc (Table 1) may be due to gender differences or differences between years. For the most part these elements are not thought to be at toxic or deficient concentrations. However, magnesium concentrations found in the Tay caribou from 2010 (renal concentration average=935 $\mu g \cdot g^{-1}$ dry weight) would be considered 'excessive' for domestic cattle (Puls 1994). It is unknown whether this applies to wild caribou. In general





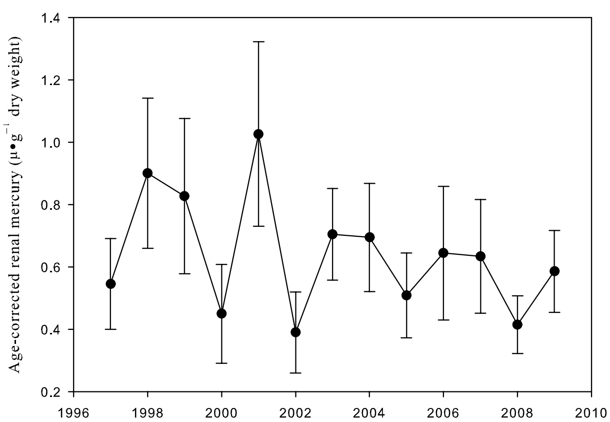


Figure 2. Renal element concentrations in male fall-collected Porcupine caribou from 1997–2009.

woodland caribou tend to have higher levels of magnesium than barren-ground caribou and caribou from the western Arctic tend to have higher levels of this element than those from the eastern Arctic (Gamberg, unpublished data). Although magnesium toxicity is possible, it is an essential element that is homeostatically controlled within the body and magnesium toxicity in natural environments is rare.

Renal concentrations of mercury in the Tay caribou were higher than those found in the Porcupine caribou, but similar to those found for several barren-ground herds in NWT (Figure 1). Most mercury data exists for fall-collected caribou, and in those cases females usually have higher concentrations of mercury than males. However, the limited data that exists for spring-collected animals often shows higher concentrations of mercury in males than females. This is likely due to parturition, since some of the mercury from the mother is transferred to the fetus and even more is eliminated from the body during milk production. So females would likely experience a drop in their mercury concentrations while pregnant and nursing (spring) whereas males would not.

The difference in mercury concentrations between the two sampling times for the Tay caribou could also represent a change between the two years (1993 and 2010). It is important to note that even if this is the case it does not necessarily mean that mercury concentrations are rising in this caribou herd. Research on the Porcupine caribou herd indicates that mercury in that herd cycles over time and selecting just two points within any cycle to determine a trend could yield erroneous results. Further annual sampling of the Tay herd would be required to determine whether mercury levels are increasing, decreasing or stable over time.

While there is a significant negative correlation between year of collection and both renal arsenic and lead concentrations in male, fall-collected Porcupine caribou (Figure 2), the absolute decline is small and particularly in the case of arsenic, may reflect an increased ability for the laboratory detection of smaller amounts of the element rather than an actual decline in the caribou over time.

Zinc is positively correlated with age and is increasing in these caribou over time. It is not clear why this increase is occurring, but Figure 2 shows that while concentrations were low from 2002-06, levels since then have continued to increase. It is not likely that this increase is of concern toxicologically at this point. Zinc is an essential and homeostatically controlled element and is unlikely to occur at toxic levels in a natural environment. Even the highest levels seen in these caribou do not approach levels that are thought to be toxic for domestic cattle (Puls 1994). Nevertheless, continuing to monitor zinc in the herd would be prudent.

Neither cadmium nor mercury are increasing or decreasing significantly over time. Figure 2 shows age-corrected data for renal mercury over time and demonstrates high variability for any given year. While cadmium and zinc increase with the age of both genders of caribou, mercury increases with age in female caribou but decreases with age in male caribou (Figure 3). It is of note that both genders start life with approximately the same concentrations of mercury, then over time male caribou experience a net loss while females experience a net gain, even though females have the additional mercury elimination routes of the fetus and lactation. This is likely due to the greater relative intake of mercury by female caribou. Their smaller body size requires almost as much food (and hence mercury) intake as the larger males, so concentrations are inherently higher (Gamberg 2009). Over time, females apparently ingest more that they can eliminate resulting in increasing concentrations with age, whereas the opposite occurs in males.

Contaminants of concern in the Porcupine caribou are generally stable over time, although the increase in zinc should continue to be monitored. Levels of most elements measured in both the Porcupine and Tay caribou herds were not of concern toxicologically, although renal mercury and cadmium concentrations may cause some concern for human health depending on the quantity of organs consumed. Yukon Health has advised restricting intake of kidney and liver from Yukon

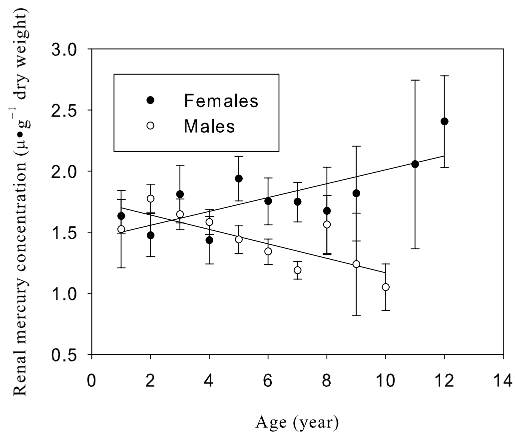


Figure 3. Renal mercury concentrations in Porcupine caribou.

caribou, the recommended maximum varying depending on herd (e.g. a maximum of 7 kidneys/year from the Tay herd or 32 Porcupine caribou kidneys/year). The health advisory confirms that heavy metals are very low in the meat (muscle) from caribou and this remains a healthy food choice.

NCP Performance Indicators

Number of northerners engaged in this project: 5

Number of meetings/workshops held in the north: 2

Number of students involved in this project: 1

Number of citable publications: 1 anticipated (in addition to NCP synopsis report)

Expected Project Completion Date

This program is ongoing.

Acknowledgements

Many thanks to Alpine Aviation who have supported this project over the years, and to Yukon Environment staff, especially Tena Fox, Krista Funk and Angela Milani. Thanks also to Xiaowa Wang from NLET for meticulous handling of our samples. I would 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, Department of Northern Affairs and administered by the Yukon Conservation Society.

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Mercury Input to the Beaufort Sea from the Mackenzie River

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Abstract

Concentrations of toxic monomethyl mercury (MeHg) in the tissues of marine mammals living in Canada's Beaufort Sea (Arctic Ocean) can be above those recommended for human consumption. Several factors likely contribute to MeHg contamination of these mammals, however the large volume of sediment-rich water delivered by the Mackenzie River (MR) cannot be overlooked as a potential source of mercury (Hg) contamination to this region. Currently, it is not known how much Hg is delivered from the MR each year and therefore the river remains an important, yet unmeasured, source of Hg to the Beaufort Sea. We have been sampling surface waters from the lower MR and its delta channels for total Hg (THg; all forms of Hg in a sample) and MeHg since 2004 to help establish a long-term dataset of Hg delivery from the MR. There are two overarching goals of our ongoing research and monitoring program. First, we will accurately measure the amount of THg and MeHg delivered annually by the MR to the Beaufort Sea using a dynamic ice-jam flow model through a partnership with the International Polar Year Project *Study of Canadian Arctic River-delta Fluxes* (IPY-SCARF). Secondly, we will quantify the influence of the

Résumé

Les concentrations du méthylmercure (MeHg) toxique dans les tissus des mammifères marins vivant dans la mer de Beaufort (océan Arctique) au Canada peuvent être supérieures aux niveaux recommandés pour la consommation humaine. Plusieurs facteurs contribuent probablement à la contamination au MeHg de ces mammifères, cependant on ne peut pas passer outre au grand volume d'eau riche en sédiments amené par le fleuve Mackenzie (FM) comme étant une source potentielle de contamination au mercure (Hg) dans la région. Actuellement, on ne connaît pas la quantité de Hg amenée par le FM chaque année. Le fleuve reste donc une source importante, mais non mesurée, de Hg pour la mer de Beaufort. Nous avons échantillonné les eaux de surface du bas Mackenzie et des canaux du delta pour évaluer les niveaux totaux de Hg (HgT; toutes les formes de Hg dans un échantillon) et de MeHg, et ce, depuis 2004 afin d'aider à établir un ensemble de données à long terme du Hg amené par le FM. Notre programme continu de recherche et de surveillance comprend deux objectifs très importants. Premièrement, nous mesurerons précisément la quantité de HgT et de MeHg amenée annuellement par le FM à la mer de

ecologically-rich, yet rapidly changing, floodplain of the Mackenzie River Delta (MRD) on the delivery of Hg from the MR. Here we present preliminary results from our sampling program including multi-year filtered and unfiltered THg and MeHg concentrations in river water from several locations throughout the MRD.

Beaufort en utilisant un modèle dynamique du mouvement des embâcles, et ce, grâce à un partenariat avec le projet mené dans le cadre de l'API Étude des flux dans les deltas fluviaux de l'Arctique canadien. Deuxièmement, nous quantifierons l'influence de la plaine inondable du delta du fleuve Mackenzie (DFM), une région écologique très riche qui change néanmoins très rapidement, sur le Hg amené par le FM. Nous présentons ici les résultats préliminaires tirés de notre programme d'échantillonnage, y compris les données pluriannuelles sur les concentrations filtrées et non filtrées de HgT et de MeHg dans les eaux du fleuve puisées à plusieurs lieux dans le DFM.

Key Messages

i) In Canada's MR, strong seasonal fluctuations in river flow, its large and diverse watershed, effects of ice and large floodplain areas combine to determine Hg concentrations and export to the Beaufort Sea.

ii) Concentrations of Hg in MR water are very low but the total amount of Hg exported from the MR to the Beaufort Sea annually is currently poorly constrained.

Messages clés

i) Dans le fleuve Mackenzie (FM) au Canada, les fortes variations saisonnières dans le débit fluvial, le bassin hydrologique grand et diversifié, les effets de la glace et des vastes aires de plaines inondables se cumulent pour déterminer les concentrations de Hg et les quantités amenées dans la mer de Beaufort.

ii) Les concentrations de Hg dans les eaux du FM sont très faibles, mais la quantité totale de Hg amenée annuellement du FM à la mer de Beaufort est actuellement mal restreinte.

Project Objectives

i) To generate accurate annual THg and MeHg flux estimates from the Mackenzie River to the Beaufort Sea.

ii) To assess the biogeochemical influence of the ecologically-rich floodplain of the MRD on the delivery of THg and MeHg from the Mackenzie River to the Beaufort Sea.

iii) To assess changes in THg and MeHg export from the Mackenzie River over time using our long-term dataset (2004–2010).

Introduction

The increasing Hg pool in Arctic ecosystems has impacted local wildlife and indigenous communities due to the bioaccumulation of toxic MeHg in mammals and fish (1–2). Hg contamination of marine foodwebs has been an especially important issue in the Mackenzie River (MR) coastal region of Canada's western Arctic where flesh of beluga whale (*Delphinapterus leucas*) and liver tissue from ringed seals (*Pusa hispida*) often contain concentrations of Hg well above those recommended for human consumption (0.5 μg/g wet wt., 3–5). Much of the near shore habitat of these marine mammals is influenced by discharge from the large, sediment rich MR (6).

To thoroughly understand Hg sources to and cycling processes within the Beaufort Sea ecosystem, the substantial influence of the MR outflow on the coastal marine habitat cannot be overlooked. For example, the MR is the largest riverine source of sediment and the fourth largest contributor of river water to the Arctic Ocean. Though much of the Hg exported from the MR is particulate-bound inorganic Hg(II) (7) rather than MeHg, the specific sources of MeHg to Beaufort foodwebs are not well characterized.

The degree to which 1) riverine Hg(II) inputs influence Hg methylation in the Beaufort and 2) direct riverine MeHg inputs contribute to food-web contamination remain completely unknown. Despite its wide biogeochemical influence across the Beaufort Sea, the amount of Hg delivered by the MR to this habitat is poorly constrained.

The geography, hydrology and climate of the MR create an extremely challenging environment for proper measurement of river flow, and by association, export of Hg(II) and MeHg. Three main factors have complicated previous attempts to accurately quantify Hg export from the MR. First, historical Hg flux estimates do not appropriately account for ice breakup effects during annual snowmelt-related high flows in spring. During ice breakup, channel cross sections become filled with varying amounts of moving and jammed ice, which compromise discharge-water level relationships during this month-long period. Secondly, water Hg concentrations during the rising limb of the annual hydrograph (which generally corresponds the period of ice breakup) have never been adequately characterized because of sampling challenges. This important period corresponds to the highest rates of sediment transport and nutrient and Hg export during the year (*8–10*). Finally, historical Hg flux measurements fail to account for effects that the MRD may exert on river water chemistry. The MR main stem breaks into numerous river channels just downstream of the town of Tsiigehtchic, NT and flows 200 km downstream through the vast MRD floodplain before discharging to the Beaufort Sea. The MRD floods annually in the late spring during peak river flows on the MR and temporarily holds river water in its lakes and wetlands until high water passes. During this storage period, physical and biological activity in these lakes and wetlands can alter the biogeochemistry of the water before it drains back into the river. Individual floodplain lakes are sites of net MeHg production for a portion of the open water season and they may play a role in altering MeHg concentrations in river water leaving the delta environment (*10*). Preliminary evidence indicates that these delta effects may be large enough to influence the delivery of both THg and MeHg to the coastal region.

We proposed to generate improved, multi-year estimates of dissolved and particulate (as estimated by the difference between unfiltered and filtered water Hg concentrations) THg and MeHg export from the MR to the Beaufort Sea. To address the shortcomings associated with previous flux estimates described in the previous section, we proposed to: 1) expand temporal sampling of the MR to include under-ice (early May), freshet and open water periods, 2) use modeled river flows that integrate ice effects, flooding of delta lakes and wetlands, and storm surges from the coastal Beaufort Sea by partnering with collaborators from the International Polar Year-Study of Canadian Arctic River-delta Fluxes (IPY-SCARF), and 3) perform extensive water sampling of the MR both *upstream and downstream* of the delta to integrate delta effects on export of THg and MeHg to the Beaufort Sea. In addition to better characterising inputs of THg and MeHg from the MR to the Beaufort Sea, our research has also provided a rare and valuable long-term monitoring dataset (2004, 2007–2010) against which future changes in Hg export from the MR can be measured. The MRD is changing rapidly due to climate change (*11*) and is also poised to become a centre of oil and gas development related to the future Mackenzie Gas Project.

Activities in 2010–2011

In 2010, we collected surface water samples from the two largest rivers entering the MRD (Mackenzie and Peel rivers), one mid-delta site (MR at Horseshoe Bend) and two of the largest channels exiting the MRD to the coastal Arctic Ocean (Reindeer, Middle Channel at Langley; Figure 1a). We sampled both inflow rivers fourteen times between early May and late September, weighting ten of the samples during the high flow period (May–June). Mid- and lower-delta sites were sampled during five helicopter surveys throughout May 2010. Three delta lakes of different elevations (L129, L56 and L520) were sampled 4 times in June 2010 to evaluate the influence of temporary river water storage in delta lakes on Hg speciation and concentration. All samples were collected using trace-level sampling methods (e.g. clean-hands, dirty-hands technique). All 2010 filtered and unfiltered THg and MeHg samples have been analyzed and average filtered and unfiltered THg concentrations in the Mackenzie River and Peel River have been included in the upcoming CACAR report (*12*).

Capacity Building and Training:
A postdoctoral researcher (Jennifer Graydon) and Ph.D. candidate (Craig Emmerton) have been the principal investigators on this project. Collaborative field sampling was organized by a Ph.D. candidate from Simon Fraser University (SFU) (Jolie Gareis). Additional field help was provided by a full-time undergraduate summer student (Larissa Duma; working towards an undergraduate degree in Biology and Environmental Science from SFU). Larissa was first employed by the SFU team on their larger project in 2008. Her 2010 field work was progressive training and experience (i.e., she had additional responsibilities and performed more difficult analytical work this summer). Technical support was provided by Valery Bazira Girishaka and Crystal Raab in the *University of Alberta Biogeochemical Laboratory Low-level Mercury (Hg) Analytical Unit*.

Our work, in combination with IPY-SCARF work by the SFU team, trained local assistants in the collection of trace-level metals from surface waters. This experience should prove valuable to local field assistants in light of expanding oil and gas exploration and possible extraction in the MRD region. Oil and gas activity will most certainly require stringent water quality sampling across the region which will often involve sampling of trace level organic and metal contaminants. A total of 4 northerners assisted with the field work for this project during the summer of 2010; one technician from the Aurora Research Institute (ARI) (Donald Ross, Inuvialuit beneficiary) was hired for one day of field work. Donald assisted with water sampling during one helicopter survey of the MRD during ice-breakup and learned new skills including trace metal sampling techniques and the use of a Teflon Kemmerer water sampler. Two summer students from ARI and one volunteer also assisted at different times with lab work including preparation of lab-ware and sample bottles.

Communications:
During the process of applying for an NWT science license for this work through the ARI, we communicated with and received feedback on our proposal from stakeholders and communities in our study area. Groups that responded with comments on our application included the Aklavik Hunters and Trappers Committee (AHTC) and the Tuktoyaktuk Hunters and Trappers Committee (Tuk HTC). We are currently in the process of assembling our 2010 NWT science licence report which will be compiled (the NWT research compendium, assembled by ARI) and distributed to all communities and organizations in the NWT. We have been in contact with our SFU collaborator in charge of field sampling (Jolie Gareis; currently employed at ARI) and she has offered to post a plain language poster that summarizes our research in the Western Arctic Research Centre. This poster will describe our research in basic terms, and will be translated for the community members to understand. This poster is currently under construction and will first be sent to the NWT RCC for feedback prior to printing to ensure that the way in which our research is presented is appropriate and helpful to the community.

We have presented our research results in poster format at meetings attended by northern community members, including: 1) the 18th Annual Results Workshop of the Northern Contaminants Program (INAC) in Whitehorse, Yukon, September 28–30, 2010 and 2) Understanding Circumpolar Ecosystems in a Changing World: Outcomes of the International Polar Year. University of Alberta Conference Centre, Edmonton, Alberta, 3–6 November 2010. Shortly, we will be presenting our research results at the upcoming International Conference on Mercury as a Global Pollutant to be held in Halifax, N.S. in July 2011. Of course, our results will also be published in annual NCP synopsis and CACAR reports (*12*) and in peer-reviewed scientific journals.

Traditional Knowledge:
Over the past four years, our field sampling crew has relied on the local expertise of Inuvialuit and G'wichen peoples as assistants during field sampling trips of the Mackenzie, Peel and delta channels. Their assistance was especially crucial during ice-influenced samples where reading ice conditions and auguring was required.

Results, Discussion and Conclusions

Rivers with strong seasonal changes in flow often show a positive correlation between river Hg concentrations and water flow (*13–15*). Hg bound to organic-rich material in soils and Hg in rock minerals are mobilized when runoff water contacts soils and erodes surface materials during downstream travel. In the MR, both filtered and unfiltered THg and MeHg concentrations are closely linked to river flow during the ice breakup and open water seasons from May to September (*7*, *10*, Figure 1).

Winter low flow: Hg immobilization

Since surface water movement is minimized during the winter, little watershed material is transported into the MR and its tributaries. The MR itself is ice-covered during this time and receives particle and Hg-poor water from oligotrophic lakes and deeper groundwater. During under-ice, low flow conditions in early May, both THg (filtered 1.0±0.9 ng L^{-1} and unfiltered 7.8±6.3 ng L^{-1}) and MeHg (filtered 0.02±0.01 ng L^{-1} and unfiltered 0.04±0.01 ng L^{-1}) concentrations in the lower MR were generally low (Figure 1). Hg concentrations during early May were approximately 2–8 times lower than concentrations during higher river flow periods later in spring.

Spring freshet high flows: Watershed Hg mobilization and the role of particles and organic matter

Hg concentrations in the MR are overwhelmingly dominated by particle-bound Hg, originating mostly from mountain-fed rivers (*7*). Rivers draining mountain areas are efficient at eroding catchment and bank material and mobilizing elements that associate closely with particles, including Hg (*13*). Rivers draining the mountainous western MRB flow intensely during the short snowmelt season and deliver large quantities of suspended rock and soil material. These mountainous tributaries (e.g., the Peel and Liard Rivers) can have up to two times higher particle-bound Hg concentrations than the low-relief, plains-influenced MR (7; Figure 1). After integrating water from flashy mountain tributaries and the effect of in-channel ice scour, Hg in the lower MR is predominantly particle-bound (73–87%, 7; Figure 1). Huge increases in dissolved and particulate THg and MeHg (2–3 fold) are observed in the river during the spring thaw period compared to summer lower flow when mountain rivers deliver much less water to the MR (*7*, *10*, Figure 1). Hg concentrations in other arctic river systems show a similar flow and particle-driven response (*16–17*). There is also evidence of DOC-bound Hg export from rivers with extensive wetland and organic soil influences within their watershed (e.g., *17–18*). The MRB has wetlands and organic-rich soils (*19*) that contribute water to the MR during the snowmelt period. DOC concentrations are also highest in the MR during the freshet period (*8*, *20*).

Summer and Autumn declining flows: event-driven mobility of Hg

After the ice clears and river discharge peaks, runoff within the MRB originates from lower in the soil profile and erosion decreases as river velocities and water levels decrease. These factors combine to deliver less organic matter and sediment to the river water and THg and MeHg concentrations decline rapidly (*7*, *10*). Throughout the summer, precipitation events in the MRB can mobilize organic matter and sediment through surface runoff and increase Hg concentrations in the MR for short periods of time. There is also evidence of post-freshet mid-summer spikes in Hg concentration in the lower MR as high as freshet concentrations, possibly due to coastal storm surges (Figure 1). These storms create dynamic backwater conditions in the lower MR and its delta floodplain which can erode and flood low-lying organic s oils and increase Hg concentrations locally.

Delta Lakes

THg concentrations were highest in the lake continuously connected to the river and decreased up the lake elevation gradient (2010). Mean MeHg concentrations were similar in the lakes continuously and intermittently connected to the river channel and lower in the lake that did not flood in 2010 (Figure 2).

Discussion and Conclusions

While filtered and unfiltered THg and MeHg concentrations in MR channels and lakes are very low and show strong seasonal patterns (as discussed above), it is difficult to put

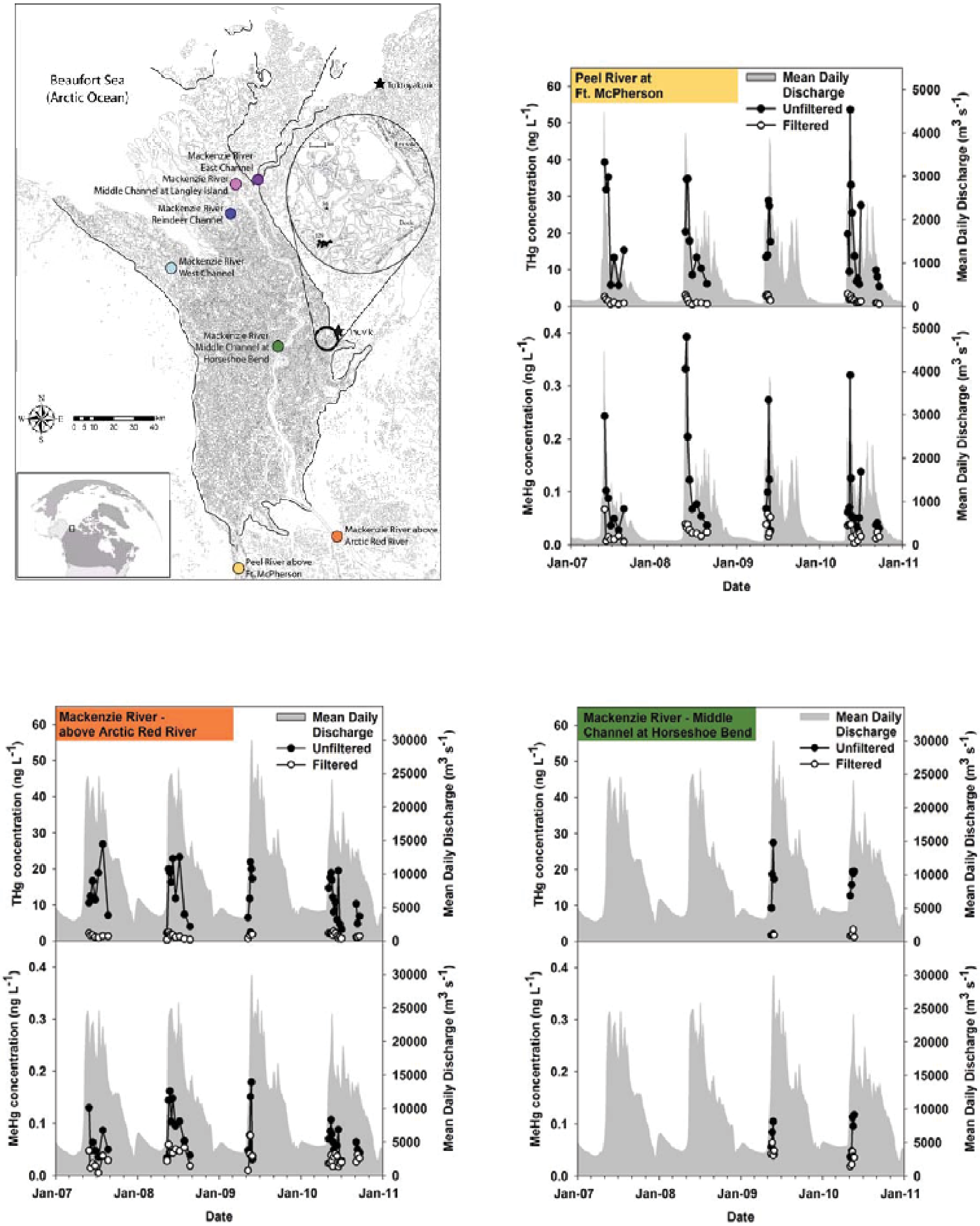

Figure 1: a) Location of river sampling sites upstream and downstream of the MRD and locations of 3 delta lakes sampled in 2010 near Inuvik. Colours of site indicators in a) correspond to subsequent graphs of the same colour. Filtered and unfiltered THg and MeHg concentrations of river water from b) Peel River at Ft. McPherson and Mackenzie River c) above Arctic Red River, d) Middle Channel at Horseshoe Bend, e) West Channel, f) Reindeer Channel, g) Middle Channel at Langley Island and h) East Channel. River flow data is for MR at Arctic Red River except in case of b) Peel River at Ft. McPherson.

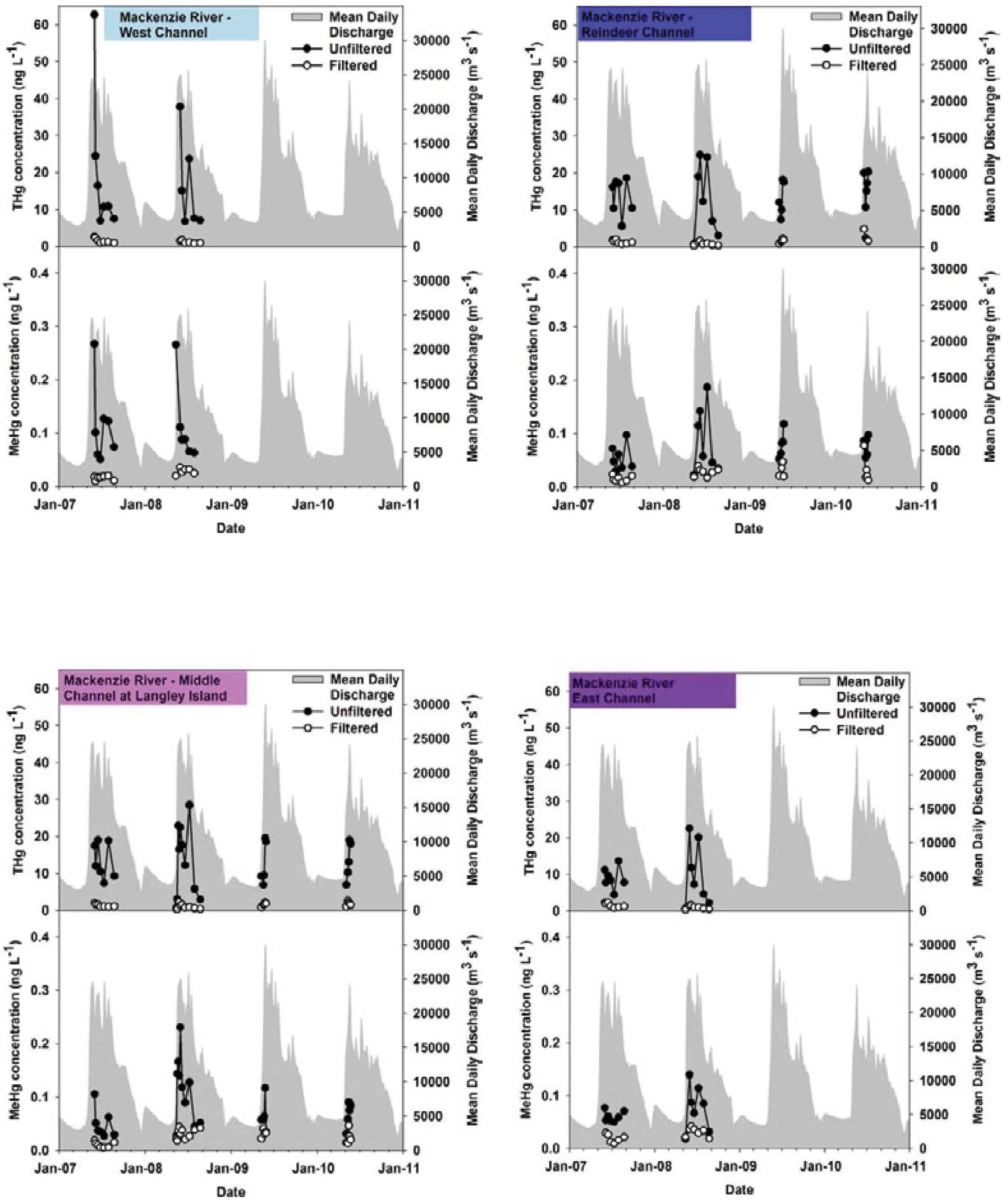

Figure 1 (continued): a) Location of river sampling sites upstream and downstream of the MRD and locations of 3 delta lakes sampled in 2010 near Inuvik. Colours of site indicators in a) correspond to subsequent graphs of the same colour. Filtered and unfiltered THg and MeHg concentrations of river water from b) Peel River at Ft. McPherson and Mackenzie River c) above Arctic Red River, d) Middle Channel at Horseshoe Bend, e) West Channel, f) Reindeer Channel, g) Middle Channel at Langley Island and h) East Channel. River flow data is for MR at Arctic Red River except in case of b) Peel River at Ft. McPherson

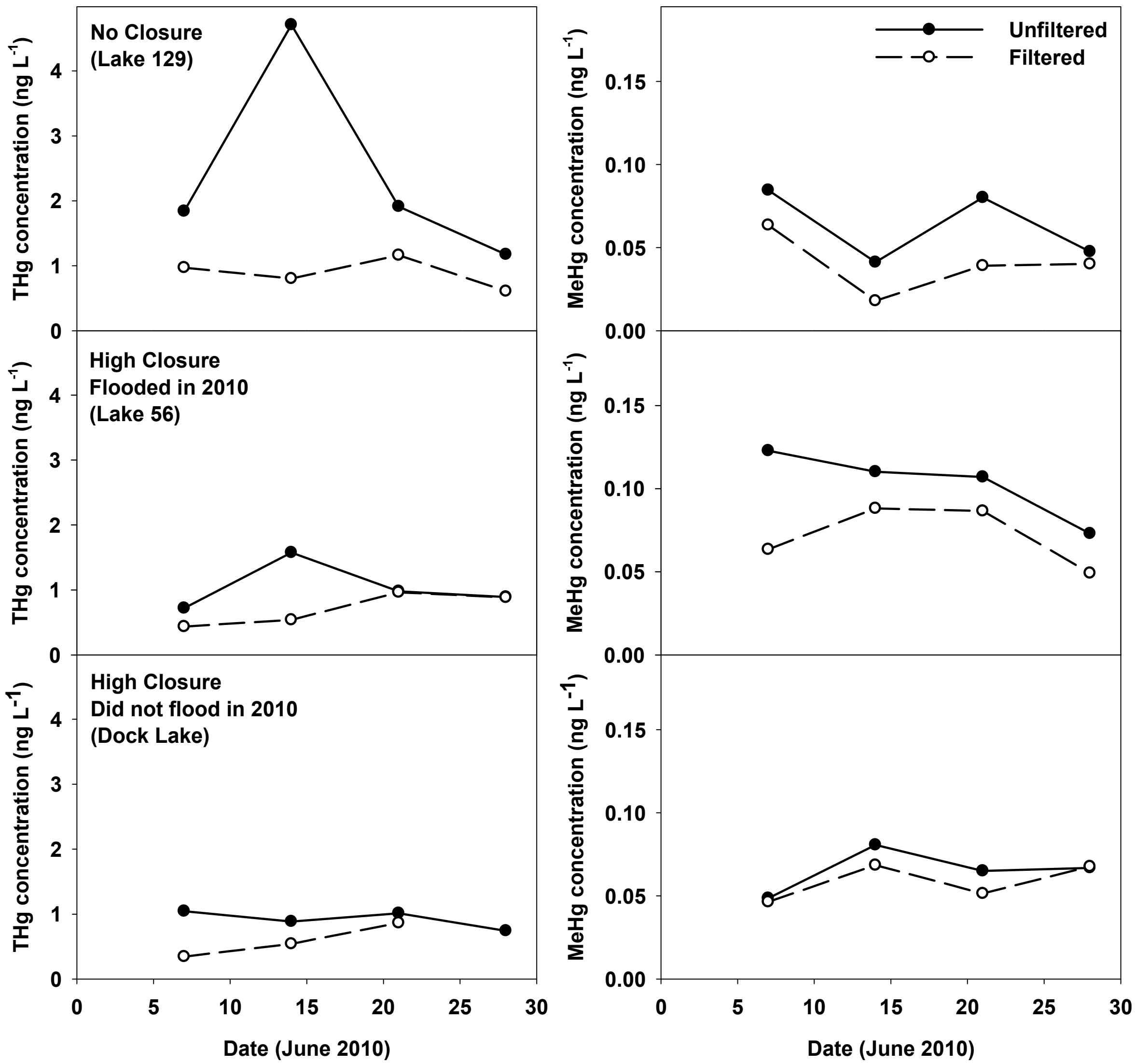

Figure 2: Filtered and unfiltered THg (left column) and MeHg (right column) in three delta lakes in June 2010. Most MRD lakes flood annually with the degree of flooding depending on sill elevation relative to river water level. No-Closure lakes (~60%) always flood in spring and continue to exchange water with channels during summer. Low-Closure lakes (~25%) flood each spring and rarely re-flood during summer. High-Closure lakes (~ 15%) are not necessarily flooded each spring and never in summer.

these concentration data in a broader context because, at this early stage, we lack final estimates of MeHg and THg export to the Beaufort Sea. To generate an accurate estimate of THg and MeHg flux from the Mackenzie River to the Beaufort Sea, we require accurate annual estimates of river flow emerging from delta river channels. Our collaborative partners with the IPY-SCARF project (Dr. Faye Hicks and Jennifer Nafziger, Department of Civil and Environmental Engineering, University of Alberta) are addressing this issue through the development and calibration of an enhanced one-dimensional network model (Mackenzie Delta Hydrodynamic Model; HDHM) based on the public domain *RIVER1D* model. This model will estimate total river flow from river channels at the mouth of the MRD and will integrate several complex processes that have not been previously assessed on the Mackenzie River. The model will incorporate several dynamic processes including: 1) ice jamming in delta river channels which create complex flow conditions which retard and dam flow upstream during this critical high flow period; 2) ice cover development and decay in river channels due to thermal influences during ice breakup; 3) storm surges which push Beaufort Sea water into the delta and alter river flow during storm events; and 4) storage of river water in MRD floodplain lakes and wetlands during high flow periods using the help of newly acquired high-resolution topography data from recent LIDAR flights in the MRD. We have been in close contact with our University of Alberta colleagues throughout this past year. They are making good progress towards having a functional and useable Model (HDHM). We will use this model in conjunction with our THg and MeHg concentration data to generate improved annual (2007–2010) export estimates for THg and MeHg from the MR to the Beaufort Sea.

NCP Performance Indicators

The number of northerners engaged in your project: 4

The number of meetings/workshops you held in the North: 1 (attended)

The number of students (both northern and southern) involved in your NCP work: 5

The number of citable publications (e.g., in domestic/international journals, conference publications, book chapters, etc…): 4

Expected Project Completion Date

The field and laboratory components of this study are already complete and we are hoping to have the model results integrated with our concentration data and a manuscript published within the next year (before April 2012).

Acknowledgments

This research program was funded by the Northern Contaminants Program and the Natural Sciences and Engineering Research Council of Canada (NSERC). Additional support was provided by the Polar Continental Shelf Project, Northern Scientific Training Program (NSTP) and the Alberta Ingenuity Fund. We appreciate technical and logistical support from Les Kutny and others at the Aurora Research Institute. We also appreciate the excellent assistance provided by Canadian Helicopters and Water Survey of Canada-Inuvik. We thank the University of Alberta low-level Hg analytical laboratory for analytical support and assistance.

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Northern Contaminants Air Monitoring for Organic Pollutants and Data Interpretation

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Abstract

Air monitoring of organic pollutants has been continuously conducted at Alert, Nunavut, Canada since 1992. Time trends for α- and γ-HCH measured at Alert (1993–2008) were compared with those observed at two other Arctic stations, namely Storhofdi and Zeppelin. α-HCH shows continuous decline at all three stations with estimated halflife of approximately 4 years at all stations. γ-HCH shows accelerated decline in Arctic air after its ban in Canada, as well as globally. A novel flow-through air sampler (FTS) designed for use under cold environment, which does not require electricity to operate but can potentially capture a relatively large volume of air over a short time period (over several weeks), was deployed at Alert since October 2007 to compare its performance under Arctic conditions in parallel with the high volume air sampler for routine measurements. Comparable results were obtained for several organochlorine pesticides (OCPs), polybrominated diphenyl ethers (PBDEs) and new flame retardants (FRs), indicating the feasibility of the FTS under extreme conditions. Stain-repellent-related perfluorinated compounds measured in air at Alert showed no consistent

Résumé

La surveillance des polluants organiques dans l'atmosphère est effectuée continuellement à Alert (Nunavut), Canada depuis 1992. Les tendances temporelles pour α-HCH et γ-HCH mesurées à Alert (de 1993 à 2008) ont été comparées avec celles obtenues dans deux autres stations en Arctique, soit Storhofdi et Zeppelin. Les niveaux de α-HCH ont connu un déclin continuel dans les trois stations, et la période demi-vie a été estimée à environ quatre ans dans toutes les stations. Les niveaux de γ-HCH ont connu un déclin accéléré dans l'atmosphère arctique après son interdiction au Canada ainsi qu'à l'étranger. Un nouvel échantillonneur d'air à écoulement continu a été conçu pour une utilisation dans les environnements froids. L'appareil peut fonctionner sans électricité et peut possiblement capter un volume d'air relativement élevé pendant une courte période (pendant plusieurs semaines). Il a été utilisé à Alert depuis octobre 2007 pour comparer son rendement dans des conditions comme celles de l'Arctique, comparativement à l'échantillonneur de grands volumes d'air utilisé pour les mesures de routine. Des résultats comparables ont été obtenus pour plusieurs pesticides organochlorés, l'éther diphénylique polybromé et de nouveaux

increase or decrease in trends, but levels are much lower than those previously observed in other studies. Current-use pesticides (CUPs) in air at Alert showed different seasonal variations which may reflect their usage pattern in the south. Fungicide pentachloronitrobenzene (PCNB) measured in air at Alert showed similar seasonal cycles as those observed in the Great Lakes region indicating rapid atmospheric transport to the Arctic.

produits ignifuges, ce qui indique la viabilité de l'échantillonneur d'air à écoulement continu dans des conditions extrêmes. Les composés perfluorés liés aux apprêts antitaches mesurés dans l'atmosphère à Alert n'ont démontré aucune tendance à la hausse ou à la baisse, mais les niveaux sont très inférieurs à ceux observés lors d'autres études. Les mesures des pesticides utilisés actuellement prises dans l'atmosphère à Alert ont montré différentes variations saisonnières qui pourraient être le reflet des modèles d'utilisation dans le Sud. Les niveaux de fongicide pentachloronitrobenzène mesurés dans l'atmosphère à Alert ont montré des cycles saisonniers similaires à ceux observés dans la région des Grands Lacs, ce qui indique un transport atmosphérique rapide vers l'Arctique.

Key Messages

1. Arctic air concentration of legacy pesticide α-hexachlorocyclohexane (α-HCH) continues to decline with time at 3 long-term arctic air monitoring stations. The air concentration of pesticide lindane (γ-HCH), which was banned globally in May 2009 and deregistered for use in Canada on canola seeds in July 2001, is declining faster after 2002 as compared to earlier measurements.
2. The reliability of FTS as a quantitative sampling technique under Arctic environment continued to be tested. The observed results for organochlorine pesticides and brominated flame retardants were comparable with those measured using the active sampling method.
3. Current-use pesticides measured in air at Alert showed differences in seasonal patterns which are likely related to the timing of their applications in the south and are carried by air currents to the Arctic.
4. Stain-repellent-related perfluorinated compounds measured in air at Alert from 2005 to 2009 do not show consistent increasing or decreasing time trends. Continuous monitoring is required to assess how effective global control measures are on their emissions.

Messages clés

1. La concentration dans l'atmosphère de l'Arctique d'anciens pesticides α hexachlorocyclohexane (α-HCH) continue de diminuer avec le temps dans les trois stations de surveillance de l'atmosphère à long terme dans l'Arctique. La concentration dans l'air du pesticide lindane (γ-HCH), qui a été banni à l'échelle planétaire en mai 2009 et avait perdu son agrément pour l'utilisation au Canada sur les graines de canola en juillet 2001, chute plus rapidement depuis 2002 comparativement aux mesures faites auparavant.
2. La fiabilité de l'échantillonneur d'air à écoulement continu à titre de technique quantitative d'échantillonnage dans l'environnement de l'Arctique est encore à l'essai. Les résultats observés pour les pesticides organochlorés et les produits ignifuges bromés ont été comparables à ceux mesurés en utilisant la méthode de l'échantillonnage actif.
3. Les pesticides utilisés actuellement mesurés dans l'atmosphère à Alert ont présenté des différences dans les modèles saisonniers qui sont liés au moment de leur utilisation dans le Sud, puis à leur transport par les courants atmosphériques jusqu'à l'Arctique.
4. Les composés perfluorés liés aux apprêts antitaches mesurés dans l'atmosphère à Alert de 2005 à 2009 n'ont démontré aucune tendance constante de période de hausse ou de baisse. Une surveillance continue est nécessaire pour évaluer l'efficacité des mesures globales de contrôle sur leurs émissions.

Objectives

1. To operate a major long-term trend measurement station at Alert, Nunavut (in operation since 1992), to contribute to future assessments by the Northern Contaminants Program and the Arctic Monitoring and Assessment Programme (AMAP), and to advise Canadian decision- and policy-makers in preparing contaminant control strategies.
2. To measure and understand the occurrence and trends of selected OCs, PAHs, and PCBs in the Arctic atmosphere and to determine whether concentrations are changing in response to national and international initiatives.
3. To develop new technologies for monitoring emerging chemicals, including current-use pesticides, perfluorinated compounds and brominated flame retardants, in air at Alert.
4. To provide insight into contaminant pathways (sources, transport, transformation, and removal processes) to the Arctic environment.
5. To enable validation of models of toxic chemicals in the Arctic environment with atmospheric observations.

Introduction

Atmospheric measurements of organic pollutants, including polychlorinated biphenyls (PCBs), organochlorine pesticides (OCPs) and polycyclic aromatic hydrocarbons (PAHs), have been conducted at Alert, Nunavut, since 1992. In this report, updated time trends of banned pesticides, α- and γ-HCH, measured at Alert up to 2008 are shown in comparison with those measured at two other arctic stations under AMAP. In 2004–2005, an 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 organochlorine pesticides (OCPs), polybrominated diphenyl ethers (PBDEs) and new flame retardants (FRs) measured by the FTS was compared with those by the superhivol to assess its feasibility for deployment under Arctic conditions.

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

Activities in 2010–2011

Field and laboratory studies

1. Regular atmospheric measurements of OCPs, PAHs, PCBs and PBDEs continued at Alert on a weekly basis, which include field sampling, solvent extraction, clean-up, instrumental analysis, and data archive.
2. Testing work was initiated at Alert in December 2005 for the atmospheric sampling of emerging chemicals, including currently used pesticides (CUPs) and perfluorinated compounds (PFCs). Sampling generally occurred once per month from October to February and once every other week from March to September. Eighty-four sets of samples were collected in 2005–2009. Samples were analyzed for 22 CUPs and 7 PFCs (results presented below). Continuous measurements are required to examine the relative concentrations of these compounds during different seasons and what factors influence their transport to the Arctic. This information will inform national and international control initiatives of the long-range transport ability of these chemicals for potential consideration for control.
3. An FTS has been deployed at Alert since October 2007 to test the use of this type of sampler under Arctic conditions. Monthly air samples have been taken with the FTS to compare with results obtained using the superhivol (see results presented below).

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

4. The Little Fox Lake station in Yukon has been restarted in August 2007 and super-HiVol sampling ended October 2009.

5. Two papers on PAHs measured in air at the Little Fox Lake station have been published:

   Sofowote, U.M., Hung, H., Rastogi, A.K., Westgate, J.N., Su, Y., DeLuca, P., McCarry, B.E. (2010) Assessing the long-range transport of PAH to a sub-arctic site using positive matrix factorization and potential source contribution function. Atmospheric Environment, doi: 10.1016/j.atmosenv.2010.11.005.

   Sofowote, U.M., Hung, H., Rostogi, A.K., Westgate, J.N., Su, Y., Sverko, E., D'Sa, I., Roach, P., Fellin, P., McCarry, B.E. (2010) Modeling the gas/particle partitioning of polycyclic aromatic hydrocarbons collected at a sub-Arctic site in Canada. Atmospheric Environment, doi: 10.1016/j.atmosenv.2010.08.028.

6. Chemical analysis of the super-HiVol air samples collected at Little Fox Lake has mostly been completed. Data analysis is on-going.

7. With supplemental funding from IPY, a FTS was deployed at Little Fox Lake between March and May 2010 to collect air samples during the spring period with the highest probability of intercontinental transport. Many of the Asian sites operated until the end of April which will overlap with this period. The samples are currently undergoing chemical analysis.

Data interpretation

A paper titled "Atmospheric Concentrations of Halogenated Flame Retardants at Two Remote Locations: The Canadian High Arctic and the Tibetan Plateau" by Xiao et al. comparing air concentrations of PBDEs and other FRs measured at Alert with those measured at a remote lake (Nam Co Lake) on the Tibetan Plateau has been submitted for publication in Atmospheric Environment. The influence of the ''Penta-BDE'' technical mixtures is apparent at both sites. Atmospheric PBDE concentrations measured in Nam Co were generally lower than those at Alert. The lack of seasonality at Lake Nam Co suggests that FRs in Tibet do not have regional sources, reflecting global background contamination. Three new FRs, namely BTBPE, EHTeBB and TBPH were detected at relatively high concentrations at both sites, with concentrations similar to PBDEs. This is the first report of these FRs in the remote global atmosphere and suggests significant potential for long-range atmospheric transport.

A paper titled "Field evaluation of flow-through air sampler under the Arctic environment", which compares the air concentrations of OCs, PBDEs and new FRs at Alert measured by the FTS and those by the super-HiVol (Oct 2007–Nov 2008), is close to completion. Results are discussed below.

In terms of CUPs and PFCs, 84 sets of samples were collected in 2005–2009. Samples were analyzed for 22 CUPs and 7 PFCs. Preliminary trends of 4 neutral PFCs detected in air at Alert have been developed. See Results section below for details.

Time trends and air concentration data from NCP and AMAP are included in the chapter on "Observations and Capabilities" for the first POPs transport review in the Hemispheric Transport of Air Pollution (HTAP) 2010 Assessment. This assessment aims to inform the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (CLRTAP) POPs Protocol, the Stockholm Convention on POPs and other bodies on the role of transboundary transport of air pollution to assist in the assessment of trends. Printed version of the assessment will be available from UNECE in 2011.

An article titled "Releasing ghosts: Recycling toxic pollutants in the Arctic induced by climate change" is currently under review for publication. It was shown that after removing the temporal linear trends of PCBs and selected OCs measured in air at Alert and the Norwegian Arctic station of Ny-Ålesund, the residual change is strongly associated with arctic warming and ice retreat. The response of Arctic air concentrations of organic pollutants to arctic warming is dependent on their rates of exchange between air and environmental reservoirs including ocean and ice/snow.

Capacity Building

As in previous years, the NCP atmospheric organic pollutants and mercury monitoring projects have joined forces for communication and capacity building activities because they are closely related in terms of goals, facilities and technical support. Since Alert is isolated, not near any community and restricted by the military we have been challenged, in the past, to meet our capacity building and training expectations. To address these challenges we continue to work with members of the NCP management committee, the NAC and ITK to develop ideas and strategies for training and capacity building within the Alert projects. We feel that we have made considerable progress over the years in our abilities to communicate our work and have begun to disseminate this information and, in this manner build capacity, in some northern locations including Whitehorse, Skagway, Yellowknife, Anchorage and Barrow, Alaska. We welcome any recommendations as to where our communication abilities may fit within capacity building and training initiatives led by the NAC, ITK and ICC programs.

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

Outreach and Communication Activities

Hayley Hung reviewed the chapter on "Up the Food Chain: Pollution in the Arctic" for the textbook titled "Polar Science and Global Climate – An International Resource for Education and Outreach" commissioned by the International IPY Joint Committee. Dr. Hung was quoted on the back cover of the book (Kaiser, B. ed. Polar Science and Global Climate – An International Resource for Education and Outreach. Pearson Education Limited, 2010, London, UK, ix+237 pp.).

January 28, 2010 – Radio interview with Kirsten Murphy, CKLB Radio in Yellowknife

October 8, 2010 – Radio interview with Hilary Bird, CKLB Radio in Yellowknife

Hayley Hung was interviewed on how contaminants are transported to the north and activities being conducted under NCP and IPY INCATPA.

August 17, 2010 – International Air Quality Advisory Board – Expert Consultation on Northern Transboundary Air Quality Issues
Hayley Hung and Sandy Steffen presented results from NCP and IPY INCATPA.

January 18–19, 2011 – Yukon IPY Results Conference
Hayley Hung and Sandy Steffen presented results from IPY INCATPA and NCP.

January 19–21, 2011 – NWT IPY Results Conference

A plain language poster related to IPY INCATPA was presented by Ms. Alana Mero, NWT International Polar Year Coordinator, on behalf of the INCATPA team. A project summary brochure has also been sent for sharing electronically.

Traditional Knowledge

19. At this time, traditional knowledge is only indirectly related to this project. As mentioned in previous proposals, when on board the Amundsen Icebreaker, Hayley Hung participated in a Traditional Knowledge Workshop. This meeting provided insight on pollutant movement between air and open seawater.

We welcome ideas where traditional knowledge could become applicable to the baseline monitoring at Alert and Little Fox Lake as well as to the passive air sampling work in communities. The team would also appreciate any opportunity to meet with elders to discuss the application of traditional knowledge to these programs.

Results

Long-term time trends measured at Alert for α- and γ-HCH are updated and are compared with those of 2 other arctic stations, namely Storhofdi (Iceland) and Zeppelin (Svalbard/Norway) (Figure 1 and 2). Trends and seasonal cycles are derived using the digital filtration method (Hung et al., 2010). For each station and each compound, the overall estimated halflife ($t_{1/2}$), which is the time required to decline to half the original concentration, is given in the figure.

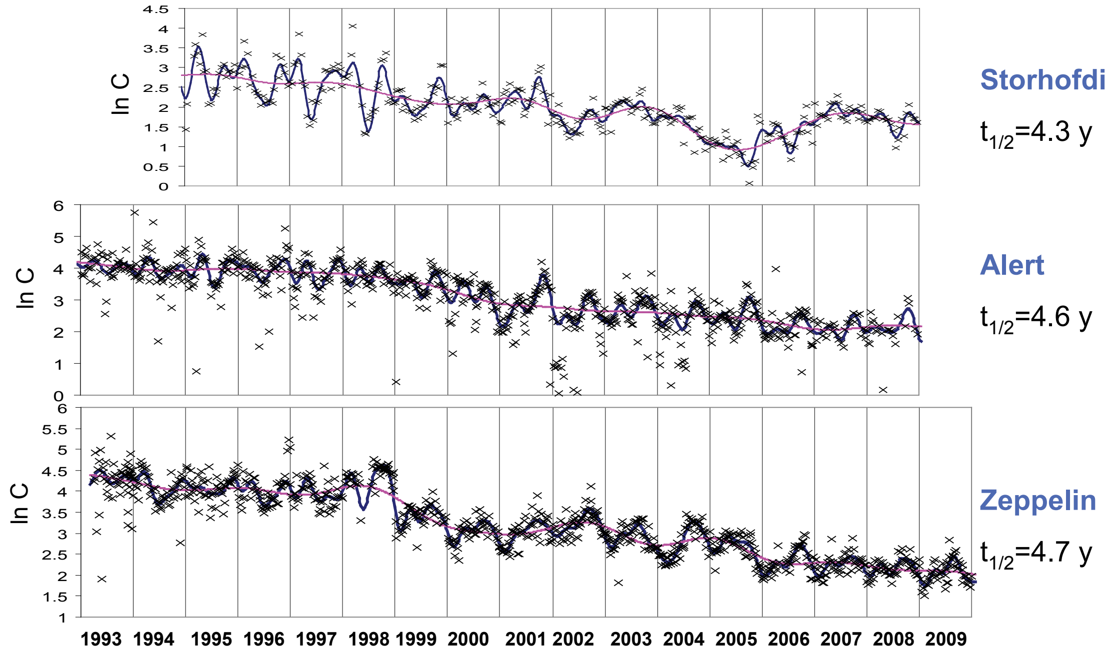

Figure 1. α-HCH time trends measured at Storhofdi, Alert and Zeppelin $t_{1/2}$=estimated halflives

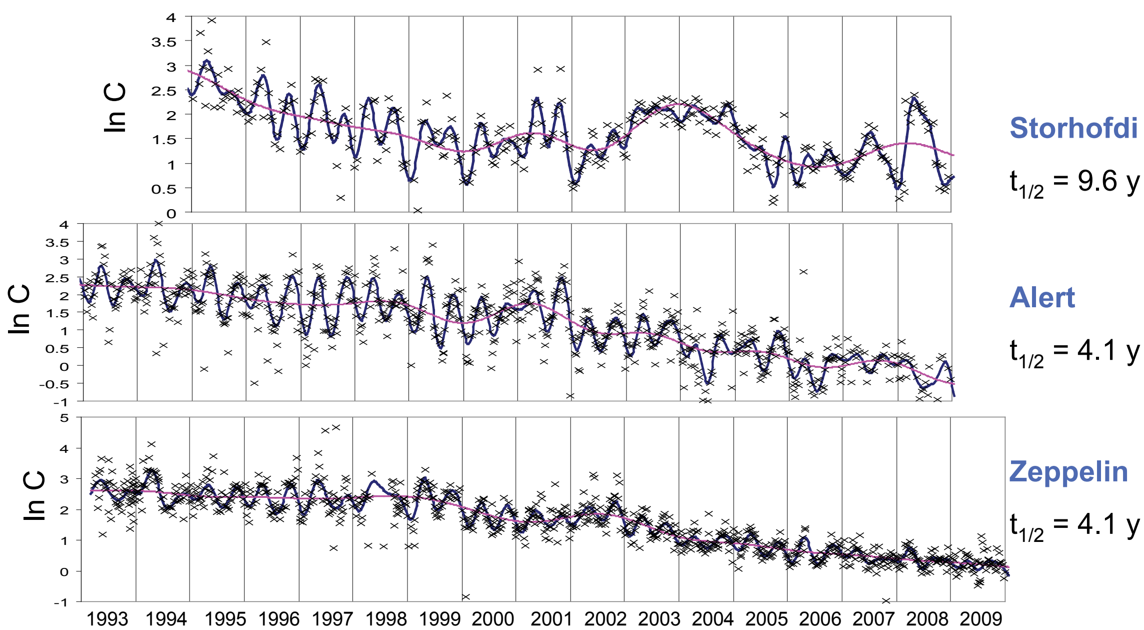

Figure 2. γ-HCH time trends measured at Storhofdi, Alert and Zeppelin $t_{1/2}$=estimated halflives

A FTS was deployed at Alert in September 2007 and monthly samples have been collected using this sampler with air volumes ranging from 2360 to about 14000 m3 per month. Detail description of this sampler was given in Xiao et al. (2007). Weekly-integrated air samples were also collected with the superhivol at Alert which included one glass fiber filter (GFF) and two polyurethane foam plugs (PUFs), trapping the particle and gas phase compounds, respectively. An updated comparison between the two types of samplers for measured OCP, PBDE and new FR concentrations is given in Figure 3.

Total air concentrations (gas+particle phase) are given in this figure for all compounds measured by the superhivol, except for BDE 209 where only particle phase concentrations are given. Gaseous air concentrations of BDE 209 measured using the superhivol at Alert in 2006 did not meet the quality assurance/ quality control (QA/QC) standards due to apparent contamination of the PUF plugs by this specific congener. Since BDE 209 is mainly particle-bound and the FTS captures both gas and particle phase chemicals, measured results obtained from the FTS can be compared directly with the particle phase concentrations measured using the superhivol.

In terms of CUPs and PFCs, 84 sets of samples were collected in 2005–2009. Samples were analyzed for 22 CUPs and 7 PFCs. Preliminary trends of 4 neutral PFCs detected in air at Alert have been developed using the DF technique (Figure 4). Seasonal cycles and temperature dependence of 4 CUPs, namely dacthal, pentachloronitrobenzene (PCNB), trichlorfon and trifluralin, are shown in Figure 5.

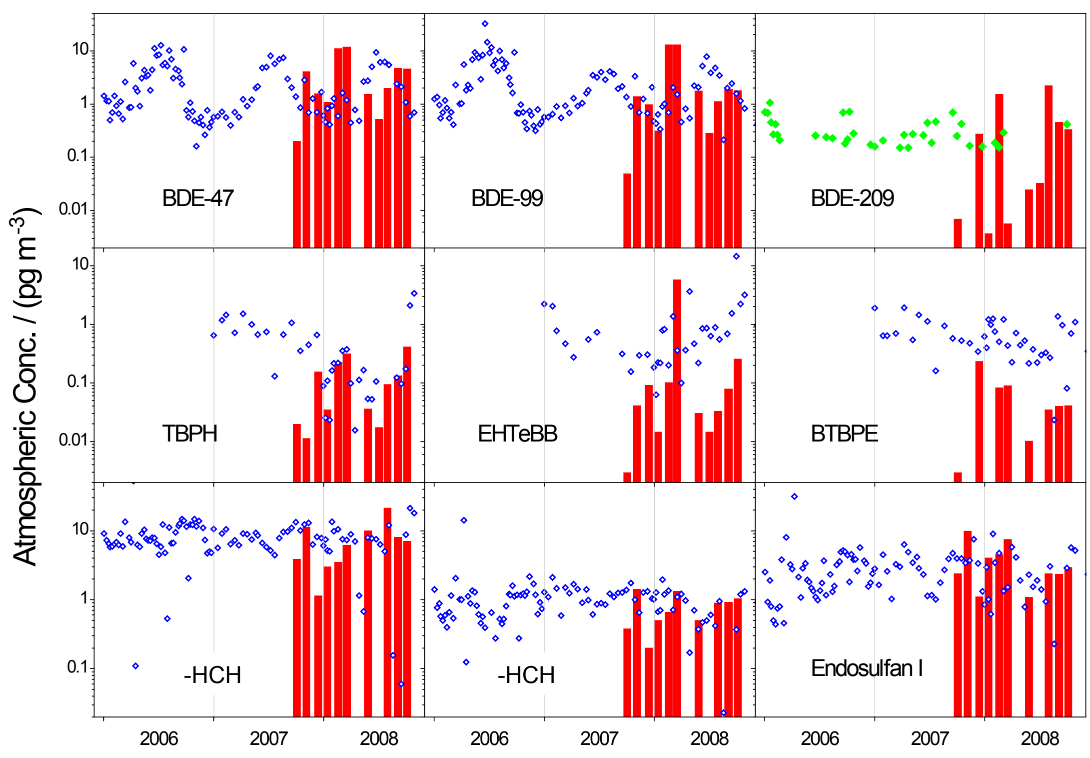

Figure 3. Measured air concentrations of PBDEs, new FRs [1,2-bis(2,4,6-tribromophenoxy)ethane (BTBPE), 2-ethyl-1-hexyl 2,3,4,5-tetrabromo-benzoate (EHTeBB) and bis(2-ethyl-1-hexyl)tetrabromophthalate (TBPH)] and OCPs (α- and γ-HCH and endosulfan I) at Alert using the FTS (red bars) and the superhivol (gas+particle phase: blue circles, particle phase only: green dots)

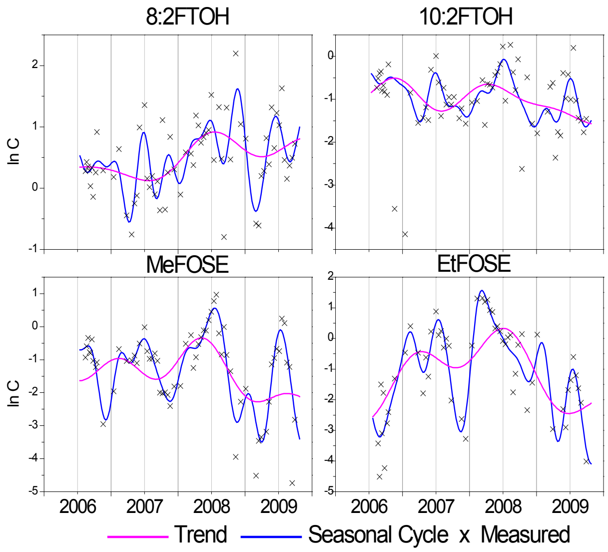

Figure 4.PFC atmospheric trends at Alert (8:2FTOH=1H,1H,2H,2H-perfluorodecanol; 10:2FTOH=1H,1H,2H,2H-perfluorododecanol; MeFOSE=methyl perfluorooctane sulfonamide ethanol; EtFOSE=ethyl perfluorooctane sulfonamide ethanol)

Discussions and Conclusions

Long-term trends of α- and γ-HCH in arctic air

From Figure 1, it can be seen that α-HCH in air is showing consistent declining trends at all 3 arctic stations with similar halflives (~4 years). This indicates that α-HCH, as a major constituent of technical HCH, is relatively well-mixed in the arctic atmosphere which is expected since technical HCH has been banned globally for 20–30 years now.

γ-HCH (lindane) has been included in the Stockholm Convention on POPs since May 2009. Declining trends of atmospheric γ-HCH was also observed at all 3 stations (Figure 2). 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. It is apparent that after 2002, the decline in trends accelerated at both Alert and Zeppelin. At both stations, the halflife of γ-HCH in air from 1993 to 2001 was approximately 7 years, compared to halflives of 3.4 years (2002–2008) at Alert and 3.3 years (2002–2009) at Zeppelin. This indicates the rapid atmospheric transport of lindane to the arctic.

Comparison of FTS OCP Measurements with Super-high-volume Air Sampler Results

An FTS has been deployed at Alert since winter 2007, collecting monthly air samples in parallel with the superhivol to assess its performance in capturing legacy POPs and new FRs. The year-long comparison shows that these two techniques gave similar absolute values (Figure 3) for selected OCPs, PBDEs and new FRs [1,2-bis(2,4,6-tribromophenoxy) ethane (BTBPE), 2-ethyl-1-hexyl 2,3,4,5-tetrabromobenzoate (EHTeBB) and bis(2-ethyl-1-hexyl) tetrabromophthalate (TBPH)]. The concentrations of new FRs detected in both types of samples were similar to those of PBDEs, while showing no obvious seasonality. Comparable air concentrations of OCPs, PBDEs and new FRs obtained from the FTS and the super-HiVol confirmed the FTS's usability under arctic ambient conditions.

Perfluorinated Compounds (PFCs) and Current-use Pesticides in Arctic Air

The dominant PFC measured was generally 8:2FTOH. The median total (gas + particle) concentration of 8:2FTOH is 1.47 pg/m3 (mean: 1.86 pg/m3; BDL–8.99 pg/m3; n=68) which is much lower than those previously reported in arctic air [North Atlantic and Canadian Archipelago (Shoeib et al., 2006): 5.8–26 pg/m3; Cornwallis Island, Nunavut (Stock et al., 2007): BDL-18.6 pg/m3], Statistically significant correlations were observed between 10:2 FTOH and 8:2 FTOH ($r2=0.60$, $p<0.0001$), and between EtFOSE and MeFOSE ($r2=0.58$, $p<0.0001$); indicating that these two pairs of PFCs originated from the same source. However, no correlation was observed between the FTOHs and the FOSEs; implying that different sources are responsible for these two groups of compounds in Alert air.

With slightly more than 3 years of PFC data, it can be seen that the air concentrations at Alert fluctuated without consistent increasing or declining trends, except for 8:2FTOH which seems to exhibit a consistent increasing tendency. In terms of seasonality, 10:2FTOH, MeFOSE and EtFOSE showed spring maxima which may be associated with the increase in particulate input during the Arctic Haze. Summer maxima are also apparent for 10:2FTOH and MeFOSE which may

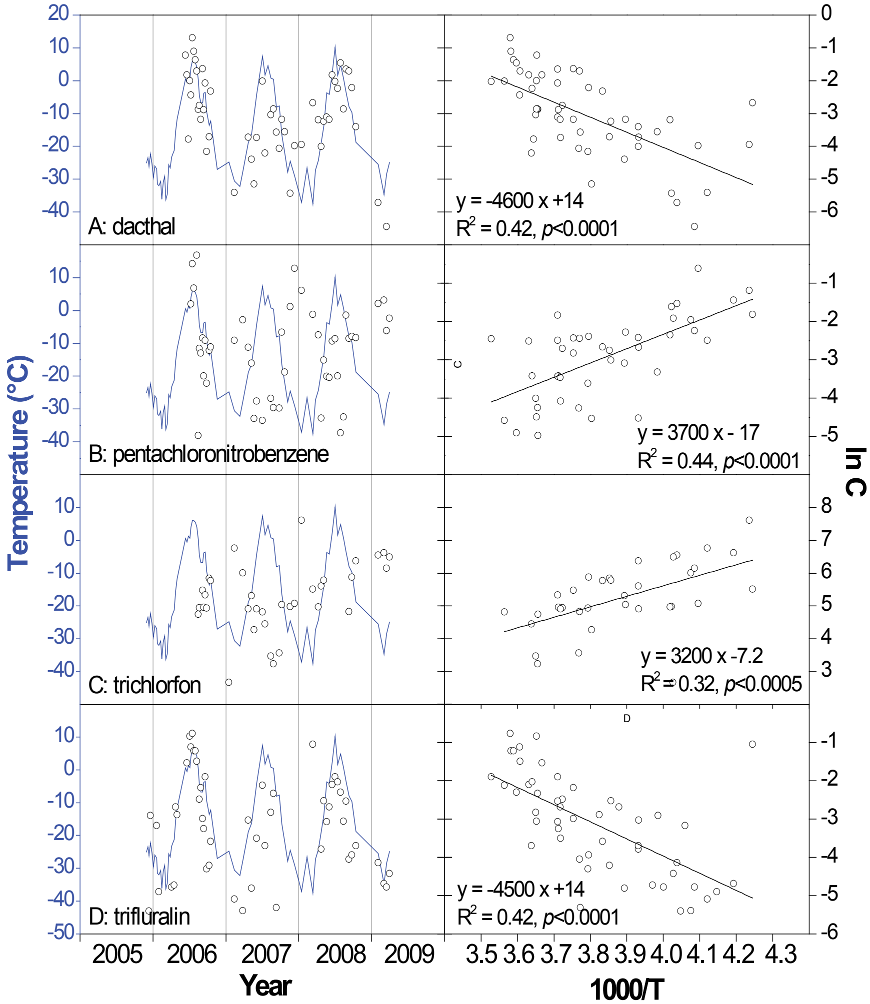

Figure 5. Seasonality of dacthal (A), pentachloronitrobenzene (B), trichlorfon (C), and trifluralin (D) and their temperature dependencies at Alert. Blue solid line represent temperatures; black circles indicate air concentrations; and black solid lines are linear regression lines.

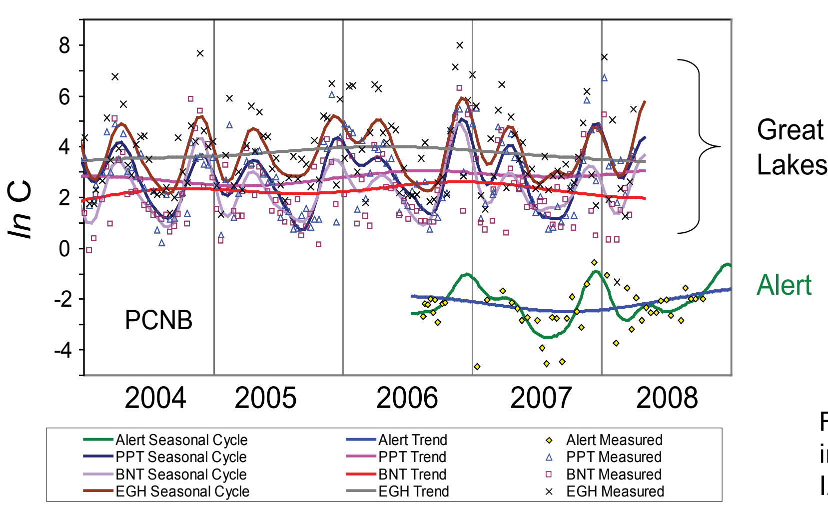

Figure 6. Seasonal variations of PCNB in the Great Lakes region (measured under IADN) and at Alert (IADN station names: PPT=Point Petre, BNT=Burnt Island, EGH=Eagle Harbor)

be related to volatilization due to higher temperatures. Continuous measurements are required to examine the relative concentrations of these compounds during different seasons and what factors influence their transport to the Arctic.

For CUPs, elevated concentrations of endosulfan I were found in spring and fall, which is consistent with previous findings. Concentrations of dacthal and trifluralin were high in summer time and low in the winter. Significant temperature dependence of air concentrations was found for these two chemicals (Figure 5). On the other hand, high concentrations were found in winter for pentachloronitrobenzene (PCNB) and trichlorfon (Figure 5).

No apparent seasonality was seen for air concentrations of chlorpyrifos, endosulfan sulphate, and tefluthrin. Different seasonality of CUPs in the Arctic atmosphere is likely related to their respective application patterns and subsequent LRT to the Arctic.

PCNB, a fungicide commonly used on turf, showed similar seasonality at Alert and in the Great Lakes [derived from measurements collected under the Integrated Atmospheric Deposition Network (IADN)] (Figure 6) corresponding to its unique usage pattern; reflecting rapid atmospheric transport from sources. No decline trends of PCNB found for over 4 years of measurements in the Great Lakes and Alert.

NCP Performance Indicators

The following performance indicators reflect the combined effort of both NCP and IPY INCATPA which are related projects:

The number of northerners engaged in your project: Northern students 0, northern participants 7

The number of meetings/workshops you held in the North: 4

The number of students (both northern and southern) involved in your NCP work: 3

The number of citable: Journal 5, Presentations 6

Expected Project Completion Date

On-going.

Acknowledgements

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

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Contaminant Bioaccumulation in Landlocked Char Food Webs in the High Arctic

Project Leader:

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Abstract

The purpose of this two year project (2010–2012) is to study how food webs influence the transfer of contaminants to the top predator, landlocked Arctic char, in the Northern Contaminants Program's (NCP) "focal ecosystem" lakes on Cornwallis Island. Mercury (Hg) and perfluorinated chemicals (PFCs) are carried into Arctic lakes during spring melt and are taken up and concentrated through the food web into char. This research will examine food web accumulation of Hg, which has both natural and human sources and undergoes complex transformations in lakes, and of PFCs, which are entirely human-made, arrive solely by atmospheric deposition, and are not transformed in the environment. We are building on previous research by contrasting how these two persistent contaminants concentrate through lake food webs and examining factors that affect their levels in char and other organisms in High Arctic systems. The research is on lakes in the Resolute Bay area (North, Small, Meretta, Resolute, 9 Mile, and Char). Results from the 2010 field season show significant differences in mean total Hg concentrations

Résumé

Ce projet d'une durée de deux ans (2010–2012) a pour objectif d'étudier comment les réseaux trophiques influent sur le transfert des contaminants au prédateur de niveau trophique supérieur, soit l'omble chevalier confiné aux eaux intérieures, dans les lacs du Programme de lutte contre les contaminants dans le Nord (PLCN) qui présentent des « écosystèmes d'intérêt », sur l'île Cornwallis. Le mercure (Hg) et les produits chimiques perfluorés (PCPF) sont entraînés et déversés dans les lacs de l'Arctique durant la fonte printanière, où ils sont absorbés dans les réseaux trophiques puis concentrés dans l'omble. La recherche examinera l'accumulation de mercure dans les réseaux trophiques, lequel trouve sa source autant dans la nature que dans l'activité humaine et subit des transformations complexes dans les lacs, de même que des PCPF, lesquels sont entièrement de source humaine, arrivent uniquement par dépôt atmosphérique et ne sont pas transformés dans l'environnement. Nous prenons appui sur la recherche précédente en comparant la manière dont ces deux contaminants persistants se concentrent dans les réseaux trophiques des lacs, et en examinant les facteurs qui influent sur leurs

(0.08-0.29 μg/g, wet wt) in char between these lakes, and that Hg is higher in larger than smaller fish. PFCs in char also varied from one lake to another and levels were highest in fish from Meretta and Resolute Lakes. Furthermore, several invertebrate samples showed higher concentrations than adult fish (i.e. 1.7 υg/g vs. 0.07 +/- 0.001 υg/g PFOA in 9 Mile). The diet of the char is being assessed using carbon, nitrogen and sulfur isotopes (measures of energy flow and trophic position). More sampling of the lakes will be done in 2012 and all results will be used to model the movement of contaminants through these lakes. Information from this study will be used to understand whether persistent contaminants are transferred through High Arctic food webs at a greater rate than has been observed at lower latitudes.

Key Messages

- Hg concentrations in adult char are similar to those reported by Gantner et. al. in previous years. Results to date show that trophic position (determined by nitrogen isotope ratios or δ15N) was a significant predictor of Hg in these food webs.
- Temporal water data showed a general decline in both total mercury (THg) and methylmercury (MeHg) across lakes as the summer progressed.
- Several PFCs were detected in char from four of the six lakes analyzed to date. Interestingly, some PFC levels in emerging chironomids are higher than those found in adult char. This holds implications for the biomagnification of PFCs in these Arctic lakes and requires further investigation.

niveaux dans l'omble et d'autres organismes des systèmes de l'Extrême-Arctique. La recherche s'effectue dans les lacs de la région de la baie Resolute (les lacs North, Small, Meretta, Resolute, 9 Mile et Char). Les résultats de la campagne sur le terrain de 2010 montrent des différences significatives entre ces lacs dans les concentrations totales moyennes de mercure (0,08 0,29 μg/g, poids humide) trouvées dans l'omble, et indiquent que le mercure est plus élevé dans les poissons plus gros que dans les poissons plus petits. Les PCPF dans l'omble variaient également d'un lac à l'autre et les niveaux étaient les plus élevés dans le poisson des lacs Meretta et Resolute. En outre, plusieurs échantillons d'invertébrés indiquaient des concentrations supérieures à celles des poissons adultes (c'est-à-dire, 1,7 μg/g par opposition à 0,07 +/- 0,001 μg/g de PFOA dans le lac 9 Mile). Le régime alimentaire de l'omble fait actuellement l'objet d'une évaluation au moyen d'isotopes du carbone, de l'azote et du soufre (mesures du flux d'énergie et de la position trophique). D'autres échantillons seront prélevés dans ces lacs en 2012, et tous les résultats serviront à créer un modèle du mouvement des contaminants dans les lacs. Les données issues de cette étude seront utilisées pour comprendre si les contaminants persistants sont transférés par l'intermédiaire des réseaux trophiques de l'Extrême Arctique à une vitesse plus rapide que celle observée à de plus basses latitudes.

Messages clés

- Les concentrations de mercure dans l'omble adulte sont similaires à celles que Gantner et al ont démontrées dans les années passées. Les résultats à ce jour montrent que la position trophique (déterminée par les coefficients d'isotopes de l'azote ou δ15A) a été un paramètre de prévision significatif de mercure dans ces réseaux trophiques.
- Les données temporelles sur l'eau ont montré une baisse générale du mercure total et du méthylmercure dans l'ensemble des lacs à mesure que l'été avançait.
- Plusieurs PCPF ont été détectés dans l'omble habitant quatre des six lacs analysés jusqu'à ce jour. Curieusement, il y a des niveaux de PCPF dans les chironomes émergents qui sont plus élevés que ceux trouvés dans l'omble adulte, ce qui a des répercussions sur la bioamplification des PCPF dans ces lacs arctiques, et nécessite une étude plus approfondie.

Objectives

- Study and contrast the transfer of perfluorinated chemicals and mercury (mainly the organic form methylmercury, MeHg) through food webs to landlocked Arctic char (Salvelinus alpinus) in High Arctic lakes.
- Investigate chemical, physical and biological factors influencing contaminant levels in landlocked char by sampling lakes with a range of catchment/lake area ratios, nutrient concentrations, and organic carbon inputs (i.e. through permafrost melting), and by assessing the diet of char with stable nitrogen, sulfur and carbon isotope and gut content analyses.
- Provide this information to the Hamlet of Resolute Bay (Qausuittuq) and to the Niqiit Avatittinni Committee (Nunavut) on a timely basis.

Introduction

Contaminant levels in fish can fluctuate from one lake to another, even within the same region. This study explores the differences in contaminant concentrations between neighbouring lakes around Resolute Bay, Nunavut (NU), focusing on the accumulation of two particularly problematic contaminants, mercury (Hg) and perfluorinated chemicals (PFCs). Despite the many contaminant studies done on Arctic systems, we are still unsure whether or how physical and chemical differences between lakes affect the transfer of contaminants through food webs. Features such as catchment area, water chemistry, and food web characteristics may account for localized variability in contaminant levels. This study will compare the Hg and PFC concentrations in the food webs from six lakes, each with differing physical and chemical characteristics.

Both PFCs and Hg are carried to the Arctic through long range atmospheric transport and deposited around lakes in annual snowfall. This snowmelt is thought to be one of the main sources for certain contaminants to enter lakes. Each summer this snow melts, transporting the contaminants into lakes where they are accumulated by the biota (Gantner et. al. 2009; Loseto et. al. 2004; Stock et. al. 2007). Snow runoff and melt waters are the main source of Hg in small High Arctic lakes (Semkin et. al. 2005). Once taken up by organisms at the bottom of a food web, these contaminants accumulate and concentrate through the trophic levels, resulting in relatively high levels in top predators (Dewailly et. al. 1993; Martin et. al. 2004; Wyn et. al. 2009).

Arctic char are the top predator and often the only fish species in High Arctic lakes and therefore represent an important indicator species for Northern contamination (Gantner et. al. 2009). Due to the biomagnification of contaminants to top predators, Arctic char have been found with relatively high levels of Hg (Gantner et. al. 2009; Gantner et. al. 2010). The same pattern is expected for PFCs, though less is known about their levels in landlocked char. Given that char are an important part of Arctic food chains and are eaten by Inuit, contaminant levels in these fish are of particular concern.

Similar to predatory fish in southern systems (Houde et. al. 2008), contaminant levels in char at high latitudes can vary by 2-3 times between neighbouring lakes. One possible reason for this variability is the differing physical characteristics and food web dynamics between lakes. Studies have shown that features such as catchment area, water chemistry, food web structure, and lake area can play a role in the transfer and biomagnification of contaminants (Wyn et. al. 2008; Gantner et. al. 2010; Gantner et. al. 2010b).

Although Hg is a naturally occurring element, human activities release Hg into the atmosphere, contributing to its widespread environmental contamination (NRC 2000; Gantner et. al. 2009b; Health Canada, 2007). Concentrations of Hg in many Arctic predatory fish, including Arctic char, often exceed the governmental recommendation, which is currently set at 0.5 ppm for total Hg (Gantner et. al. 2010b; Health Canada, 2007).

Overall, far less is known about the behaviour of PFCs in aquatic systems when compared to Hg. Two lakes near Resolute Bay have been found with similar if not higher PFC levels in water than the Great Lakes, approximately 10 ng/L (Stock et. al. 2007). PFCs have been detected at elevated levels in fish from these lakes (Muir et al. 2010 NCP Synopsis report) and at much lower levels in other lakes. While there have been previous studies of PFCs in Arctic marine food webs

(Tomy et. al. 2004; 2009; Kelly et. al. 2009), to our knowledge, this is the first study looking at the biomagnification of PFCs through Arctic freshwater food webs supporting landlocked char.

This report describes the sampling and results from the first field season in 2010. A second year of sampling will be done in 2011 to collect water, sediments, invertebrates and fish from these same lakes. More emphasis will be put on collecting invertebrates from these lakes to better characterize the food webs supporting char. This project is in its 2nd and final year and is anticipated to be completed in June 2012.

Activities in 2010–2011

Sample Collection: Six lakes on Cornwallis Island were sampled in 2010 over 7 weeks, starting in early July, for char, lower-trophic-level organisms, water and sediments to assess concentrations of Hg and PFAs as well as food web structure in these systems. Field work was done under the guidance of three members of the local community (Debbie Iqaluk, Brandy Iqaluk, and Pilipoosie Iqaluk). A key difference between the 2010 sampling and previous work (Gantner et al.) is the more detailed sampling of water and food web organisms beginning at the initial ice melt and continuing through the ice out period in this recent study. Water samples were collected weekly using clean techniques, in order to measures temporal changes in contaminant concentrations. All chironomids (adults and larval) were separated into general predator (Tanypodinae) and herbivore (Orthocladiinae and Chironomidae) sub-families before analysis. Adult chironomids were collected as they emerged through the ice. Benthic invertebrates were collected by benthic sweep nets and Eckman grabs. Zooplankton were sampled with a Wisconsin net pulled through the water column. In addition, representative samples of terrestrial vegetation and periphyton were collected from each lake to characterize the stable isotope signature of the primary producers potentially supporting the lakes' biota. Sediment cores from profundal and littoral areas were collected from each of these lakes once during the field season using a Uwitec gravity corer and clean techniques. At the end of the season, adult fish were collected with gill nets. Juvenile fish were also collected by electrofishing along the shore. Fish were kept cool in the field and then processed back in the lab for length, weight, and ageing structures. Gut contents and muscle tissues were removed and frozen for diet and contaminant analyses. In total, approximately 125 fish were collected and between 8 and 19/lake were analyzed for Hg and PFCs (Tables 1 and 2).

Chemical Analysis: Mercury: Total Hg was determined on whole tissues using a DMA (Milestone Instruments, Shelton, CT) at the UNB. MeHg in water and sediments were determined at Environment Canada, Burlington. MeHg analyses of biota were done at Acadia University (in collaboration with Nelson O'Driscoll). Analyses of all samples for MeHg used EPA Method 1630 and involved distillation (water) or methanol-potassium hydroxide digestion (sediment and organisms), aqueous phase ethylation, GC separation, and CVAFS detection using a Brooks Rand MERX automated MeHg analyzer. Water and sediment quality: Organic carbon in sediments will be determined by a CHN analyzer. Water chemistry analyses were conducted by the National Laboratory for Environmental Testing (NLET) following standard protocols outlined by Environment Canada (1994). Perfluoroalkyl compounds: Samples were analyzed for a full range of PFCs, including C6 to C15 perfluorocarboxylates (PFCA) and C6 to C12 perfluoroalkanesulfonates (PFOS) at Environment Canada (Burlington, ON). The extraction procedure involves the addition of mass-labeled internal standards (13C-labeled PFCA and PFOS) and an ion-pairing agent and extraction with acetonitrile (Müller et. al. 2011). The PFCs in sample extracts were determined by high-performance liquid chromatography with negative electrospray tandem mass spectrometry (HPLC-MS/MS). Stable Isotope Analysis: Freeze-dried and homogenized tissues of individual fish and pooled invertebrates were analyzed for stable carbon and nitrogen isotope ratios at the UNB (SINLab) and for sulfur isotopes at the Universities of Waterloo (water) and Arizona (sediment and biota) using a continuous-flow isotope-ratio mass spectrometer.

Quality assurance: Certified reference materials (NRC DORM-2 and TORT-1 for Hg; NIST serum SRM 1957 for PFCs) and working lab standards (stable isotopes) were run with each batch of 12 contaminant samples to ensure accuracy of results. Sample duplicates (10% of samples) and blanks were also run with each batch of samples to test for precision and background contamination, respectively. The laboratories took part in interlab studies through NCP and among the different groups involved in the collaborative projects (INRS, Environment Canada, UNB, Acadia). More specifically, the Environment Canada lab participated successfully in an interlab calibration study of PFAs in NIST reference materials (Keller, Calafat et al. 2010).

Statistical Analysis: Statistics were run on the data generated from the first field season and are presented here. In order to understand the factors that best predict fish contaminant concentrations, hierarchical multiple regressions were run for each contaminant using a wide range of potential factors. Preliminary statistics (i.e. Kruskal Wallis) and graphing were done to estimate the order of factors, and all models were compared using Akaike Information Criterion (AIC). Normality was tested for all factors and log transformations were made when required. Similar hierarchical multiple regressions were also run on THg and MeHg concentrations in water, testing various water chemistry parameters as potential predictors.

Capacity Building and Training: The project depended heavily on the help of local people in the Hamlet of Resolute. Since 2005 Debbie Iqaluk has worked on the arctic char "core monitoring" project and enabled us to collect fish from all our targeted lakes on Cornwallis and Melville Islands in a wide range of weather and ice conditions. This year, Debbie, her daughter Brandy (Iqaluk), and son Pilipoosie (Iqaluk) assisted with field collections and preparations. Gretchen Lescord (M.Sc. Candidate) received extensive training and experience in netting and processing fishing, invertebrate collections and identification, sample processing and lab analyses for Hg, PFAs, and stable isotopes, food web modeling, data analysis, scientific presentations and manuscript writing. Traditional Knowledge: Timing of collections and number of samples collected relied heavily on the knowledge and experience of local people working on the project. This was particularly the case when the lakes were ice covered, which is frequently the case in early through late July. The traditional method of getting onto the ice (sometimes by boat or by wading from shore) and sampling proved very successful, although a bit dangerous. Communications: Graduate student Gretchen Lescord was based in Resolute (as the PCSP base) from early July until mid August 2010 and was in the nearby village of Resolute frequently. She many informal discussions about this work in the community during the field season. A similar informal approach is planned in 2011 as well as a visit to the HTA office. Up to date results from this study are also being presented at conferences in the summer and fall of 2011.

Results and Discussion

Hg in biota: Table 1 summarizes the average characteristics of adult char caught in 2010. The lowest and highest mean THg were measured in char from Small and Char Lakes, respectively (Table 1 and Figure 1).

Mercury concentrations were higher in biota with higher trophic positions (δ15N) within these lakes although there are currently limited data for the lower trophic levels (Figure 1). However, MeHg and THg concentrations in predatory adult chironomids did not differ between lakes (Kruskal-Wallis $p=0.118$, $p=0.117$, respectively).

In order to determine the best predictors of Hg levels in char, a hierarchical multiple regression was run, using the categorical variables lake and sex of the fish, and the continuous variables fish fork length and age. All factors, including THg, were log transformed. The best fit model predicting Hg concentrations in char across lakes included lake, trophic position (δ15N) and fork length ($R2=0.66$; ANOVA $p<0.001$). As was found in other studies, there were significant relationships between log-Hg and δ15N in all 6 lakes (Figure 1, $p<0.001$, $r2=0.47$ to 0.90) and the slopes of these lines were similar to what has been found in other studies (e.g. Gantner et al. 2010).

Hg in water: Table 3 shows the average water Hg and chemistry data for the 2010 samples. Unlike the char THg results, Char lake water had the lowest average THg levels, as well as the lowest MeHg levels. Interestingly, Char Lake also had the lowest average chlorophyll a and DOC levels; each approximately 11 and 1.6 times lower than the next highest lake (North Lake), respectively. North Lake also had the highest average THg

Table 1 – Select mean fish characteristics for all adult char caught from the Cornwallis Island lakes in 2010 and analyzed for total mercury (THg).

		Total Length		Weight		Condition		Age		d15N		THg	
		(cm)		(g)		(g/cm3)		(years)		(‰)		(µg/g wwt.)	
Lake	n	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
Small	19	35.3	3.0	303.6	63.2	0.7	0.1	10.9	2.2	9.29	0.48	0.08	0.04
North	17	37.2	4.7	424.3	311.1	0.7	0.1	13.0	4.8	11.05	1.28	0.28	0.30
Meretta	19	40.7	4.4	610.8	237.8	0.9	0.1	4.9	1.3	11.52	0.24	0.20	0.06
9 Mile	17	35.6	3.1	300.0	111.4	0.6	0.1	13.6	3.8	10.38	0.88	0.16	0.08
Char	9	32.4	3.4	248.6	112.1	0.7	0.1	9.2	1.1	11.23	0.69	0.29	0.12
Resolute	8	44.1	4.0	689.6	183.2	0.8	0.1	13.5	2.0	11.52	0.80	0.19	0.10

nd=No Data available, analysis is ongoing.
*Calculated without Char and Resolute Lake fish $\delta^{15}N$ data

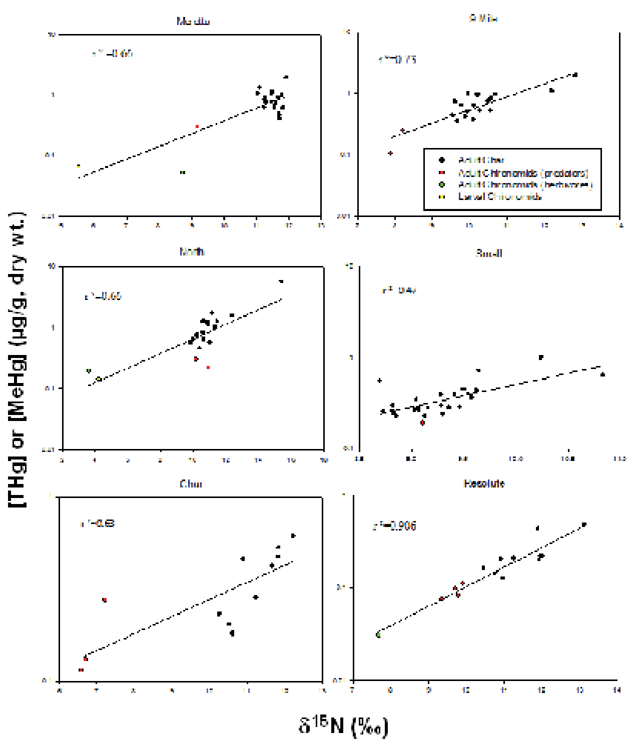

Figure 1: Mercury concentrations (mg/g dry weight) and δ15N (‰) values for char and chironomids from each lake food web. All char Hg values are THg and all chironomid values are MeHg.

concentration and the lowest percent MeHg, implying a low methylation rate consistent with the low DOC, compared to other lakes.

Temporal trends of both THg and MeHg levels in lake water are shown in Figure 3. THg concentrations decreased in all lakes except 9 Mile as the season progressed. 9 Mile was sampled later in the season because of logistical challenges and this may explain its different trend. MeHg concentrations increased slightly over the season in all lakes except Meretta, where there was a decline in both surface and deep water samples. Meretta Lake also had a significantly higher percent MeHg (Kruskal-Wallis p=0.014), suggesting a higher rate of Hg methylation in this lake (see Table 3).

PFCs in biota: Table 2 gives the mean values for various fish characteristics, as well as mean concentrations of several PFCs in fish from the 6 lakes. Samples from Resolute and Meretta Lakes have been analyzed but the data are still being processed, so we have included results from samples collected in 2008 (Muir et. al. 2010) to show the variable levels of PFOS in these lakes. Meretta and Resolute Lakes are downstream of the airport drainage area and have likely been contaminated due to the use of PFOS-containing foams for fighting fuel fires. Meretta Lake had higher nutrients from sewage entering wetlands just west of the lake, but has recovered after the waste effluent was stopped in 1998 (Douglas and

Table 2. Select mean fish characteristics and various PFC concentrations for all adult char caught in 2010 from Cornwallis Island lakes.

		Total Length (cm)		Weight (g)		Age (years)		$\delta^{15}N$ (‰)		PFHpA (ng/g, wwt.)		PFOA (ng/g, wwt.)		PFNA (ng/g, wwt.)		PFDA (ng/g, wwt.)		PFOS (ng/g, wwt.)	
Lake	n	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
Small	8	35.5	3.5	295.5	72.6	10.8	1.6	9.5	0.7	0.02	0.01	0.07	0.02	0.12	0.04	0.03	0.01	0.15	0.07
North	10	37.7	5.9	474.1	401.7	13.4	5.7	11.2	1.6	0.02	0.01	0.08	0.01	0.14	0.05	0.06	0.07	0.08	0.02
9 Mile	8	35.4	3.2	300.8	135.3	13.5	3.0	10.3	0.8	0.02	0.01	0.07	0.01	0.14	0.05	0.04	0.01	0.04	0.01
Char	9	32.4	3.4	248.6	112.1	9.2	1.1	11.5	0.8	0.05	0.01	0.10	0.02	0.25	0.08	0.08	0.03	0.79	0.32
*Meretta**	10	51.0	5.7	1672.6	455.3	nd	nd	11.5	0.2	0.01	0.00	0.01	0.00	0.21	0.07	0.04	0.02	11.39	3.79
*Resolute**	24	42.0	3.7	591.3	143.7	nd	nd	11.5	0.9	0.01	0.00	0.01	0.01	0.50	0.05	0.03	0.05	32.24	22.67

nd=No Data available, analysis is ongoing.

*2008 data from Muir et. al. 2010.

Table 3. Select water chemistry data (n=6–10/lake, surface and deep waters), and sulfate isotope signatures (n=1 for surface sample) from the Cornwallis Island lakes sampled in 2010.

Lake	%MeHg*		pH		Conductivity (µS/cm)		Chlorophyll a (µg/L)		DOC (mg/L)		$\delta^{34}S$ (‰)
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Surface
Small	3.52	0.70	8.12	0.07	298.13	78.47	0.75	0.26	2.08	0.39	-8.49
North	2.47	1.13	7.95	0.05	158.25	48.98	1.10	0.40	0.90	0.23	-11.17
Meretta	9.51	5.14	7.93	0.05	244.90	78.36	0.56	0.20	1.89	0.37	-2.19
9 Mile	3.54	3.91	8.09	0.03	196.50	11.50	0.30	0.22	1.25	0.08	-7.08
Char	3.50	1.34	8.14	0.03	267.10	25.50	0.05	0.08	0.59	0.06	-6.26
Resolute	4.68	1.24	8.12	0.02	356.10	16.29	0.68	0.25	1.04	0.07	-4.82
Total	4.73	3.66	8.06	0.10	255.69	82.76	0.56	0.41	1.25	0.61	-8.49

* %MeHg=MeHg]/ [THg]

* 100 for water data

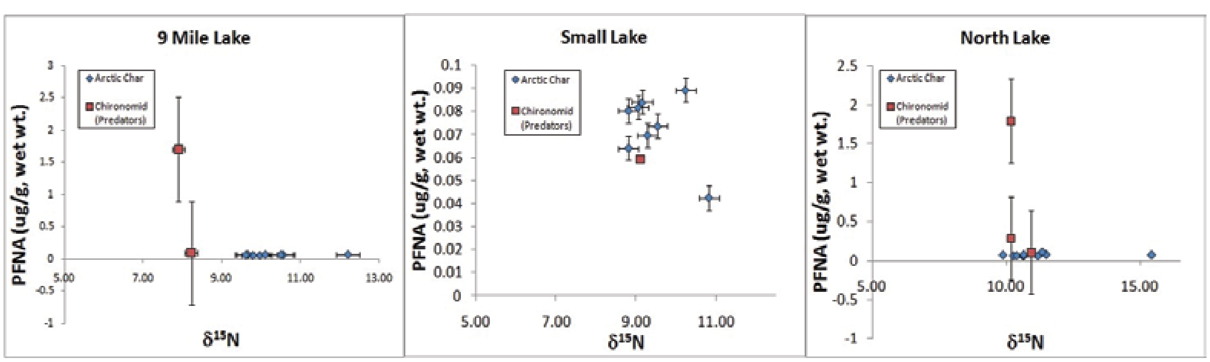

Figure 2: PFOA concentrations (mg/g wet weight) and 15N (‰) values for char and adult chironomids of 9 Mile, Small and North lakes, Cornwallis Island.

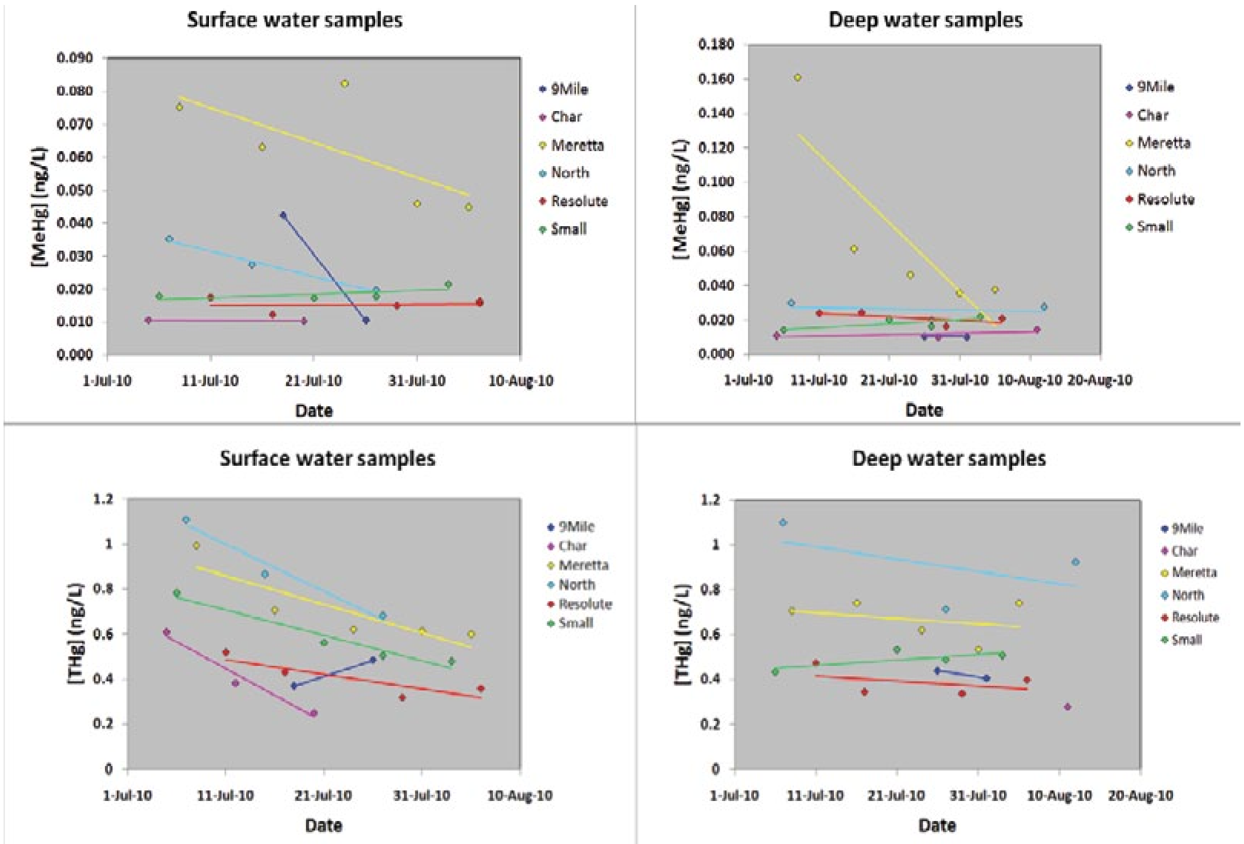

Figure 3: Temporal trends of mean THg and MeHg concentrations in lake water samples taken from Cornwallis Island lakes, 2010.

Smol, 2000). In Char, 9 Mile, North, and Small lakes, PFNA and PFOS were the dominant PFCs detected, and PFOS was much higher in fish from Meretta and Resolute than the other four lakes. Similar to Hg, exploratory hierarchical multiple regressions were run to test which factors best predict PFC levels in fish. Out of the factors tested (fish age, sex, fork length, and lake), only lake was slightly and sometimes significantly related to various PFCs (R2=0.231 for PFNA, 0.164 for PFDA, 0.348 for PFOA). As with Hg concentrations, it is expected that fish trophic position (δ15N) will be a better predictor of PFC concentrations in char and these analyses are ongoing.

Interestingly, some PFC levels in emerging chironomids were higher than those found in adult char. Figure 2 shows the general trend of PFOA, a particularly abundant PFC, in predatory chironomids from three of the lakes (Small, North and 9 Mile). Concentrations of PFOS and other sulfonates are still being calculated for all invertebrate samples.

Conclusions

This report has added to our understanding of Hg concentrations in High Arctic lakes by generating information on how Hg concentrations in lake water vary over the open water season, and by assessing the levels of PFCs in abiotic and biotic compartments of these lakes. As found in other studies, concentrations of Hg food web organisms vary from one lake to another and are higher in fish than invertebrates. In contrast, concentrations of some PFCs were similar in fish and adult chironomids, suggesting that PFCs and Hg are not accumulated through food webs at a similar rate. However, further sampling during the 2011 field season will improve our understanding of these food webs and their contaminant concentrations, and allow for some more detailed modeling of the biological, chemical and physical characteristics that predict contaminant concentrations in Arctic char.

The sampling in 2011 will focus more on invertebrate collections, including more frequent kick sweeps for benthic inverts, and more sampling of adult chironomids and zooplankton. This sampling will hopefully help provide a clearer picture of the contaminant levels in lower-trophic level organisms and the structure of these food webs. Temporal water sampling, as well as sediment coring and fishing will also be repeated. Results from these analyses will be used to understand how Hg and PFCs are transferred through these food webs to char and whether their accumulation is higher or similar to what has been observed in other studies.

NCP Performance Indicators

Number of Northerners engaged in your project: 3

Number of meeting/workshops held in the North: 2

Number of students involved in the work: 1

Number of citable publications: None to date

Acknowledgments

We graciously thank the NCP for continued funding and support. We also thank the Iqaluk family for their continued assistance and guidance in the field. As well, we thank Polar Continental Shelf Project Base for logical support and accommodations.

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The Impacts of Climate-Induced Increases in Primary Productivity on the Cycling of Mercury and Methylmercury in Focal Freshwater Arctic Ecosystems

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Abstract

Mercury is a top priority contaminant in Canadian Arctic freshwater ecosystems because concentrations of methylmercury, the toxic form of mercury, are often above human consumption guideline in freshwater fishes, such as landlocked Arctic char. We are examining key aspects of the mercury cycle which directly impact methylmercury concentrations in fish 1) the behavior of inorganic mercury after it is deposited to lakes from the atmosphere 2) the rates and mechanisms of production of methylmercury from inorganic mercury and 3) the impact of climate-induced increases in lake primary productivity on 1) and 2). To examine 1), we have analyzed numerous dated lake sediment cores from across the Canadian high and subarctic for mercury and climate-indicators, including algal-derived or S2 carbon and microfossil remains. This study represents the most geographically extensive dataset of mercury-climate dynamics in the Arctic.

Résumé

Le mercure représente un contaminant prioritaire dans les écosystèmes d'eau douce de l'Arctique canadien qui suscite un intérêt prioritaire à cause des concentrations de méthylmercure, forme toxique du mercure, que l'on y retrouve. Les concentrations de ce contaminant sont souvent supérieures aux recommandations relatives à la consommation humaine de poissons d'eau douce, notamment de l'omble chevalier dulcicole. Nous étudions les principaux aspects du cycle du mercure qui ont des effets directs sur les concentrations de méthylmercure dans le poisson : 1) le comportement du mercure inorganique, provenant de l'atmosphère, qui se dépose dans les lacs; 2) les taux et les mécanismes de production du méthylmercure à partir du mercure inorganique; 3) les effets de l'augmentation de la productivité primaire dans les lacs attribuable aux changements climatiques sur 1) et 2). Dans le cadre de l'étude du point 1, nous avons analysé de nombreuses carottes de sédiments lacustres datés, prélevées dans le

We found that mercury fluxes to lake sediments increased post-industrialization (post-~1850) in 9 of our 11 study lakes. Results also suggested that atmospheric mercury deposition increased since industrialization in all 11 lakes, whereas mercury inputs from the catchment increased in 9 lakes, likely due to catchment erosion. Several study lakes showed recent shifts in algal assemblages consistent with climate-induced changes. 8 lakes showed post-1850's increases in algal derived carbon or S2 fluxes, suggesting that lake primary productivity recently increased in these lakes. We also examined relationships between mercury and S2 to determine if increased primary productivity has affected the loss of mercury to lake sediments through time. In ~half the lakes, we observed no positive relationship between mercury and S2. In five of the six lakes where a positive mercury: S2 relationship was observed, algal assemblages either did not change through time or the timing of the shifts did not correspond to changes in mercury deposition. Our results suggest that, although Arctic lakes are experiencing many changes, increased lake primary productivity is not driving changes in mercury fluxes to sediments. To examine 2), we are examining the effects of increased algal production on methylmercury production in lake surface sediments using state-of-the-art mercury stable isotope tracer experiments. In July 2010, experiments were conducted at Meretta and Char lakes. In addition to amendments with stable mercury isotope 202Hg(II) (to measure rates of methylmercury production) and Me198Hg (to measure rates of methylmercury loss), a subset of cores were also amended with organic carbon, sulfate, and molybdate (which stimulate and inhibit potential pathways of methylmercury production) to examine the mechanisms of methylmercury production and the impacts of increased lake primary productivity on these processes. Experiments at Amituk Lake will be carried out in summer 2011 as part of a larger field campaign being coordinated for other NCP projects. A great deal of progress has been made on this project; however our results have stimulated a variety of important research questions regarding mercury-carbon-sulfur-climate dynamics which we are currently exploring.

Haut-Arctique et la région subarctique du Canada, en vue de déceler des indicateurs climatiques et la présence de mercure, y compris des traces de carbone S2 provenant des algues et de microfossiles. Cette étude comprend l'ensemble de données le plus complet au plan géographique portant sur la dynamique entre le mercure et le climat dans l'Arctique. Nous avons ainsi découvert que les flux de mercure dans les sédiments lacustres ont augmenté depuis la postindustrialisation (après ~1850) dans 9 des 11 lacs visés par notre étude, ce qui semble indiquer un accroissement récent de la productivité primaire dans ces lacs. Les résultats donnent aussi à penser que le dépôt de mercure transporté dans l'atmosphère a augmenté, depuis l'industrialisation, dans l'ensemble de ces 11 lacs, alors que les apports de mercure du bassin versant ont augmenté dans 9 de ces lacs, probablement à cause de l'érosion du bassin. Ainsi, dans plusieurs lacs visés par l'étude on a observé de récents changements aux assemblages d'algues coïncidant avec des changements climatiques. Nous avons relevé des augmentations de carbone provenant des algues ou de flux de S2 datant de la période subséquente à 1850 dans 8 de ces lacs, ce qui laisse supposer qu'il y a eu une augmentation récente de la productivité primaire de ces éléments. Nous avons également étudié les rapports entre le mercure et le S2 pour voir si l'augmentation de la productivité primaire avait eu des effets sur la perte de mercure dans les sédiments lacustres au fil du temps. Dans le cas d'environ la moitié des lacs, nous n'avons relevé aucun rapport positif entre le mercure et le S2. Dans 5 des 6 lacs où nous avons observé un rapport positif mercure : S2, soit les assemblages d'algues n'avaient pas changé au fil du temps soit le moment des changements ne coïncidait pas avec les changements dans le dépôt de mercure. Les résultats obtenus semblent indiquer que, bien que les lacs arctiques aient subi de nombreux changements, l'augmentation de la productivité primaire dans ces lacs n'entraîne pas de changements aux flux de mercure dans leurs sédiments. Dans le cadre de l'étude du point 2, nous avons examiné les conséquences de l'augmentation de la production d'algues sur la production de méthylmercure dans les sédiments de surface de ces lacs au moyen d'expériences utilisant les plus récents traceurs isotopiques stables du mercure. En juillet 2010, nous avons mené ces expériences dans les lacs Meretta et Char. En plus d'ajouter aux carottes l'isotope stable de mercure 202Hg (II) (pour mesurer les taux de production de méthylmercure) et le Me198Hg (pour mesurer les taux de perte de méthylmercure), on a également ajouté à un sous-ensemble de carottes du carbone organique et du sulfate, ainsi que du molybdate (agent de stimulation et agent d'inhibition, respectivement, des voies de passage potentielles de la production de méthylmercure) afin d'examiner les mécanismes régissant la production de méthylmercure et les effets sur ces processus de l'augmentation de la productivité primaire des lacs. Des expériences seront menées au lac Amituk au cours de l'été 2011, dans le cadre d'une initiative plus importante sur le terrain coordonnée avec d'autres projets menés dans le cadre du PECN. Des progrès importants ont été réalisés dans le cadre de ce projet. Toutefois, les résultats obtenus ont soulevé bon nombre de questions importantes concernant la recherche et liées à la dynamique mercure-carbone-soufre-changements climatiques que nous explorons en ce moment.

Key Messages

- Mercury deposition has increased in sediments since ~1850 in most lakes looked at; but it is important to note that current sediments levels are not a risk to people's health.
- Some of the increase in sediment mercury levels is likely due to deposition of mercury which has travelled in the atmosphere from Southern industrial regions.
- Some of the increase in sediment mercury levels is from increased erosion in the watersheds of lakes, likely because of climate-induced changes, such as increased rain and snow, temperature warming and permafrost melting.
- Several lakes showed changes in algae fossils through time which are likely due to climate-induced changes, such as shortening of the ice covered season and longer summers.
- Several lakes showed increases in certain forms of carbon, suggesting that lake production has recently increased in some lakes.
- Climate-induced increases in lake primary production may be stimulating production of toxic methylmercury by sulfate reducing

Messages clés

- Le dépôt de mercure a augmenté dans les sédiments depuis environ 1850 dans la plupart des lacs qui ont fait l'objet de notre étude, mais il est important de noter que les niveaux actuels de sédiments ne présentent aucun risque pour la santé des gens.
- L'augmentation des taux de mercure dans les sédiments est probablement due en partie au dépôt de mercure transporté dans l'atmosphère en provenance des régions industrialisées du Sud.
- L'augmentation des taux de mercure dans les sédiments est en partie attribuable à l'augmentation de l'érosion des bassins versants des lacs, probablement due aux changements climatiques, notamment à l'intensification de la pluie et de la neige, au réchauffement de la température et à la fonte du pergélisol.
- Plusieurs lacs ont connu des changements dans les fossiles d'algues au fil du temps, probablement attribuables à des changements climatiques, notamment à la réduction de la saison où tout est couvert de glace et aux étés plus longs.

bacteria in high Arctic lake sediments; but it is important to note that current water levels are also not a risk to people's health. State-of-the-art mercury stable isotope tracers experiments are being carried out to examine the relationship between lake primary productivity and methylmercury production.

- Plusieurs lacs ont vu certaines formes de carbone augmenter, ce qui semble indiquer que la production lacustre a récemment augmenté dans certains lacs.
- Les augmentations de la production primaire des lacs attribuables aux changements climatiques peuvent stimuler la production de méthylmercure toxique causée par des bactéries qui réduiraient le sulfate dans les sédiments lacustres du Haut-Arctique. Or, il est important de noter que les niveaux actuels dans l'eau ne présentent également aucun risque pour la santé des gens. On mène actuellement des expériences au moyen des plus récents traceurs isotopiques stables du mercure en vue d'étudier le rapport entre la productivité primaire des lacs et la production de méthylmercure.

Objectives

Long term objectives:

1. Understand the effects of climate-driven increases in primary production on mercury (Hg) and methylmercury (MeHg) cycling in high Arctic lakes, particularly in NCP focal ecosystems.
2. Determine why MeHg concentrations in freshwater fishes are over Canadian fish consumption guidelines in some Arctic lakes, such as Amituk and Char, but not in others.

Short term objectives:

1. Test the "scavenging hypothesis", that algal derived carbon (C) drives the deposition of Hg to lake sediments, by examining Hg, S2 or algal derived C, and microfossil remains in dated sediment cores from numerous carefully selected high Arctic lakes of Nunavut, Nunatsiavut, and Nunavik.
2. Examine whether climate-induced catchment erosion is resulting in increased delivery of Hg to lake sediments through analysis of lithogenic elements in dated sediment cores.
3. Quantify rates and examine mechanisms of MeHg production in the surface sediments of a subset of our study lakes (Amituk, Char and Meretta) using state-of-the-art Hg stable isotope tracer experiments.
4. Examine the role of climate-induced increases in primary production in stimulating MeHg production in Arctic lake sediments by examining the relationship between S2 and reduced inorganic sulfur in lake sediment cores.
5. Provide this information to the Hamlet of Resolute Bay (Qausuittuq) and to the Niqiit Avatittinni Committee (Nunavut) on a timely basis.

Introduction

Mercury (Hg) is a priority contaminant in Canadian Arctic lakes. NCP supported monitoring has shown that methyl Hg (MeHg; the toxic, bioaccumulative form of Hg) concentrations in Arctic char of Amituk and Char lakes (Cornwallis Island), are above human consumption guidelines and have increased until ~2005 (Muir et al. 2010). Increases in fish Hg concentrations have also been observed the Mackenzie River (Carrie et al. 2009) and Great Slave Lake (Evans and Muir 2009). Research is required to understand the factors driving trends in biota so that mitigation strategies can be developed and the impacts of projected climate change can be predicted. We are thus examining key factors that affect MeHg concentrations in freshwater fish: 1) the post-depositional behavior of inorganic

Hg(II) 2) the rates and mechanisms of production of MeHg from Hg(II) and 3) the impact of climate related changes on 1) and 2). This project links with numerous other NCP projects led by Derek Muir and Karen Kidd and addresses research needs described under "Pathways of Long-Range Transportation" and "Ecosystem Based Monitoring and Research: Freshwater Ecosystems" of the NCP blueprint.

It is well known that increasing atmospheric loading of Hg(II) to aquatic ecosystems can increase fish MeHg concentrations (Harris et al. 2007). Due to the paucity of real-time Hg deposition measurements in the Arctic, dated sediment cores have therefore been extensively used to examine Hg deposition to Arctic lakes over time. Hg fluxes have been determined in ~90 Arctic lakes, and have increased in recent decades in most systems (Muir et al. 2009, Lindberg et al. 2007, Outridge et al. 2007, Fitzgerald et al. 2005, Bindler et al. 2001). The reason for these increases is, however, debated. In several studies (for example, Muir et al. 2009, Fitzgerald et al. 2005, Bindler et al. 2001), post-industrialization increases in Hg fluxes have been attributed mainly to increased anthropogenic atmospheric Hg deposition as patterns of atmospheric circulation result in the transport of Hg emissions from southern regions, such as Asia, to the Arctic (Durnford et al. 2010). In other studies (Carrie et al. 2010, Stern et al. 2009, Outridge et al. 2007), a large portion (~70–78%) of increased post-industrialization Hg deposition has been attributed to increased algal scavenging brought about by climate-induced changes. This "scavenging hypothesis" is based upon significant positive relationships between Hg and S2, or algal-derived organic C (OC) in lake sediments, as well as upon the numerous paleolimnological studies that have demonstrated wide-spread, climate-induced changes in Arctic lakes. For example, increased algal production and sedimentation of detritus have been observed in numerous Baffin Island lakes (Michelutti et al. 2007) and changes in algal species composition beginning in ~1850 have been observed in lakes spanning the circumpolar Arctic (Smol et al. 2005). To date, sediment cores from only seven lakes have been analyzed for Hg and S2 (for example, Carrie et al. 2010, Stern et al. 2009, Outridge et al. 2007). Further study is clearly warranted and we are thus examining the relationships between Hg, S2, algal assemblages, and lithogenic elements in dated sediments from numerous Arctic lakes spanning both latitudinal and longitudinal gradients to examine the link between primary productivity and Hg in lake sediments and determine how to most effectively use Hg flux data obtained from dated sediment cores.

Although the quantity of Hg(II) available for methylation is an important factor driving fish MeHg concentrations, the rate of MeHg production in a system is also of great importance. Hg(II) methylation is primarily carried out by sulfate reducing bacteria in lake surface sediments (Compeau and Bartha 1985). Therefore, factors controlling populations of sulfate reducing bacteria, such as DOC and sulfate, can affect MeHg production rates. In temperate regions, stable Hg isotope tracer experiments have been used extensively to measure potential rates of sediment methylation and demethylation and to elucidate the mechanisms of MeHg production. We are therefore quantifying sediment methylation rates using Hg stable isotope techniques in a series of lakes, including Amituk and Char lakes. Sediments are being amended with Hg stable isotope tracers to quantify potential rates of Hg(II) methylation and MeHg demethylation, as well with sulfate and OC to examine mechanisms for MeHg production. Amendments with OC, for example, allow us to examine the impact of climate-induced increases in primary production on rates of MeHg production, which directly links to the work described above.

Activities in 2010–2011

What? Where? When? Who? How?

- We analyzed several (11) dated lake sediment cores from across the Canadian high and subarctic for concentrations of Hg, multielements, and climate-indicators, including microfossil remains and algal-derived or S2 C.
- This work resulted in a publication in the journal Environmental Science and Technology (Kirk et al. 2011) and the results are shaping the work we are doing currently.
- Based on data gaps illustrated from the above work, 10 additional cores were carefully selected for analysis. We have

in our possession ~20 cores collected between 2007–present, many of which have already been dated using 210Pb methods. We selected six cores that have already been dated for analysis and three others that have not been dated yet.

- A new core is being collected from Meretta Lake this summer (2011) by Gretchen Lescord, Paul Drevnick, and Brandy Iqaluk as part of a large field campaign being coordinated for several NCP projects. Meretta Lake is an important site as long term chlorophyll a concentrations from this lake will be compared to S2 profiles to calibrate S2 as a proxy for primary productivity.
- Dated cores have been analyzed for concentrations of Hg at the Trace Mercury Analytical Laboratory at the Canada Centre for Inland Waters (CCIW) and are currently being analyzed for algal assemblages, S2 and multielements by Hedy Kling (Algal Taxonomy and Ecology, Winnipeg, Manitoba), Baseline Resolution (Shenandoah, Texas), and the National Laboratory for Environmental Testing (NLET; CCIW), respectively.
- The three un-dated cores are currently being dated using 210Pb methods by Fan Yang at our dating laboratory at CCIW.
- Plans are underway to analyze a subset of cores using visible reflectance spectroscopy (VRS) at Queen's University, as this techniques has recently been shown to successfully reconstruct lake chlorophyll a concentrations (Michelutti et al. 2010).
- Hg stable isotope tracer experiments were conducted at Meretta and Char lakes in July 2010 by Paul Drevnick to examine the production of MeHg in lake surface sediments.
- Experiments were not conducted at Amituk Lake in 2010 due to bad weather which prevented helicopter work; however, these experiments will be carried out by Paul Drevnick, his student, and Brandy and Debbie Iqaluk in summer 2011 as part of a larger field campaign being coordinated for several NCP projects.
- A paper was published in Environmental Science and Technology in 2010 (Drevnick et al. 2010) which demonstrates that sulfate reduction and OC deposition are increasing in Arctic lakes, including Char and Amituk. These results suggest that MeHg production may also be increasing.

Capacity Building

For the portions of the project on MeHg production, which involve new sample collections, we hired Debbie and Brandy Iqaluk from the Hamlet of Resolute Bay. They both worked on this project and on the Arctic char "core" monitoring project which hires local people each year. Both Debbie and Brandy will be working on the project again this summer. They were trained in sediment core collection, processing (e.g. sectioning), and in state-of-the-art Hg stable isotope tracer techniques. Thus the project is helping to build expertise in scientific sampling among hunters of the community. In addition, the work on MeHg methylation is part of a M.Sc. thesis on the "effect of increased carbon flux on net Hg(II) methylation in high Arctic lakes." The student is gaining expertise on many aspects of environmental research, including highly specialized laboratory skills, such as analysis of reduced inorganic sulfur using gravimetric determination, and Hg stable isotopes using GC-ICP-MS.

Traditional Knowledge

The portions of the project that involve new sample collection (work on MeHg production and sediment core collections at Meretta Lake), rely on Traditional ecological knowledge for safe access to sampling lakes during the summer months when the ice may be unstable. In summer 2010, Debbie and Brandy Iqaluk of Resolute Bay participated in the project and provided this expertise to the field team.

Communications

During the field season in July 2010, Derek Muir visited the HTA office in Resolute Bay, Nunavut and spoke with HTA Manager Nancy Amarualik to describe and update her on the project. During the field work at Resolute in July 2011, the principal investigators will again visit the HTA office, as well as the Wildlife office and the Hamlet Council office to discuss the project. Results have been, and will continue to be, communicated to NCP and the HTA in written reports and presentations. For example, a poster entitled "Impacts of climate-induced increases in primary productivity on Hg cycling in freshwater Arctic ecosystems" was presented at the fall 2010 NCP workshop in Whitehorse, Yukon and an updated presentation will be made at the 2011 workshop. In addition, a small poster with numerous photos was made, then translated and submitted to the HTA in March 2011 to provide background and updates on the project. Another poster was presented at the American Geophysical Union (AGU) conference in San Francisco, CA in December, 2010 and two papers were published in Environmental Science Technology in 2010 and 2011 (Drenvick et al. 2010, Kirk et al. 2011).

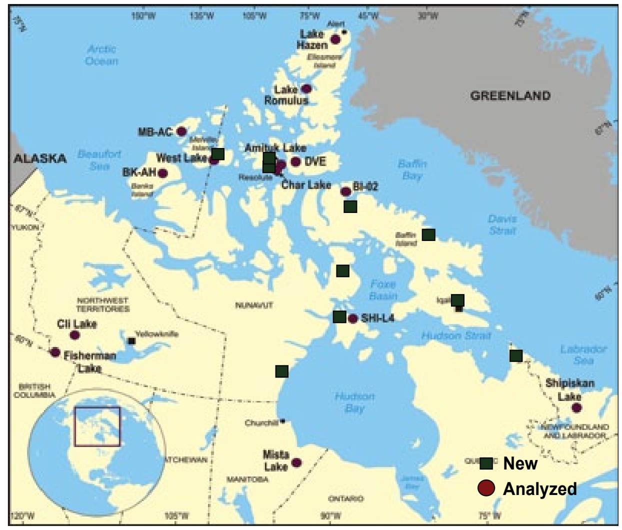

Figure 1. Location of Canadian high and subarctic lakes where sediment cores were collected then analyzed for Hg and climate-change indicators including microfossils and algal derived, or S2 C (red circles) and location of 10 new sediment cores that are currently being analyzed (green squares).

Results, Discussion, and Conclusions

1) The post-depositional behavior of Hg(II) in Arctic lakes and the impact of climate-induced increases in primary productivity on this behavior: 11 dated lake sediment cores from across the Canadian high and subarctic were analyzed for concentrations of Hg and climate-indicators, including microfossil remains and algal-derived or S2 C (Figures 1 and 2). This study represents the most geographically extensive data-set of Hg-climate dynamics in the Arctic and includes more comprehensive microfossil data than previous studies of its kind as species-level diatom analysis was obtained in a subset of study lakes (Kirk et al. 2011).

We found that Hg fluxes increased post-industrialization (post-~1850) in 9 of our 11 study lakes (post-industrialization Hg fluxes (ΔHgFF)=1.5-24.2 μg m-2 y-1; Figure 2). Correction of HgFF for catchment contributions demonstrated that Hg deposition originating from catchment-independent factors, such as atmospheric deposition, increased since industrialization in all 11 lakes whereas Hg inputs from the catchment increased in 9 of the lakes. Several study lakes also showed post-industrial shifts in algal assemblages consistent with climate-induced changes. 8 lakes showed post-1850's increases in S2 fluxes, suggesting that lake primary productivity recently increased in the majority of our sites (ΔS2FF=0.1-3.7 g m-2 y-1). To explore the algal scavenging hypothesis, which postulates that Hg fluxes to Arctic sediments are largely driven by S2 C, we examined relationships between Hg and S2 in our sediment cores. Interestingly, in four of our lakes we observed no Hg:S2 relationship, and in one lake a significant negative Hg:S2 relationship was observed. In five of the six lakes where a significant positive Hg:S2 relationship was observed, algal assemblages either did not change through time or the timing of the shifts did not correspond to changes in Hg deposition (Figure 2). In two of the study lakes where a significant Hg:S2 relationship was observed (Shipiskan and Fisherman), the ratio between S2 and the refractory fraction of C decreased from the top to the bottom of the cores indicating post-depositional degradation of S2 to RC.

Overall, our results suggest that, although Arctic lakes are experiencing a myriad of changes, including increased Hg and S2 deposition, or changing algal assemblages, increased lake primary productivity is not driving changes in Hg fluxes to sediments. Thus, although a great deal of progress has been made on this project, our results have simulated a variety of important research questions regarding Hg-OC-climate dynamics such as: Are climate-induced increases

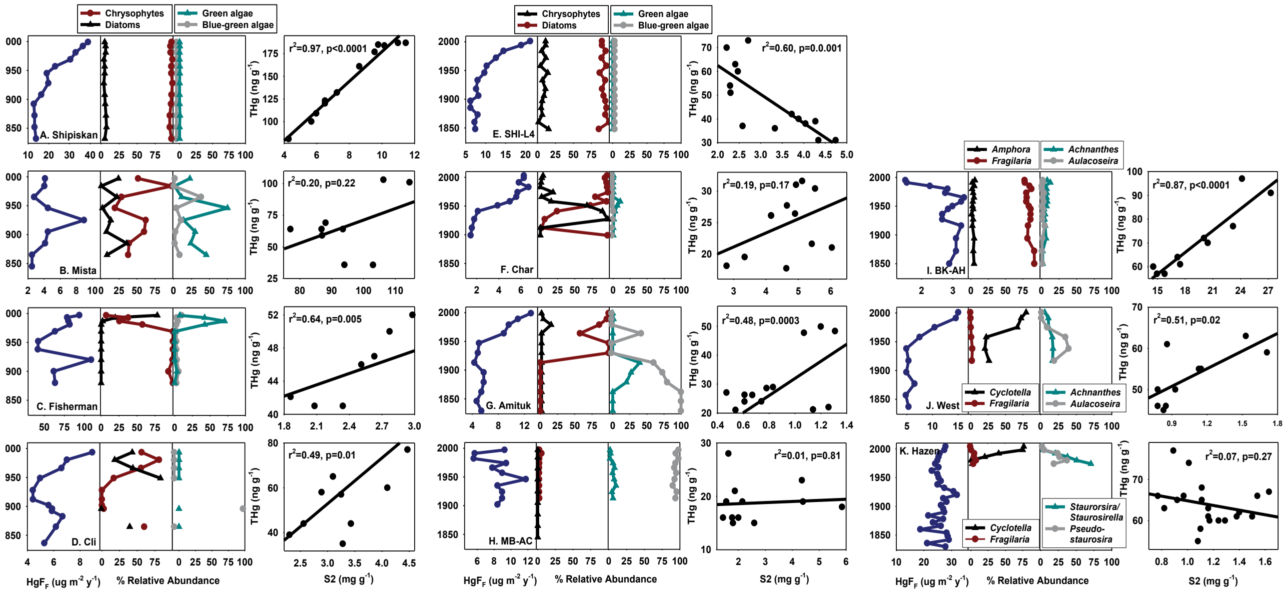

Figure 2. Focusing adjusted Hg fluxes (HgFF), relative abundance (%) of microfossils including either diatoms, chrysophytes, green algae, and blue-green algae (A-J), or predominant diatom species (I-K), and the relationship between Hg and S2 C concentration (ng g^{-1}) in dated sediment cores from 11 Canadian Arctic lakes.

in catchment Hg inputs to Arctic lakes widespread across the Canadian Arctic? Why are Hg and S2 strongly correlated in some lakes but not in others? Is there a regional component to these differences? Is S2 well conserved in Arctic cores and is S2 a good proxy for primary productivity? We are currently exploring these questions by analyzing 10 new high and subarctic sediment cores provided to us by paleoliminologists we are collaborating with (Kirk et al. 2011, Muir et al. 2009) (Figure 1). Many of the cores selected have already been dated using 137Cs and 210Pb methods, thus funding is being used to carry out Hg, S2, algal assemblage, and multielement analyses as well as other new analysis (see Table 1 for status of analysis). To complement our work at Meretta Lake on rates and mechanisms of MeHg production, a new sediment core will be collected from this lake in summer 2011 and will also be analyzed.

Results to date (Kirk et al. 2011) also suggest that S2 C may be subject to post-depositional degradation and indicate that S2 may not be an ideal proxy of lake primary productivity. To explore these issues in more detail, we have entered into a collaboration with John Smol (Queen's University) to analyze a subset of our sediment cores for visible reflectance spectroscopy (VRS), which has recently been shown to successfully reconstruct lake chlorophyll a concentrations (Michelutti et al. 2010). Reconstructions of sediment chlorophyll a concentrations, obtained by VRS analysis, will be compared to S2 profiles to "calibrate" these methods. In addition, long-term lake chlorophyll a data from Meretta Lake, also obtained through collaboration with John Smol, will be compared to S2 profiles to further calibrate S2 as a proxy for primary productivity. VRS work will be carried out in winter 2011.

2) Rates and mechanisms of MeHg production and the impact of climate-induced increases in primary productivity on these processes: Newly published work by Drevnick et al. (Drevnick et al. 2010) suggests that climate-induced increases in lake primary productivity are stimulating MeHg production by sulfate reducing bacteria in high Arctic lakes. Algal detritus is a rich source of labile C, and therefore has the potential to stimulate populations of sulfate reducing bacteria, which are the primary producers of MeHg in surface sediments. Firstly, an increase in sedimentary accumulation of reduced inorganic sulfur was

observed in high Arctic lakes, including NCP focal lakes, Amituk, Char, and Hazen, in recent years (Drevnick et al. 2010; Figure 3).

In addition, incubations of sediment slurries from Amituk and Char lakes with acetate (labile C) resulted in significant increases in sulfide, the end product of sulfate reduction. Analyses of the different forms of sulfur and sulfur stable isotopes (δ34S) in sediment profiles from these lakes indicated that the sulfide that is produced during sulfate reduction is subsequently oxidized to elemental sulfur and stored in sediment. Finally, in the sediment profiles from Amituk Lake and Char Lake, OC is positively related to the %THg that is MeHg, a crude proxy of methylation rate (Drott et al. 2008). Taken together, these suggest that there may be potential to use sediment profiles of reduced inorganic sulfur as a historical record of sulfate reduction, and perhaps even of MeHg production in Arctic lakes. As part of this project, we are therefore now examining the effects of climate-driven increases in algal production on Hg(II) methylation using Hg stable isotope tracers experiments.

Hg stable isotope tracers experiments were conducted at Meretta and Char lakes in July 2010 to examine the production of MeHg in lake surface sediments. Due to our past work and links to the char monitoring programs, Amituk and Char lakes are obvious choices for these experiments. Meretta Lake is also of importance because it has a known history of eutrophication (Schindler et al. 1974, Michelutti et al. 2002) and will help us explore the link between primary production and MeHg production. If increased availability of OC during periods of high primary productivity stimulated Hg(II) methylation by sulfate reducing bacteria in Meretta Lake, we should observe

Table 1. List of new high and subarctic sediment cores that are currently being analyzed for Hg and climate indicators. A subset will be selected for analysis by visible reflectance spectroscopy.

Lake	Location	Latitude (N)	Longitude (W)	Status of analysis
A5	Rankin Inlet Nunavut	61° 16.816	94° 19.291	^{210}Pb dating and Hg analysis complete, algal assemblage analysis underway
IqaluitA1	Iqaluit Nunavut	63°46.915	68°32.935	^{210}Pb dating and Hg analysis complete, algal assemblage analysis underway
B35	Baker Lake Nunavut	64° 20.003	95° 54.167	^{210}Pb dating and Hg analysis complete, algal assemblage analysis underway
C1	Clyde River	70° 27.784	68° 30.495	^{210}Pb dating and Hg analysis complete, algal assemblage analysis underway
North	Resolute Nunavut	74° 48.000	90° 06.000	^{210}Pb dating and Hg analysis complete, algal assemblage analysis underway
Meretta	Resolute Nunavut	74° 42.000	94° 54.000	Core collection will be carried out in July 2011 and ^{210}Pb dating will be conducted immediately.
Lab 003	Saglek Bay Labrador	58° 25.000	63° 09.900	^{210}Pb dating underway.
BI-27	Bylot Island Nunavut	73° 08.845	80° 02.647	^{210}Pb dating and Hg analysis complete, algal assemblage analysis underway.
East	Melville Island Nunavut	74° 55.000	109° 64.350	^{210}Pb dating underway.
Fish	Boothia Peninsula Nunavut	68° 52.867	82° 57.283	2^{10P}b dating underway.

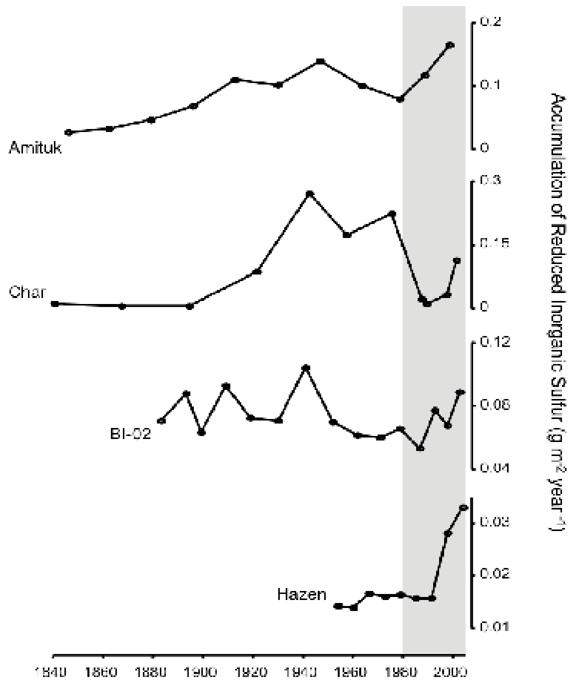

Figure 3. Fluxes of reduced inorganic sulfur (g m-2 year-1) over time measured in sediment cores collected from two NCP focal ecosystems located on Cornwallis Island (Amituk and Char lakes), BI-02, located on Bylot Island, and Lake Hazen, located on Ellesmere Island. The highlighted region illustrates the time period during which increases in reduced inorganic sulfur fluxes were observed in most of these lakes.

spikes in both inorganic sulfur and S2 in sediment cores during the eutrophication period. In addition to all the parameters described above, new dated sediment cores from Amituk, Char, and Meretta lakes are therefore being analyzed for reduced inorganic sulfur. In addition to amendments with stable Hg isotope 202Hg(II) (to measure rates of Hg(II) methylation) and Me198Hg (to measure rates of MeHg demethylation), a subset of cores were also amended with OC (acetate), sulfate, and molybdate (which stimulate and inhibit, respectively, the sulfate reducing bacteria that produce MeHg) to examine the mechanisms of MeHg production and the impacts of increased lake primary productivity on these processes. Experiments were not conducted at Amituk Lake in 2010 due to bad weather which prevented helicopter work; however, these experiments will be carried out in summer 2011 as part of a larger field campaign being coordinated for several other NCP projects. PCSP support has been secured for this work. Analysis of samples collected in summer 2010 is underway and will be completed in winter 2012.

NCP Performance Indicators

Number of northerners engaged in your project: Two for both summers 2010 and 2011 (Debbie and Brandy Iqaluk).

Number of meetings/workshops you held in the North: One informal meeting took place with HTA manager in Resolute Bay, summer 2010. Another informal meeting will be conducted in summer 2011. This project relies heavily on archived samples; thus numerous meetings were conducted during collection of the sediment cores being used in this study. The following communities were consulted:

Repulse Bay, Nunavut
Clyde River, Nunavut
Iqaluit, Nunavut
Arviat, Nunavut
Rankin Inlet, Nunavut
Baker Lake, Nunavut
Coral Harbour, Nunavut
Cape Dorset, Nunavut
Igloolik, Nunavut
Pond Inlet, Nunavut
Whapmagoostui-Kuujjuarapik, Nunavik
Kangiqsujuaq, Nunavik

In addition, investigators were invited to speak to the municipality of Clyde River by the mayor Andrew Iqalujuaq and deputy mayor Nick Illauq, meetings were conducted with local hunters from several of the above communities, as well as with Hunters and Trappers Organizations (HTO) in all Nunavut communities listed above. Finally, each time John Smol is in Iqaluit, he gives talks at the museum (last one was in 2008).

Number of students (both northern and southern) involved in your NCP work: Three students are involved in this project: One master's student supervised by Paul Drevnick at the University of Quebec and two co-op students (from Guelph University and the University of Waterloo) supervised by Jane Kirk at the Canada Centre for Inland Waters.

Number of citable publications: Two papers have already been published in Environmental Science and Technology, which is a high impact factor peer reviewed journal (Drevnick et al. 2010, Kirk et al. 2011) and two more publications are expected. Three conference presentations have been made (SETAC North America (2009), AGU (2010), and NCP workshop 2010), and several more are expected.

Expected Project Completion Date

We expect all sample and data analysis to be completed by April 2012 and publications to be submitted soon after.

Acknowledgements

NCP has been acknowledged formally in all publications and presentations and will continue to be acknowledged.

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Bioaccumulation Modelling of Current Use Pesticides and New Organohalogens in Arctic Marine and Terrestrial Food Webs

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Abstract

A range of studies carried out by team members from 2007–2010 have accumulated a large pool of data for several classes of legacy, current use and new/emerging organic contaminants in multiple Arctic marine food webs and in the terrestrial vegetation-caribou-wolf food chain. Some of these contaminants do not exhibit "legacy type" biomagnification patterns in these food webs (i.e. increasing concentration with increasing trophic level is not observed). This suggests that their uptake, storage, biotransformation and/or excretion patterns may be different than those observed for legacy contaminants. These datasets are being used to develop, parameterize, evaluate and apply detailed food web bioaccumulation models to a range of organic contaminants in our study systems. After the models have been shown to perform well with the contaminants of interest,

Résumé

Une série d'études réalisées par des membres de l'équipe de 2007 à 2010 ont permis de constituer un vaste ensemble de données sur plusieurs classes de contaminants anciens, de contaminants encore en utilisation et de contaminants organiques nouveaux ou émergents, présents dans de nombreux réseaux trophiques marins de l'Arctique et dans la chaîne alimentaire végétation terrestre-caribou-loup. Certains de ces contaminants ne présentent pas les caractéristiques de bioamplification propres aux contaminants anciens (on ne note pas d'augmentation des concentrations avec l'augmentation du niveau trophique), ce qui pourrait signifier que les modes d'absorption, de stockage, de biotransformation et/ou d'excrétion pourraient différer de ceux qui sont observés pour les contaminants anciens. Ces ensembles de données nous permettent d'élaborer, de paramétrer et d'évaluer des modèles détaillés de

we can then experiment with model parameters in order to help explain the differences observed between contaminants, between food webs and between trophic levels in our study systems. The models will also allow us to estimate field-based biotransformation rates for our suite of contaminants, which are key factors when predicting their bioaccumulation behaviour. The tested models will then be used in a number of applications including bioaccumulation assessments of new organic contaminants and experiments manipulating environmental parameters that are likely to be affected by climate change.

bioaccumulation dans les réseaux trophiques, et d'appliquer ces modèles à une gamme de contaminants organiques. Une fois que l'efficacité des modèles a été vérifiée pour les contaminants à l'étude, nous pouvons faire des essais de paramètres afin de tenter d'expliquer les différences observées entre les divers contaminants, réseaux trophiques et niveaux trophiques. Les modèles nous permettront également d'estimer les taux de biotransformation sur le terrain des contaminants étudiés, ces taux étant essentiels pour la détermination du comportement de bioaccumulation. Les modèles mis à l'essai seront ensuite employés de diverses manières, notamment pour évaluer la bioaccumulation de nouveaux contaminants organiques et pour manipuler divers paramètres environnementaux qui seront vraisemblablement touchés par les changements climatiques.

Key Messages

- Differences in organic contaminant bioaccumulation patterns for different Arctic ecosystems and classes (or subclasses) of chemicals are evident from related studies and in the literature.
- Supporting datasets for model development and evaluation are in the final stages of completion and quality control.
- After development, evaluation and application of models to the datasets we can use them to help explain some of the observed differences in bioaccumulation by varying parameters in environmental and physiological compartments and observing the resulting affect on food web concentrations and contaminant behaviour.
- The models will also be used to evaluate other new use or emerging contaminants (particularly new use brominated flame retardants) in efforts to predict their bioaccumulation potential and behaviour in Arctic food webs.

Messages clés

- Des différences sont manifestes en ce qui concerne les caractéristiques de bioaccumulation des contaminants organiques entre les divers écosystèmes de l'Arctique et les diverses classes (ou sous-classes) de substances chimiques, selon des études et des documents publiés sur le sujet.
- Des ensembles de données servant à l'élaboration et à l'évaluation de modèles en sont aux dernières étapes de mise au point et de contrôle de la qualité.
- Après l'élaboration et l'évaluation des modèles et leur application aux ensembles de données, nous pouvons les utiliser pour tenter d'expliquer certaines différences observées en matière de bioaccumulation en modifiant les paramètres liés aux compartiments environnementaux et physiologiques et en observant les effets produits sur les concentrations dans les réseaux trophiques et le comportement des contaminants.
- Les modèles serviront également à évaluer des contaminants nouveaux ou émergents (plus particulièrement les nouveaux ignifugeants bromés) dans le but de prévoir leur potentiel et leur comportement de bioaccumulation dans les réseaux trophiques de l'Arctique.

Objectives

- Analyze and compile pesticide, flame retardant and surfactant data from multiple projects ranging across the Arctic in 3 marine (Resolute Bay/Barrow Strait, Gjoa Haven/Rae Strait and Pangnirtung/Cumberland Sound) locations and one terrestrial site (Bathurst Caribou range, northeast of Yellowknife)
- Develop and parameterize marine ecosystem-specific mass balance food web bioaccumulation models to quantify the behaviour of current use and emerging contaminants in ringed seal food webs using data collected from 2007–2010
- Develop and parameterize a mass balance food web bioaccumulation model to quantify the behaviour of current use and emerging contaminants in the vegetation-caribou-wolf food chain using data collected in 2009
- Apply the models to the measured data for CUPs, BFRs and other emerging contaminants of concern to better understand the potential for these chemicals to bioaccumulate and the mechanisms and processes most affecting bioaccumulation in Arctic food webs
- Estimate field biotransformation rates for our suite of organic contaminants

Introduction

Differences in bioaccumulation and biomagnification of current use, new and legacy pollutants have been reported for different Arctic ecosystems. These differences have been attributed to chemical and biological factors such as physical-chemical properties, ecosystem-specific processes, food web structure and biotransformation capacities (Borga and Di Guardo, 2005; Borga et al., 2004; Fisk et al., 2001a; Tomy et al., 2009). In order to improve the scientific understanding of chemical fate and bioaccumulation in the Arctic, extensive monitoring projects have accumulated large pools of environmental and wildlife contaminant data. These comprehensive datasets will allow us to effectively test existing food web models against new data and/or to develop and evaluate new food web models for Arctic marine and terrestrial ecosystems. There have been several studies reporting levels of legacy pollutants in Canadian Arctic food webs, in addition to those previously mentioned (Fisk et al., 2001b; Fisk et al., 2001c; Kelly and Gobas, 2001; Muir and Norstrom, 2000; Tomy et al., 2004). Comparatively fewer studies have measured concentrations in both biota and the physical environment (i.e. water, sediment) in order to facilitate the development, application and evaluation of food web bioaccumulation models such as in Kelly et al., (2008); Kelly et al., (2009). Datasets including measurements from physical compartments of the environment are useful for food web bioaccumulation model development. Environmental exposures are particularly important for quantifying chemical bioaccumulation in lower trophic level organisms which may act as vectors of contaminant exposure to higher trophic level organisms that are predominantly exposed to contaminants through their diet (e.g. marine mammals, humans). Environmental and food web concentrations of contaminants, particularly those of POPs and/or POP-like contaminants, can be used to develop and evaluate models that provide mechanistic insights into the bioaccumulation behaviour of these and other new chemicals in Arctic ecosystems.The development and testing of these models can help direct future monitoring efforts required to improve our understanding of ecosystem processes related to contaminant dynamics. They will also provide data for future modeling projects that can be used as stand-alone tools or that can be coupled with mass balance models used to quantify sources, sinks and fluxes of contaminants in the Arctic (e.g. Armitage et al., 2009; Wania et al., 2006; Wania and Mackay, 1995).

Activities in 2010–2011

Analyses and compilation of organic contaminants and stable isotope datasets for the 4 study systems continued throughout 2010–2011 as part of Adam Morris and Bailey McMeans PhD theses and Sabrina Sturman's M.Sc. Thesis as well as related NCP projects (Tomy et al., NCP 2008–2009). Additional samples of seawater and low trophic level biota were collected in the Barrow Strait in June 2010. Compiled results have been reviewed and discussed and the evaluation of existing models for application to these datasets is underway.

Samples investigated:
Samples were collected from 2007–2010 by various team members. The primary study site was the Barrow Strait (outside Resolute Bay, NU; 74º 37'N, 094º 53'W) with additional samples taken in the Rae Strait (outside Gjoa Haven, NU; 68º 40'N, 094º 28'W) and Cumberland Sound (outside Pangnirtung, NU; 66º 07'N, 065º 47'W). Large volume seawater samples (200–400 L; 2m and 10 m depths) were collected using stainless steel XAD resin columns and glass microfiber filters. Trophodynamics were investigated by studying ringed seal food webs containing ice algae, zooplankton, Arctic cod and ringed seals in the Barrow and Rae Straits. In the Cumberland Sound zooplankton, gastropods, bivalves, turbot, char, sculpin, Arctic skate, Greenland shark, narwhal, beluga, harp seals and ringed seals were sampled as the representative food web. Large sample sizes in lower trophic levels were a primary objective of the monitoring studies. Terrestrial food chain samples were obtained in spring-summer 2009 from the Bathurst caribou range on the NWT-NU border. Terrestrial samples consisted of vegetation including lichen, mosses and grasses, caribou and Arctic wolves.

Chemical analysis:
Stable isotope analyses (δ13C and δ15N) were carried out at The Environmental Isotope Laboratory (University of Waterloo, Waterloo, ON; Barrow and Rae Strait samples) and The Great Lakes Institute for Environmental Research (GLIER, University of Windsor, Windsor, ON; Cumberland Sound samples). Methods for stable isotope analysis are available elsewhere (Gantner et al., 2009; McMeans et al., 2007).

Hydrophobic contaminants were extracted from blubber of marine mammals; muscle of elasmobranches and in whole organism homogenates of other fish and invertebrates. PFCs were extracted from liver samples or muscle when liver was unavailable, and in whole fish and invertebrate homogenates as described in Tomy et al. (2009). Extraction and analyses of all water samples and biota samples from Barrow and Rae Straits were conducted in a clean room at Environment Canada (Burlington, ON). Cumberland Sound biota samples were extracted and analyzed at Fisheries & Oceans Canada (Winnipeg, MN). Most compounds were analyzed by low resolution GC-MS, with the MS operated in negative chemical ionization (NCI) mode. PFCs and HBCD were analyzed by reverse-phase LC-MS/MS. Compounds investigated include pentachloronitrobenzene (PCNB), chlorothalonil, endosulfan, endosulfan sulphate, PBDEs, BTBPE, C8-C12 perfluorocarboxylic acids (PFCAs), perfluoroctane sulfonate (PFOS) and perfluorooctane sulfonamide (PFOSA).

Quality assurance:
13C-labelled and non-native OC, BFR and PFC recovery standards were used for biota extraction and water sample collection. Method blanks, method spikes and standard reference materials (SRMs) were extracted with each batch of 10–12 samples. Additional travel and XAD-resin blanks were extracted and run with water samples.

Model Development:
Our food web models are being built on existing models that have been developed and evaluated in temperate regions and in Arctic environments (Arnot and Gobas, 2004; Gobas and Arnot, 2010; Kelly and Gobas, 2003; Kelly et al., 2008; Kelly et al., 2009). The food web model is comprised of bioaccumulation sub-models for organisms representing key trophic guilds, with feeding interactions connecting the bioaccumulation sub-models in the food web. The bioaccumulation models used here are expressed in rate constant format and are analogous to fugacity-based bioaccumulation models (MacDonald et al., 2000; Powell et al., 2009). The marine and terrestrial Arctic food web model is comprised of bioaccumulation sub-models for the following species: phytoplankton/algae/lichen, zooplankton, other aquatic invertebrates, fish, marine mammals, and terrestrial mammals representing the biota sampled in the field studies and addressing all components of the marine and terrestrial food webs.

Phytoplankton, Zooplankton, Aquatic Invertebrates, Fish
The bioaccumulation sub-model for aquatic organisms in the Arctic marine food web is based on the assumption that the exchange of chemicals between the organism and its ambient environment can be described by a single equation:

$$dMB/dt=\{WB.(k1.[mO.\phi.CWT,O + mP.CWD,S] + kD.\Sigma(Pi.CD,i))\} - (k2 + kE + kM).MB \qquad (1)$$

where MB is the mass (g) of the chemical in the organism, dMB/dt is the net flux of chemical being absorbed or eliminated by the organism at any point in time t (d), WB is the weight of the organism (kg) at time t, k1 is the clearance rate constant ($L.kg^{-1}.d^{-1}$) for uptake via the respiratory area, mO is the fraction of the respiratory ventilation that involves overlying water, mP is the fraction of the respiratory ventilation that involves sediment associated pore water, ϕ (unitless) is the fraction of the total chemical concentration in the overlying water that is freely dissolved and can be absorbed via membrane diffusion, CWT,O is the total chemical concentration in the water column above the sediments ($g.L^{-1}$), CWD,S is the freely dissolved chemical concentration in the sediment associated pore (or interstitial) water ($g.L^{-1}$), kD is the clearance rate constant (kg/kg.d) for chemical uptake via ingestion of food and water, Pi is the fraction of the diet consisting of prey item i, CD,i is the chemical concentration ($g.kg^{-1}$) in prey item i, k2 is the rate constant (d^{-1}) for chemical elimination via the respiratory area, kE is the rate constant (d^{-1}) for chemical elimination via excretion into egested feces and kM is the rate constant (d^{-1}) for parent chemical loss via metabolic biotransformation. For phytoplankton and algae, kD,i is zero and kE is considered to be insignificant.

Equation 1 can be simplified by applying a steady-state assumption (dMB/dt=0), resulting in:

$$CB=\{k1.(mO.\phi.CWT,O + mP.CWD,S) + kD.\Sigma Pi.CD, i\}/(k2 + kE + kG + kM) \qquad (2)$$

where CB is the chemical concentration in the organism ($g.kg^{-1}$ wet weight). The steady-state assumption may be reasonable for organisms that have been exposed to relatively consistent chemical concentrations over a long period of time. One of the implications of applying a steady-state assumption is that the growth of the organism needs to be expressed as a growth rate constant kG, which is dWB/(WB.dt). The growth rate constant assumes that over the period of time the model applies, the growth of the organism can be represented by a constant fraction of the organism's body weight.

Mammals

The approach for modelling bioaccumulation in mammals is similar in many respects to the approach for modelling bioaccumulation in aquatic organisms. The general equation used to simulate chemical uptake and elimination in a marine mammals is represented at steady state by the following mass balance equation:

$$CM=kACAG + kD.\Sigma(Pi.CD,i) - (kO + kE + kU + kG + kP + kL + kM) \qquad (3)$$

where CM is the chemical concentration in the mammal, CAG is the gaseous aerial concentration ($g.L^{-1}$), kA is the inhalation rate constant ($L.kg^{-1}.d^{-1}$), and kD is the clearance rate constant ($kg.kg^{-1}.d^{-1}$) for chemical uptake via ingestion of food and water. Pi is the fraction of the diet consisting of prey item i and CD,i is the chemical concentration ($g.kg^{-1}$) in prey item i. kO, kE, kU, kG, kP, kL, kM are the first order rate constants (d^{-1}) for chemical elimination via the lungs, fecal egestion, urinary excretion, growth dilution, parturition, lactation, and metabolic biotransformation of the parent chemical, respectively. Loss via parturition and lactation are only applicable to breeding females. Due to the larger sizes of these mammals compared to fish and the generally larger spatial movement of these organisms in the Arctic, the simplifying assumption of steady state may not always be appropriate. However, at this time there is not enough spatially and temporally resolved monitoring data to warrant the development of a dynamic, spatially resolved bioaccumulation model for Arctic mammals.

Outreach and Capacity Building:

The outreach component of the project was completed March 2011. Adam Morris travelled to Resolute Bay and delivered a presentation to the Qarmartiliq School senior students (age 12–18) (see Figure 2). The presentation focussed on organic contaminants in the Arctic with an hour-long open format for students to contribute or ask questions as the presentation was given. The primary field assistant from the community (Peter Amarualik Senior) also attended in order to facilitate more effective communication and provide feedback. The presentation was well received with the students participating well. The teachers responded positively to the material presented, and provided useful feedback for future outreach efforts. Using studies from Resolute Bay as exam-

ples helped to put some of the research efforts going on around the community into context. Continued funding will be sought for cooperative outreach efforts, both in Resolute Bay and possibly to other communities involved in our studies.

Results and Discussion

A sub-set of the stable isotope and contaminant data to be used in the model development and evaluation are summarized in Figure 1. Data are from Morris et al. (2008, 2009, 2010a, 2010b); Morris et al. (2011a, 20011b); Tomy et al., (NCP 2008–2009). Thorough morphometric data were also compiled for fish and mammals. Identification of the invertebrates in bulk plankton and amphipod samples is currently underway. PBDE/BFR contaminant datasets are also currently being finalized.

Stable isotope analyses suggest that we successfully sampled key organisms composing the food webs in the Cumberland Sound, Barrow Strait and the terrestrial Bathurst system. Terrestrial vegetation δ13C and δ15N varied widely, however with increased sample sizes (N) for each species more in depth interpretations of potential food sources can be made, and species will be assessed individually rather than as bulk vegetation. Rae Strait biota δ13C signatures suggest that the cod sampled (Arctogadus glacialis) may not be feeding on the pelagic zooplankton and further that they may not be a significant food source for the ringed seal. Despite our best efforts, we could not obtain Boreogadus saida Arctic cod samples from Rae Strait, or Arctogadus glacialis samples in Barrow Strait.

Generally, the legacy and PFC contaminants investigated in Cumberland Sound showed increases with increasing TL (Figure 1, left panel). Marine mammals, elasmobranches and high trophic level teleosts (e.g. turbot) had different contaminant concentration patterns despite theoretically feeding in similar trophic positions. Additional differences in contaminant concentrations between similar, closely related organisms are also evident (e.g. beluga vs. narwhal, ringed vs. harp seal and Greenland shark vs. Arctic skate). For example, legacy OC compounds were consistently higher in narwhal than in beluga; but we observe the opposite trend with PFCs. Both physical and physiological differences might account for variations in both the uptake and/or metabolism of these compounds, resulting in the observed differences in patterns of contaminants within the food web.

The analyses of CUPs in the Cumberland Sound is currently being finalized, however data from the other 2 marine study systems are presented in the right panel of Figure 1. Unlike the legacy OCs and PFC compounds, the CUPs investigated either decrease consistently with increasing TL or increase in the mid-range TLs and drop back off in the higher trophic position animals to concentrations at or below those of the lowest TL organisms. Differences in the behaviour of the CUPs compared with legacy OCs in the Cumberland Sound suggest that it is not appropriate to regard all hydrophobic contaminants with the same assumptions in terms of bioaccumulation and biomagnification. Differences in the structure (such as charged or polar moieties) and other physical-chemical properties of the CUPs could generate the observed disparity in bioaccumulation due to changes in uptake (particularly dietary assimilation efficiency) and biotransformation. It is also important to ascertain concentrations in different tissues with less thoroughly studied contaminants, as this will allow us to better understand their transport and storage in biota. For example, concentrations of some CUPs are higher in seal liver than in blubber; further analyses will also investigate blood concentrations. This will allow for model

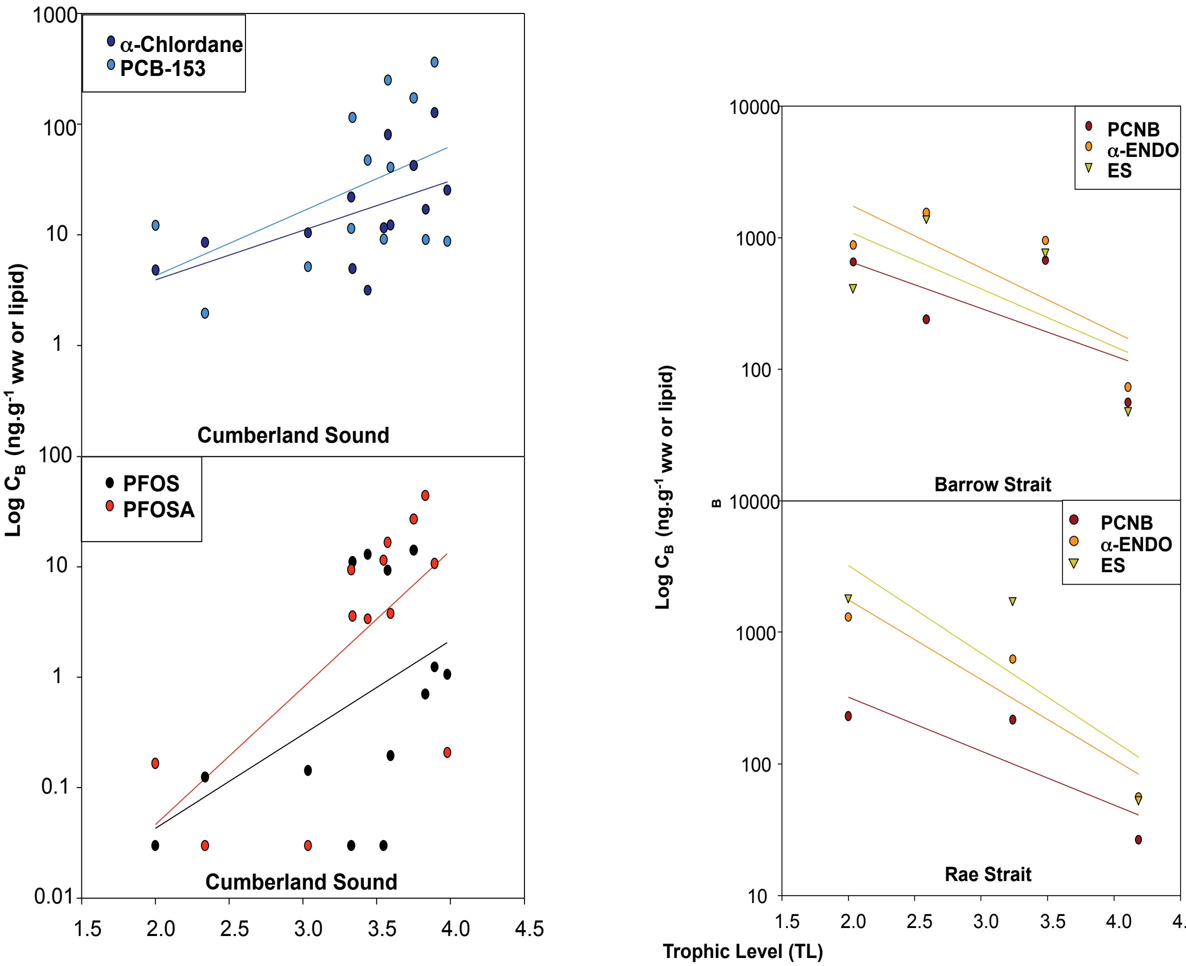

Figure 1. Trophic magnification figures for some fluorinated and legacy organochlorine contaminants investigated in the Cumberland Sound, NU (left panel) and for CUPs investigated in the Barrow and Rae Straits (right panel). Data are presented in ng.g^{-1}wet weight for PFCs and ng.g^{-1} lipid for OCs, and pg.g^{-1} lipid for CUPs. Points represent arithmetic means for each trophic level. Trophic level calculated as TL = 2 + ($\delta^{15}N_{consumer}$ - $\delta^{15}N_{Herbivore}$)/ΔN using the trophic enrichment factor (ΔN) = 3.8 as described in Hobson et al. (2002). PFOS = perfluorooctane sulfonate, PFOSA = Perfluorooctane sulphonamide, PCB = Polychlorinated biphenyl, PCNB = Pentachloronitrobenzene, ES = Endosulfan sulfate. Note scale changes on the y-axis.

detailed input to the models, and result in more accurate output. Application of a food web bioaccumulation model will allow us to alter specific physiological variables and observe resulting effects on contaminant concentrations and will ideally help us to explain some of the differences that we see 1) between food webs 2) between marine and terrestrial systems and 3) between types of contaminants.

Ongoing Activities

Final extractions and compilations of the datasets, QA/QC materials, and supporting data are underway. The modelling team is being supplied with the measured datasets as they are completed, and have begun parameterizing the bioaccumulation sub-models and marine and terrestrial food web models for the sampled organisms. Parameterization includes water concentrations, biological parameters (e.g. organism size, lipid contents), chemical parameters (e.g. octanol-water partition coefficients, octanol-air partition coefficients, metabolic biotransformation rate constant estimates), and food web parameters (e.g., trophic interactions).

Once the models have been parameterized, ideally, preliminary food web bioaccumulation model simulations will also be completed.

The food web bioaccumulation model calculations will be compared to the measured data to assess the preliminary modelling results. Based on this evaluation, improvements and revisions may be sought to improve model performance. These revisions may include re-evaluation of the simplifying model assumptions and the parameterization of key chemical properties such as the metabolic biotransformation rate constants. The initial estimates for metabolic biotransformation rate constants are from a database derived for fish and from a QSAR model that was developed for fish. These estimates from fish (mostly temperate species) may not be applicable to all fish species or to higher order organisms such as mammals. One of the objectives of this project is to better ascertain metabolic biotransformation rate constants for Arctic species and mammals in general. Once fully parameterized, applied and evaluated against monitoring data for legacy pollutants (i.e., PCBs), the models may provide insights into chemical- and species- specific biotransformation capacities and rates for emerging contaminants.

NCP Performance Indicators

Number of Northerners engaged in project: 1, Peter Amarualik Sr. assisted with the outreach presentation. Additionally, at least 8 Inuit and other aboriginal guides and assistants were involved in the related monitoring projects

Number of meetings/workshops held in the North: 1 school presentation in Resolute Bay, March 2011

Number of Students involved in NCP work: 18 students were involved in the presentation/workshop in Resolute Bay

Number of citable publications: None at present, several in process

Expected Project Completion Date

The development and testing of the models should be completed in November–December 2011, with additional model experiments to run after that. We expect to be finished the project entirely in January–February 2012, with publications being prepared shortly thereafter.

Acknowledgments

We would like to acknowledge the Northern Contaminants Program for support and funding for the current project. We would also like to thank the Molson Foundation, Environment Canada, Fisheries and Oceans Canada, The University of Guelph, GLIER and the University of Windsor, University of Toronto, The Government of the Northwest Territories, Mary Gamberg, Sharon Katz, International Polar Year and Arcticnet for funding, logistical support and sample collection in the contributing projects. We would also like to greatly acknowledge our Inuit and other aboriginal partners who guided and assisted us with sample collection and, importantly, survival. These include the Hamlets and Hunters and Trappers Associations of Resolute Bay, Gjoa Haven, and Pangnirtung, as well as individual guides Nancy Amarualik, Peter Amarualik Sr., Mark Amarualik and Debbie Iqaluk (Resolute Bay), George and Steven Konana (Gjoa Haven), Timothy Evic, Simeonie Kullualik and Livee Kullualik (Pangnirtung), and Chloe Smith and Bruno Croft (GNWT Yellowknife).

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Temporal Trends of Persistent Organic Pollutants and Metals in Ringed Seals from the Canadian Arctic

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Abstract
The objective of this project is to determine changes in concentrations of legacy contaminants, such as PCBs and other persistent organic pollutants (POPs), and mercury, as well as new contaminants, in ringed seals. All sampling is done with the help of hunter and trapper committees in each community who are supplied with sampling kits and instructions. In 2010 samples were collected by local hunters in the communities of Arviat, Resolute and Sachs Harbour. Chemical measurements were combined with results from previous years, including samples archived from the 1970s to examine the trends

Résumé
Cette étude à long terme examine les tendances temporelles des concentrations de mercure et d'autres oligo éléments ainsi que de polluants organiques persistants (POP), anciens et nouveaux, chez le phoque annelé en eau douce, au moyen d'échantillons prélevés tous les ans dans trois lacs (Amituk, Char et Resolute) situés 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 Island. En 2010, des échantillons de phoques annelés ont été recueillis dans les lacs Char, Hazen et Resolute. Afin d'évaluer les tendances temporelles, les résultats ont été

over time and geographical differences. In this report, trends in concentrations of mercury, cadmium, and perfluorinated chemicals in ringed seal liver are discussed in detail. Average mercury and cadmium concentrations in seal liver were similar to measurements made in the 1970–1990s. There was large variation in concentrations of both metals among individual seals within a given year which probably reflects the recent diet of individual animals. Perfluorinated carboxylates (PFCAs) have become the most prominent fluorinated chemicals in ringed seal liver over the past 5 years. Concentrations of PFOS and PFCAs are about 2 to 5 times higher now than they were in seals in the 1970s.

combinés à des résultats antérieurs obtenus pour ces mêmes lacs. L'ajout des résultats de 2010 à l'ensemble des données n'a révélé aucune tendance statistiquement significative relativement aux concentrations de mercure dans les quatre lacs à l'étude. Les concentrations et les profils des produits chimiques fluorés (PFC) chez le phoque annelé en eau douce ont été comparés pour des spécimens provenant des quatre lacs à l'étude situés près de Resolute. Le phoque du lac Resolute présentait un profil particulier de PFOS et de substances chimiques apparentées utilisées dans les mousses extinctrices. Une autre classe de PFC, les perfluorocarboxylates (PFCA), présentait de faibles concentrations, semblables dans tous les lacs. Les tendances temporelles préliminaires laissent penser que les concentrations de PFOS augmentent dans les lacs Char et Hazen, alors que les concentrations de PFCA semblent diminuer.

Key Messages

- Average mercury and cadmium concentrations in seal liver were similar to measurements made in the 1970–1990s.
- Both mercury and cadmium in liver vary widely among individual seals within a given year and generally concentrations are highest in older animals.
- Perfluorinated carboxylates (PFCAs) have become the most prominent fluorinated chemicals in ringed seal liver over the past 5 years.

Messages clés

- Les concentrations de mercure chez le phoque annelé en eau douce dans les quatre lacs à l'étude ne présentent ni une hausse ni une baisse significative.
- Les produits chimiques fluorés sont aussi détectables chez le phoque annelé en eau douce dans les quatre lacs à l'étude, et les concentrations de certains membres de cette classe de produits chimiques sont en hausse. Cependant, à l'exception des lacs qui ont subi des répercussions en raison de rejets d'eaux usées antérieurs, les concentrations dans les tissus musculaires de l'omble sont très faibles.

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 1996; Muir 1997; Muir et al. 1999; Muir et al. 2001; Muir et al. 2003). Results for POPs and heavy metals including mercury are available going back to the 1980s, and earlier in some cases. This ringed seal contaminants project now has a very large database consisting of results for about 680 samples for PCBs and organochlorine pesticides (OCPs) and about 1000 samples for mercury, cadmium and selenium in liver. Biological data including age and carbon and nitrogen stable isotope data are available for about 550 individual seals collected in the past 10 years.

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

In these synopsis reports we try to focus on a different aspect of the data each year given limited space and the large size of the dataset. Our 2009–10 report focused on temporal trends of "legacy POPs" and a first detailed report on polychlorinated naphthalenes (PCNs) in seal blubber (Muir et al. 2010). This report for fiscal year 2010–11 presents new information on mercury and cadmium as well as on perfluorinated chemicals (PFCs) in seal liver.

Activities in 2010–2011

Sample collection: In 2010 ringed seal samples were successfully collected with the help of hunters in the communities of Arviat (N=25), Sachs Harbour (4), Resolute Bay (N=16). The limited collection at Sachs Harbour was caused by poor weather conditions despite best efforts of our contractor Jeff Kuptana. In addition the lab processed 25 samples from Ulukhaktok for Richard Addison's NCP project (Addison et al. 2011). Collections consisted of blubber, liver, muscle, kidney, tooth/lower jaw (for aging). Essential data on length, girth, blubber thickness at the sternum, and sex was provided for almost all animals for all locations. Samples were stored at -20^{o}C and then shipped frozen to Burlington for processing. Large subsamples of all tissues were archived in walk-in freezers at 220oC in sealed plastic bags (double bagged).

In 2010 all tooth aging was conducted by Matson Labs (Milltown, MT). Muscle samples were sent to Wildlife Genetics International (Nelson BC) for gender confirmation using a DNA marker and to the University of Waterloo (Environmental Isotope Lab) for C and N stable isotope analysis.

Short reports (in English and Inuktitut) on the results of the study to date were faxed to the Hunters and Trappers committee offices of each community in April/May 2011 as part of communication and consultations. In February 2011, project summaries were also sent to the Chairs of the Nunavut Niqiit Avatitinni Committee and the NWT Environmental Contaminants Committee.

Chemical analyses: Organochlorine pesticides (OCPs), PCBs and polybrominated diphenyl ethers (PBDEs), in seal blubber were determined as described by Muir et al. (2005) with minor modifications. Samples were extracted with dichloromethane (DCM) using either pressurized fluid extraction (ASE 300, Dionex Instruments) or a Soxhlet apparatus, and lipid was removed by gel permeation chromatography. The extracts were then fractionated on a small activated silica column into non-polar (hexane) and polar (hexane:DCM 1:1) fractions. These fractions were concentrated, vialed and then analysed by gas chromatography with electron-capture detection (GC-ECD). Separation was accomplished on a HP 6890 GC using a 30m DB-5 column with H2 carrier gas. Only samples from females or juvenile males were analysed for POPs.

PCNs and coplanar PCBs were determined in the hexane fraction from the silica column fractions. The sample was applied to a ENVITM –Carb SPE Tube using 7.5% DCM/Cyclohexane. Two fractions were collected (1) 7.5% DCM/Cyclohexane containing co-planar PCBs and (2) toluene which contained the PCNs (NLET 2007b). PCNs and co-planars were subsequently analysed by GC-MS in electron-ionization mode.

Seal liver samples were analysed for perfluorinated chemicals by the method of Powley et al (2005). Homogenized tissue was extracted twice with acetonitrile and the combined extract was concentrated to dryness, reconstituted in methanol, and then cleaned with a carbon cartridge. Instrumental analysis was performed by LC-MS/MS following previously described conditions (Butt et al. 2008).

Seal muscle was analysed for total mercury using a Direct Mercury Analyser (DMA; Milestone Instruments). Seal liver was homogenized and subsamples were acid digested and then the digest was analyzed for mercury, cadmium and 30 other elements using the inductively coupled plasma technique with mass spectroscopy (ICP-MS), and for total mercury using cold vapour atomic absorption spectroscopy (CV-AAS).

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

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).

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 and OCPs in the data for female ringed seals were analysed using the statistical program PIA (Bignert 2007).

Results and Discussion

Sample collection and hunter observations: In 2010 requested information on gender, girth, length, blubber thickness was provided for 41 of 44 animals. The identification of the gender of the seals by hunters in the field was in agreement with results for DNA markers in 40 out of 41 samples. 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. Numbers of ringed seals at Sachs Harbour were low compared to earlier years e.g. 2005–2007 due to poor weather. Also hunters there are getting more bearded seals than they did previously.

Trends of mercury and cadmium in seal liver: We have previously report trends in concentrations of mercury in ringed seal muscle from Arviat, Sachs Harbour and Resolute (Muir et al. 2010). Although there are advantages in using muscle because mercury concentrations appear to less variable from year to year (Gaden et al. 2009) most of the older data for mercury and cadmium in ringed seals is based on liver and we continue to monitor it. Therefore in this report we revisit trends of the toxic metals, mercury and cadmium in liver.

Mercury and cadmium are known to increase with age in seals with sub-adults having much lower concentrations than adults (Wagemann et al. 1998; Riget et al. 2005). This is the case in our dataset as well. The relationships of mercury and cadmium with age of seals from Arviat, Sachs Harbour and Resolute are shown in Figure 1A and B, respectively. Both mercury and cadmium increase with age up to about 5 yrs. The trend after 5 yrs of age is less clear; concentrations are more or less constant. On this basis we examined temporal trends using only animals ≥ 5 yrs. Where ages were not available seals >90 cm in length were included in the time trend analysis because, in general, all seals greater than that length were 5 yrs old or older. In fact, there were strong statistical relationships of length and age for seals from all 3 communities. Also there was no influence of gender of the animals on mercury or cadmium in liver concentrations so results for both males and female ringed seals were combined.

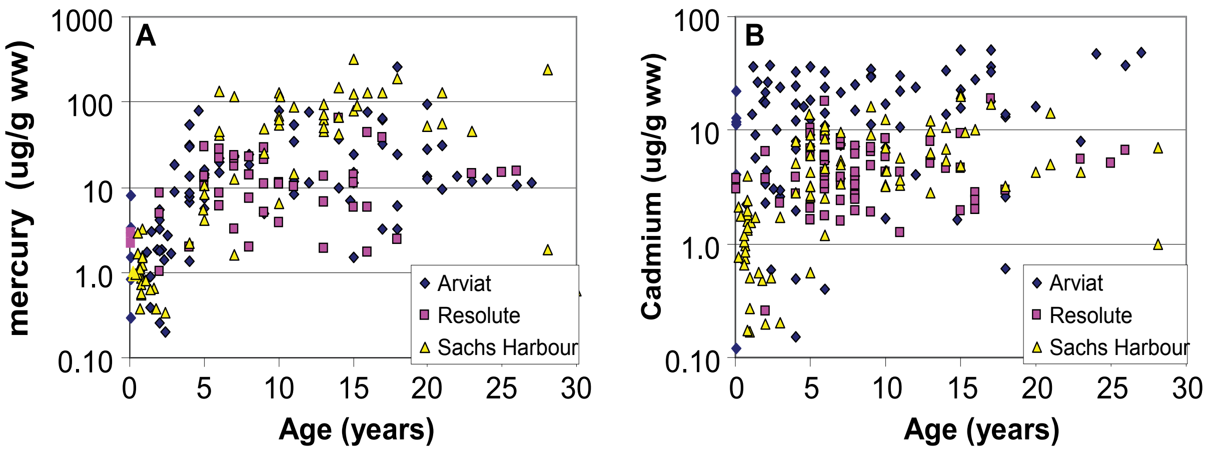

Figure 1. Relationship of (A) mercury and (B) cadmium in liver of ringed seals from Arviat, Resolute and Sachs Harbour with age of the animals.

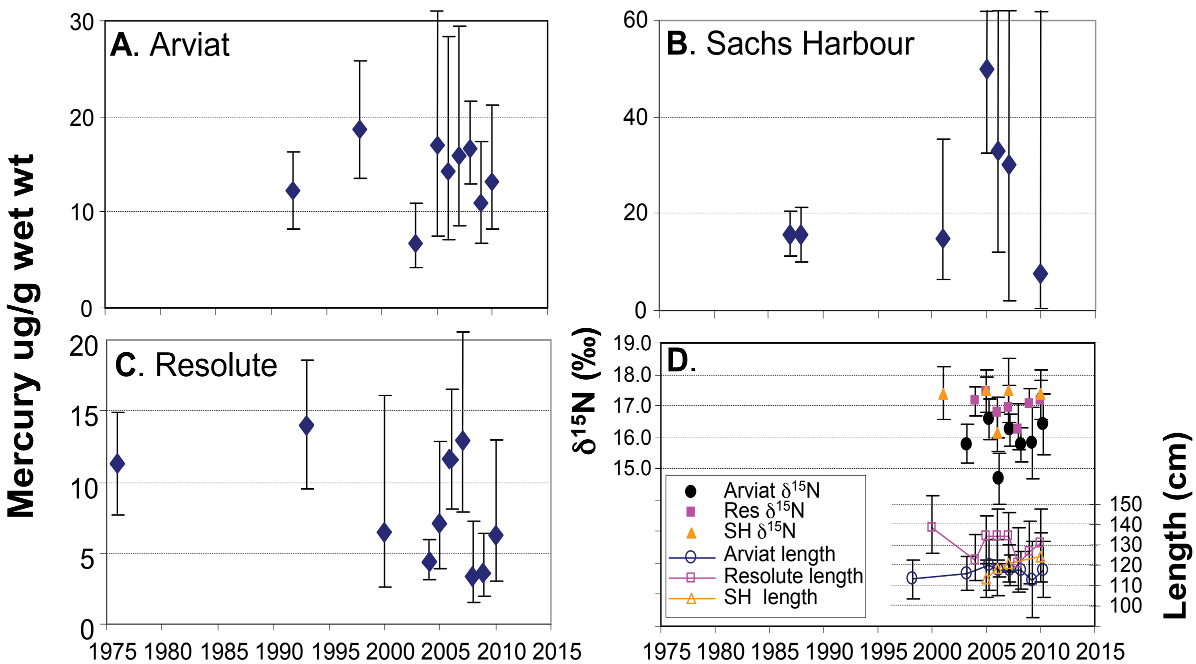

Figure 2. Time trends of mercury in seal liver Arviat (A), Sachs Harbour (SH) (B) and Resolute (C). Symbols represent geometric mean concentrations and vertical lines are 95% confidence limits for animals ≥5yrs of age. The lower right graph (D) shows average values and standard deviation (vertical lines) for nitrogen stable isotope ratio, $\delta^{15}N$ in seal muscle and length of the animals analysed for mercury.

The time trends of mercury in seal liver are shown in Figure 2A, B and C. In Figure 2D, average results for δ15N, which is an indicator of the trophic level of the seals, and seal body length are presented. Results from the 1970s, '80s and early '90s are taken from the AMAP heavy metals report data annex (Dietz et al. 1998). For the older data only standard deviations were available rather than 95% confidence limits. Mercury concentrations in liver varied among animals within the same year by up to 50% or more in a few cases as can be seen in Figure 2 by the large confidence intervals around the geometric means. The year to year range of mean concentrations is also large with differences of up to 100% between years (Figure 2A, B, C). Due to these large fluctations, there are no significant trends of mercury in liver over time. However, at all three locations, particularly at Sachs Harbour and Resolute, there were higher average liver mercury levels in the period 2005–2007 compared to 2010 or the early 2000s. This deviation is not reflected in the muscle δ15N values for those years (Figure 2D). Also average length of the seals that we collected varied by <10% over the period 2003–2010 at all three locations. However, liver mercury could reflect more recent diets of individual animals compared to measurements of muscle nitrogen. Interestingly this elevation in the period 2005–2007 was not seen in muscle samples from the same animals (Muir et al. 2010).

The time trends of cadmium in seal liver from Arviat, Sachs Harbour, Resolute and Pond Inlet are shown in Figure 3. Note that the scale for concentrations at Arviat is larger than for the other 3 locations. Cadmium concentrations are about 2–fold higher in seals from Arviat than at the other 3 locations. Surveys in the 1980–90s also showed higher cadmium in Hudson Bay and Eastern Arctic locations compared to the western Canadian arctic (Wagemann et al. 1996; Dietz et al. 1998). Cadmium concentrations in liver show quite large variations within a given year based on 95% confidence limits typically from 50–100% of the mean (Figure 3). Thus no distinct temporal trends of cadmium are apparent although mean concentrations at Arviat, Resolute and Sachs Harbour appear to have declined since peaking in 2005–07 similar to observations for mercury.

Trends of POPs

Measurement of all organic contaminants continued in 2010–11 but results for PCBs and other chlorinated organics including organochlorine pesticides, toxaphene, endosulfan, chlorinated paraffins and PCNs are pending. Results for PFCs were updated during 2010 to include archived liver samples from Sachs Harbour and Grise Fiord from 1972 provided from Environment Canada's National Wildlife Tissue Bank as well as samples

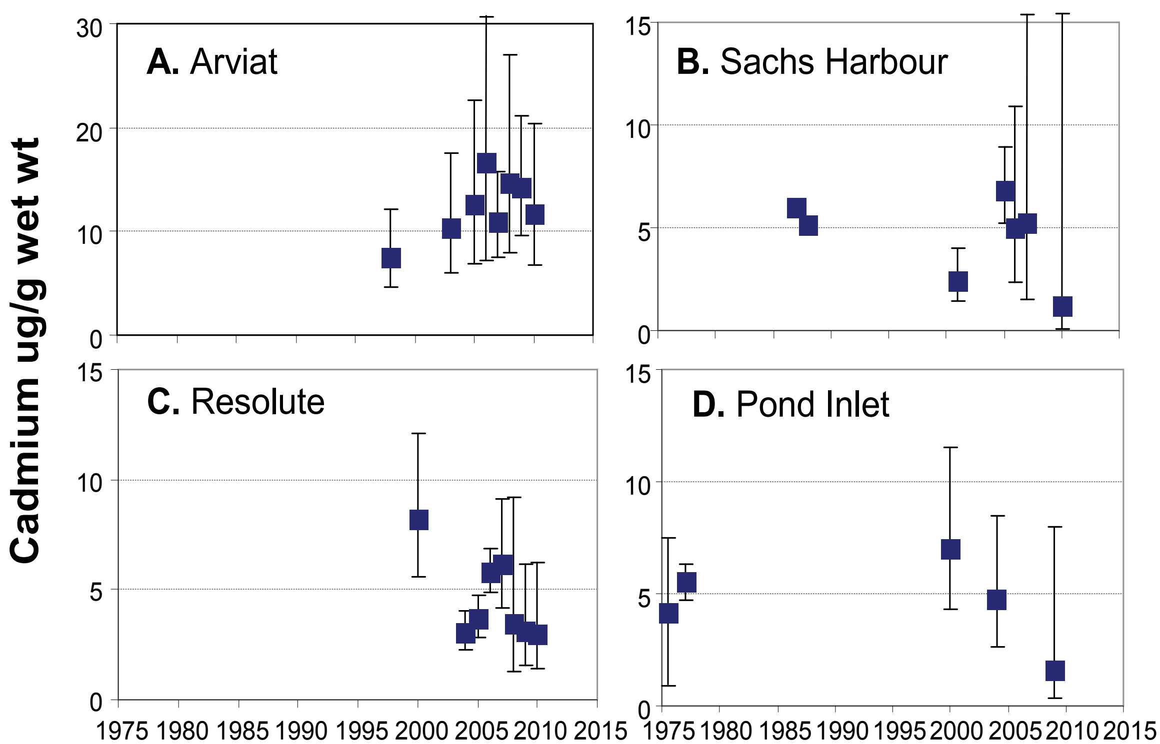

Figure 3. Temporal trends of cadmium in ringed seal liver from 4 communities. Symbols represent geometric mean concentrations and vertical lines are 95% confidence intervals except for results from the 1970s and 1970s which were reported as standard deviations (Dietz et al. 1998).

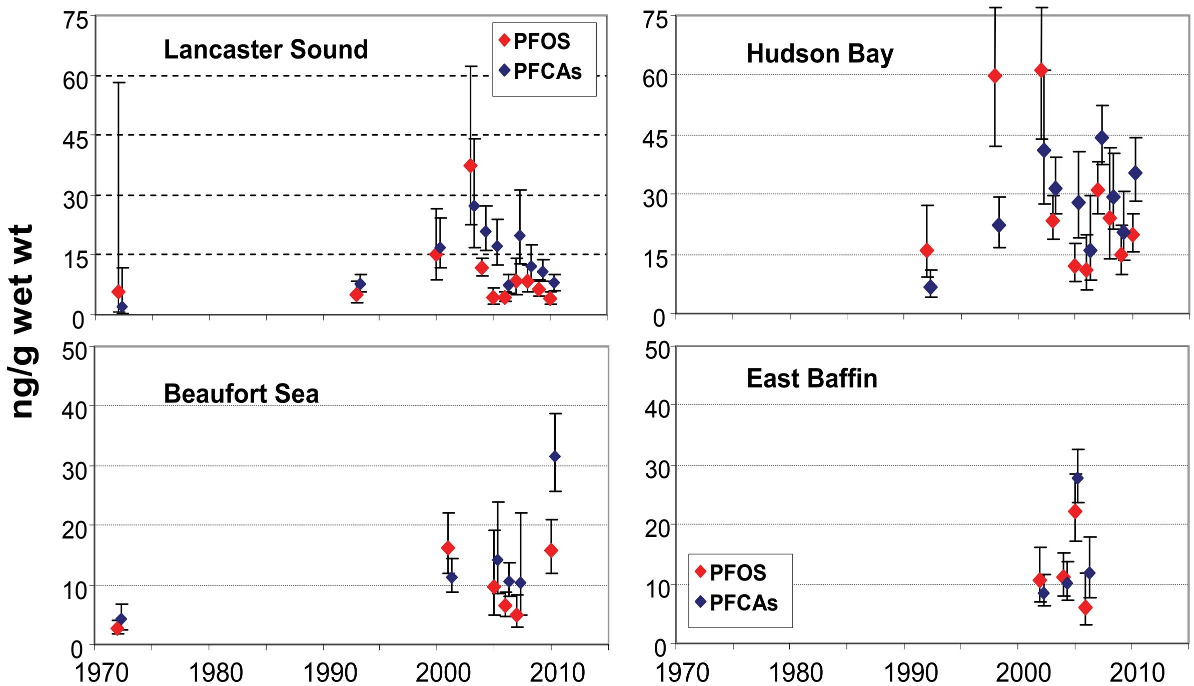

Figure 4. Temporal trends of PFOS and PFCAs in ringed seal liver. Results from neighboring communities have been combined. Lancaster Sound=Resolute, Arctic Bay, Grise Fiord; Hudson Bay=Arviat and Inukjuaq; Beaufort Sea=Sachs Harbour and Ulukhaktok; East Baffin=Pangnirtung and Qikiqtarjuaq. Symbols represent geometric mean concentrations and vertical lines are 95% confidence intervals

from 2010 from Ulukhaktok, in addition to the samples collected in 2010 from Arviat, Resolute and Sachs Harbour.

As can be seen in the scale of the upper two panels in Figure 4, PFOS and total perfluorinated carboxylates (ΣPFCA; sum of PFOA, PFNA, PFDA, PFUnA, PFDoA) are generally present at higher concentrations in liver from seals in Hudson Bay than at other locations. While most of the data are from Arviat, Resolute and Sachs Harbour, results from nearby communities were combined because of similar levels (see Figure 4 caption). While PFOS and ΣPFCA concentrations were similar in samples from the early 1970s to early 2000s, PFCAs are now more prominent contaminants. Similarly PFOS has undergone a marked decline since 2000–03 in Hudson Bay (Arviat) and since 2004 at Resolute (Butt et al. 2007). Interestingly, this decline is not evident in ringed seals in Greenland based on results to 2006 (Bossi et al. 2005; Butt et al. 2010). PFCAs seem to have declined in the Lancaster Sound area but appear to be increasing in Hudson Bay animals. Trends at the two other locations are more difficult to discern.

Discussion and Conclusions

This study has provided new information on the temporal trends of mercury, cadmium and PFCs in ringed seal liver from four regions in the Arctic. Concentrations of mercury and cadmium in ringed seal liver are similar to measurements made in the 1970–1990s. Variation in concentrations of both metals among individual seals within a given year is high probably reflecting individual prey choices. Year to year variation does not seem to be directly related to shifts in diet nor to differences in age because, on average, both were similar over the period early 2000s to 2010. The results also show that there is significant regional variation in concentrations of mercury and cadmium and that our current three sampling locations may not adequately reflect this. Thus further studies of time trends in other locations e.g. Pangnirtung where there are samples available from a number of sampling times, should be pursued.

PFCAs have become the most prominent fluorinated chemicals in ringed seal liver over the past 5 years. The increase in PFCAs is also observed in ringed seals from Greenland. The decline in PFOS is consistent with the phase out and bans on this chemical and its precursors in the early 2000 (3M Company 2000). However while PFOS has declined in recent years in seals in the Canadian arctic it has not trend downwards in Greenland for reasons that are not clear at this time. The precursors of this group are very widely used commercial chemicals although there are agreements with major manufacturers to reduce emissions of PFOA and its precursors (US EPA 2006). However concentrations continue to increase at least in Hudson Bay seals.

Expected Project Completion Date

The project is ongoing with annual sampling at 3 locations planned under the NCP 2010–11 "Blueprint".

NCP Performance Indicators

Number of northerners engaged in your project: This project involves the hunters and trappers committee in each community who approve participation, the HTC manager who distributes sample kits and makes payments, and the individual hunters. In Sachs Harbour, Jeff Kuptana was hired to do sample processing. In total an estimated 25 people participated based on 8–10 hunters in Arviat and Resolute and three HTC managers. In previous years the numbers were much higher when 5 communities per year were being sampled.

Number of meetings/workshops held in the north: 1. Met with HTC Manager, Nancy Amarualik while in Resolute (July 2010).

Number of students involved in the project: 1 – PhD student Adam Morris has contributed samples and visited Resolute in March 2011 where he spoke with the Manager of the HTC

Number of citable publications: 0. Contributed data to the AMAP Mercury assessment and the CACAR POPs assessment. The paper by Riget et al Science of the Total Environment 2010 on time trends of POPs in the Arctic included data for ringed seals contributed by this study.

Acknowledgments

Donna Zaruk and Kevin Bundy of NLET conducted the sample extraction and GC data analysis during 2010–11. We thank the Molson Foundation for financial support for graduate student research on contaminants in ringed seals during 2010.

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Temporal Trends of Persistent Organic Pollutants and Mercury in Landlocked Char in High Arctic Lakes

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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 2010, arctic char samples were successfully collected from Char, Hazen and Resolute lakes. To assess trends over time, results were combined with previous results from the same lakes. With the addition of results from 2010 we found no statistically significant trends of mercury concentrations in

Résumé

Cette 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 recueillis au moyen d'échantillons tous les ans dans trois lacs près de la collectivité de Resolute Bay, sur l'île Cornwallis (Amituk, Char et Resolute) et dans le lac Hazen, dans le parc national Quttinirpaaq, sur l'île d'Ellesmere. En 2010, on est parvenu à collecter des échantillons d'omble chevalier dans les lacs Char, Hazen et Resolute. Afin d'évaluer les tendances temporelles, les résultats ont été combinés aux résultats antérieurs pour les mêmes lacs. Après l'ajout des résultats de 2010,

char in the four study lakes. The concentrations and patterns of fluorinated chemicals (PFCs) in landlocked char were compared in the four study lakes near Resolute. Char from Resolute Lake had a unique pattern of PFOS and related chemicals used in fire fighting foams. Another class of PFCs, the perfluorocarboxylates (PFCAs), were at similar low concentrations in all lakes. Preliminary temporal trend results suggest that PFOS concentrations are increasing in Char and Hazen lakes while PFCAs appear to be declining.

Key Messages

- Concentrations of mercury concentrations in landlocked char from the four study lakes are not increasing nor are they decreasing significantly.
- Fluorinated chemicals are also detectable in char from all four lakes and some members of this class of chemicals are increasing in concentrations. However, except for lakes impacted by past waste water discharges, concentrations in char muscle are very low.

nous n'avons établi aucune tendance statistique significative en ce qui a trait à la concentration de mercure chez les populations d'omble chevalier des quatre lacs étudiés. Les concentrations et les profils des produits chimiques fluorés (PFC) chez l'omble chevalier cantonné en eau douce ont été comparés pour des spécimens provenant des quatre lacs à l'étude situés près de Resolute. L'omble du lac Resolute présentait un profil particulier de perfluorooctanesulfonate (PFOS) et de substances chimiques apparentées utilisées dans les mousses extinctrices. Une autre classe de PFC, les perfluorocarboxylates (PFCA), présentait de faibles concentrations, semblables dans tous les lacs. Les tendances temporelles préliminaires laissent penser que les concentrations de PFOS augmentent dans les lacs Char et Hazen, alors que les concentrations de PFCA semblent diminuer.

Messages clés

- Les concentrations de mercure chez l'omble chevalier cantonné en eau douce dans les quatre lacs à l'étude ne présentent ni une hausse ni une baisse significative.
- Les produits chimiques fluorés sont aussi détectables chez l'omble chevalier des quatre lacs à l'étude, et les concentrations de certains membres de cette classe de produits chimiques sont en hausse. Cependant, à l'exception des lacs où des eaux usées ont déjà été déversées, les concentrations dans les tissus musculaires de l'omble sont très faibles.

Objectives

1. Determine long term temporal trends of persistent organic pollutants (POPs) and metals in landlocked Arctic char from lakes in the Canadian high arctic islands by analysis of annual or biannual sample collections.
2. Investigate factors influencing contaminant levels in landlocked char such as the influence of sampling time, water temperature, diet and climate warming.
3. Determine levels of current POPs and metals as well as "new" potential POPs in fish from lakes of importance to the community of Resolute Bay (Qausuittuq) and provide this information on a timely basis.

Introduction

Landlocked char are important sentinel species in Arctic lakes. As the only top predators in most high latitude Arctic lakes, landlocked char (Köck et al. 2004) are good indicators of changes in inputs of methyl mercury, the toxic and bioaccumulative form of mercury. The same considerations apply to persistent organic pollutants (POPs) which are known to have similar biomagnification potential as methyl mercury. Unlike mammals and birds, fish have limited capacity to degrade most POPs and excrete many of these chemicals very slowly (Niimi and Oliver 1983; Fisk et al. 1998). They thus provide information on the range of chemical contaminants and time trends of these chemicals which complements studies on mammals and birds from the same regions. However, there is much lake to lake and individual variation in contaminant levels which needs to be better understood.

There is a lot more information now available on contaminants in landlocked char populations and their food webs as a result of studies by Gantner et al (2009; 2010a; 2010b), Swanson and Kidd (2010) and Swanson et al. (2010) and Chételat et al. (2008; 2010). These studies show that catchment-to-lake area ratio influences mercury in char as does methyl mercury concentrations in chironomids and benthic algae. The presence of anadromous Arctic char and/or lake trout does not seem to affect mercury concentrations in resident (non-andromous) char from the sample lakes (Swanson and Kidd 2010; Swanson et al. 2011).

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 2004). 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. As a result, collections of char from Char, Amituk and Hazen have not been made consistently on an annual basis. Collection numbers have 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. 2006; 2007; 2008; 2009; 2010).

Activities in 2010–2011

Sample collection: Samples were successfully collected in July 2010 from Char, Hazen and Resolute Lakes by our field teams. Our fish collection at Amituk Lake was unsuccessful. This lake is only accessible by helicopter and our day trip there yielded only one adult char. Poor visibility due to persistent fog prevented a second trip. Fish were dissected in Polar Continental Shelf Project labs at Resolute or at the Parks Canada facility at Lake Hazen. 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 archived for future age determinations.

Chemical analysis: Analytical methods were unchanged from previous reports (Muir et al. 2006; Muir et al. 2007). All analyses were performed by the National Laboratory for Environmental Testing (NLET) at Canada Centre for Inland Waters in Burlington. Mercury and 31 other elements were analysed in Arctic char muscle (skinless). Organohalogen compounds were determined in homogenized char (muscle plus skin) samples. PCBs and organochlorine pesticides (OCPs) were analysed in final cleaned up extracts were by gas chromatography with electron-capture detection (GC-ECD). All organohalogen analyses were conducted in the NLET “ultraclean” room (carbon and HEPA filtered air; positively pressured) to minimize background contamination. Toxaphene, endosulfan isomers and endosulfan sulfate, PBDEs and hexabromocyclododecane (HBCD) were analysed by low resolution GC-negative ion mass spectrometry (GC-NIMS). Toxaphene was determined as “total” toxaphene using a technical toxaphene standard and also by quantification of individual chlorobornanes (see Muir et al. (2004) for further details on methods).

Perfluorinated chemicals (PFCs) in char muscle were analysed using the method of Powley et al (2005). Homogenized tissue was extracted twice with acetonitrile and the combined extract was concentrated to dryness, reconstituted in methanol, and then cleaned with a carbon cartridge. The samples was then analysed by liquid chromatography tandem mass spectrometry as described by Butt et al. (2007). Major compounds analysed were perfluorohexanesulfonate (PFHxS), perfluoroheptanesulfonate (PFHpSA), perfluorooctane sulfonate (PFOS), perfluorooctanoate acid (PFOA), perfluorononanoate (PFNA), perfluorodecanoate (PFDA), perfluoroundecanoate (PFUnA) and perfluorooctansulfonamide (PFOSA).

Stable isotope analyses: Muscle from all fish analysed for mercury and POPs were analysed for stable isotopes of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) at University of Waterloo Environmental Isotope Lab in muscle samples using isotope ratio mass spectrometry.

Quality assurance (QA): Certified reference materials (CRMs) for heavy metals included DOLT-2, DORM-2 and TORT-2 (National Research Council of Canada) and 1588b cod liver from NIST (National Institute of Standards and Technology) for PCBs, OCPs, and PBDEs. CRMs and reagent blanks were also run with each sample batch of 10 samples. Blanks were generally <1% of measured values for individual OCPs and <5% for individual PCBs. Blanks for BDE 47 and BDE 99 ranged from 5-10% of values in samples while for BDE 209 blanks were up to 50% of sample values. All results for PBDEs were blank subtracted while no correction was used for PCB/OCPs. NLET organics and metals labs are participants in the NCP Quality Assurance Program. The NLET labs are accredited by the Standards Council of Canada through Canadian Environmental Analytical Laboratory program to the standard CAN-P-4D (ISO/IEC 17025).

Statistical analyses: Geometric mean concentrations and upper/lower 95% confidence intervals were calculated with log transformed data and back transformed for graphical presentation. Results for POPs were lipid adjusted by dividing by fraction lipid. Non-detect concentrations were replaced with a random number between 10% and 50% of the instrumental detection limit. Based on previous data analyses (Muir et al. 2010) results for all elements and POPs were log10 transformed in order to reduce coefficients of skewness and kurtosis to <2.

Results

Mercury and other elements: The trends of mercury over time in Arctic char from Amituk, Char and Resolute lakes are shown in Figure 1. We have previously reported that mercury levels were increasing slowly in Arctic char from Amituk, Char and Resolute lakes (Muir et al. 2008; 2009). However, when the 2010 results were included and trends were analysed with the PIA software (Bignert 2007) using length adjusted log transformed means for each sampling year, no statistically significant trends were found in all 4 lakes (Table 1). Results for Resolute Lake, with 14 sampling years, were closest to achieving the desired goal of detecting a 5% change (with a power of 80% at α=5 %) at 16 yrs and power of 65%.

Differences in water residence time, food web length, and watershed characteristics, as well as differences in proportions of piscivorous char, may help to explain the spatial and temporal differences in mercury among the lakes (Gantner et al. 2010b). In addition to piscivory, differential consumption of various life stages of chironomids, the main diet item of char in high Arctic lakes, may affect lake to lake mercury patterns (Chételat et al. 2008). In Lake Hazen, in particular, mercury was higher and more variable in piscivorous char

Table 1. PIA analysis of time series for mercury concentrations in landlocked char muscle.

Lake		# years	Overall trend (NS=not statistically significant; P>0.20)	Years to detect 5% change (with a power of 80% at α=5 %).	Power to detect a log-linear trend of 5% with the number of years in the current time series	lowest detectable change for a 10 y period with the current between year variation at a power of 80%
Amituk	1989–2009	10	-0.70% (NS)	19	17%	14%
Char	1993–2010	9	0.6% (NS)	13	34%	7.6%
Hazen	1990–2010	10	1.2% (NS)	23	11%	20%
Resolute	1993–2010	14	-2.2% (NS)	16	65%	11%

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

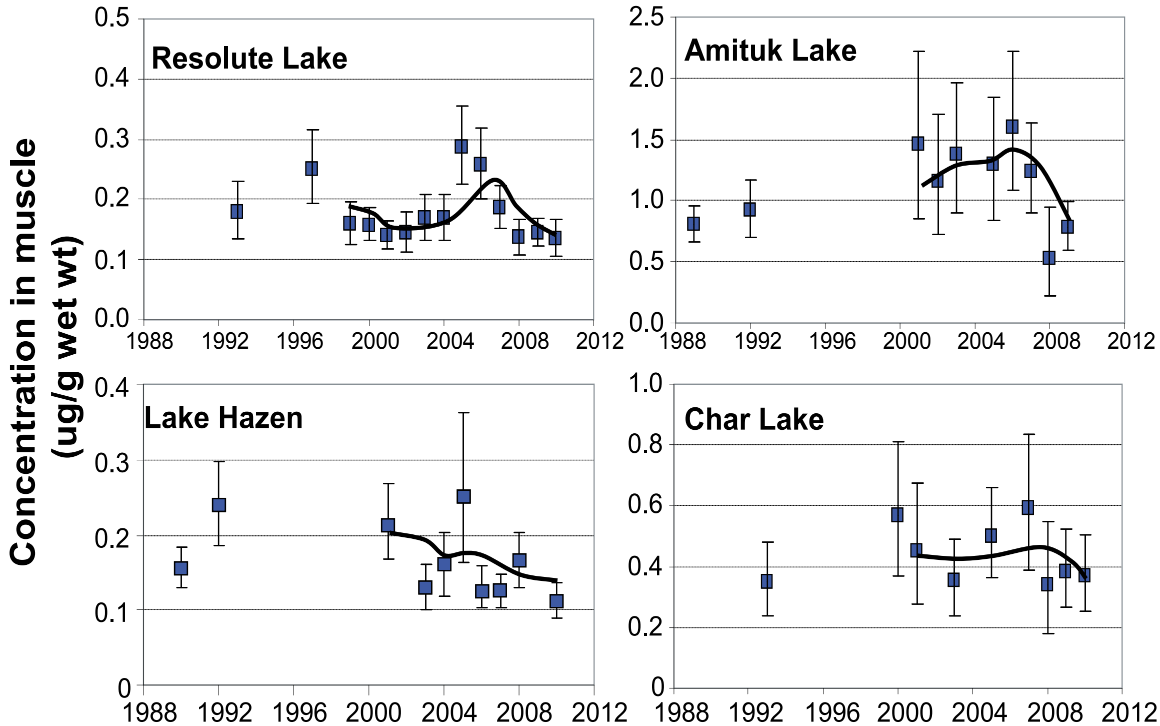

Figure 1. Trends of mercury (geometric means ± 95% confidence interval) in landlocked char from Resolute, Amituk, Char, and Hazen lakes (early 90s-2010). All results are length adjusted using analysis of covariance. Lines represent 3 year moving averages.

and we have previously examined time trends on those separately from insectivores (Gantner et al. 2009; Muir et al. 2009). However, for time trend analysis with the PIA program we combined the results for all the fish from Lake Hazen.

Persistent organohalogen compounds: In previous reports we focussed on time trends of legacy POPs, endosulfan and PBDEs (Muir et al. 2008; Muir et al. 2009; Muir et al. 2010). Here we focus on PFCs because time trend data is now available with the analysis of all samples from 2007–2010 and selected earlier archived samples. Figure 2A shows the average concentrations of major classes of PFCs in all char muscle samples collected over the period 2003–2010 from Amituk, Char, and Hazen Lakes, and for Resolute Lake from 2007–2008. Lowest concentrations are found in Char, Amituk and Hazen lakes. As we have reported previously, PFOS and its precursor PFOSA, as well as the related perfluoroalkyl sulfonate PFHxS were elevated in char from Meretta Lake, which is upstream of Resolute Lake, as well as in Resolute Lake itself (Muir et al. 2010). As first reported by Stock et al. (2007), Resolute and Meretta Lakes appear to have been contaminated with aqueous film forming foams that contain PFOS related chemicals and are used for airport and military fire fighting. This probably occurred during the years that waste water entered wetlands just west of the lake. That entry of waste effluent was stopped in 1998 when new waste water facilities were built at the airport (Douglas and Smol 2000).

The pattern of PFCs in the landlocked char muscle from the 5 lakes shows that there are similar concentrations of ΣPFCAs (sum of PFOA, PFNA, PFDA, PFUnA and PFDoA) in all lakes including Resolute (Figure 2A) indicating that the contamination is almost entirely due to products containing PFOS and related compounds. Figure 2B illustrates that the concentrations of major components of ΣPFCA (PFOA, PFNA, PFDA) are low and very similar in all lakes with only PFOA being slightly elevated in Resolute

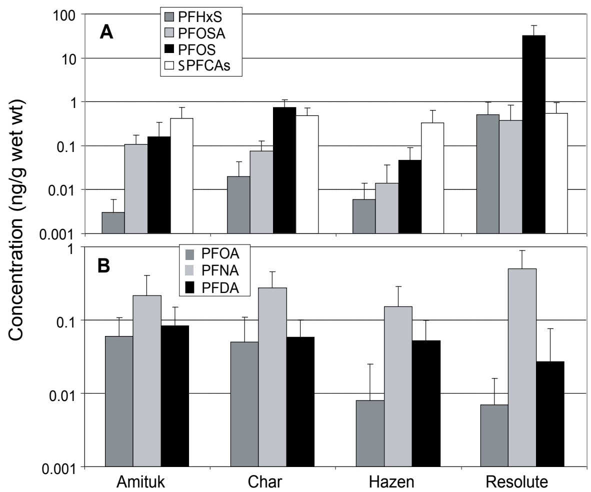

Figure 2. Concentrations (ng/g wet wt) of major perfluorinated chemicals in arctic char muscle from Amituk, Char, and Hazen Lake over the period 2003–2010, and for Resolute Lake from 2007–2008. Bars represent arithmetic means and vertical lines are standard deviations.

Lake. Analyses of lake waters and sediments have shown that Amituk and Char have background concentrations that are expected in remote lakes receiving PFCs solely via atmospheric deposition (Stock et al. 2007). A new NCP funded study (Kidd et al. 2011) is examining the current levels and food web accumulation of PFCs in Resolute Lake and nearby lakes.

Preliminary time trends for ΣPFCAs and PFOS in char muscle from Amituk, Char and Hazen lakes are show in Figure 3. ΣPFCAs were present at similar concentrations in archived char muscle from Char Lake 1993 as in samples from 2007–2010 which was surprising because increasing trends are observed in ringed seals. Also concentrations of PFCAs in Lake Hazen char in 2003 and 2008 were similar although the concentrations in the 2010 samples suggest a decline. On the other hand PFOS concentrations appear to be increasing in Char and Hazen lakes.

Discussion and Conclusions

Analysis of trends of mercury in landlocked char from the four lakes in this study shows that with results from 2010 included, there are no statistically significant trends in the four study lakes. Annual sampling, and low within year variation, is clearly needed to detect statistically significant trends of mercury. The results contrast with lake trout and burbot from Great Slave Lake (Evans and Muir 2011b), with burbot in the Mackenzie River (Carrie et al. 2010), and in fish from small lakes in the Mackenzie River basin (Evans and Muir 2011a) where increasing mercury in fish has been reported. The reasons for the differences between our high arctic lakes and the Mackenzie valley lakes aren't clear but are interesting and need further study.

The temporal trends of PFCs in landlocked char were reported for the first time in this report. Although time points are still limited, the trends for PFCAs and PFOS in landlocked char are quite different from ringed seals from the Lancaster Sound area, which show generally declining PFOS and stable or increasing PFCAs (Muir et al. 2011).

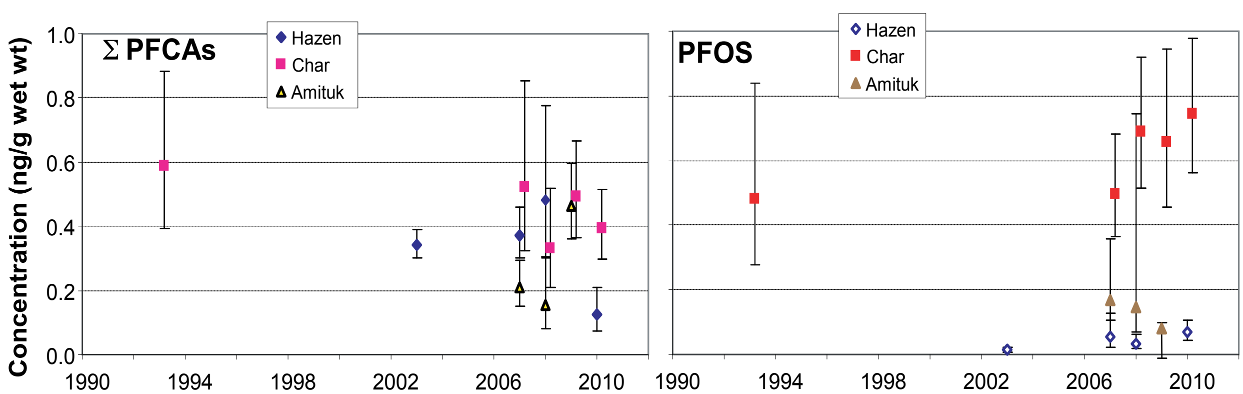

Figure 3. Time trends of ΣPFCAs (total perfluorocarboxylates) and PFOS (perfluoro-octanesulfonate) in arctic char muscle from Hazen, Char and Amituk Lakes. Symbols represent geometric means ± 95% confidence intervals.

This illustrates the value of having time trends in multiple species with completely different habitats.

NCP Performance Indicators

Number of northerners engaged in your project: 2. This project hired Debbie and Brandy Iqaluk to help sample fish.

Number of meetings/workshops held in the north: 1. Met with HTC Manager, Nancy Amarualik while in Resolute (July 2010).

Number of students involved in the project: 1. MSc student Gretchen Lescord helped with fish collections in Resolute, Char and Amituk Lakes during 2010.

Number of citable publications: 0. Contributed data to the AMAP Mercury assessment and the CACAR POPs assessment. The paper by Riget et al Science of the Total Environment 2010 on time trends of POPs in the Arctic included data for char contributed by this study.

Acknowledgements

We thank the Hamlet of Resolute Bay for permission to sample Char Lake and other lakes in the region, Parks Canada for their support of sampling at Lake Hazen and Polar Continental Shelf Project for accommodation and aircraft support.

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

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Grise Fiord HTA, Box 71, Grise Fiord X0A 0J0
Resolute Bay HTA, Box 217, Resolute Bay X0A 0V0
Northeast Baffin Bay (NE BB):Pond Inlet HTA, Box 400, Pond Inlet X0A 0S0
Clyde River HTA, Box 90, Clyde River X0A 0E0
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Abstract

The polar bear (Ursus maritimus) is the apex predator of the Arctic marine ecosystem and an integral component of Inuit and northern culture in Canada. Due to its position at the top of the marine food web, levels of persistent organic pollutant (POP) and metal contaminants in polar bears are among the highest observed in the Arctic. Results to date for 2010-2011 focused on the spatial trends and comparative changes in time of selected trace elements in liver tissue from polar bears from the seven different subpopulations in Canada as well as subpopulations in Alaska and East Greenland. For nine trace elements (As, Cd, Cu, total Hg, Mn, Pb, Rb, Se and Zn), spatial trends were investigated in 136 specimens sampled during 2005-2008 from bears from these ten subpopulations. Concentrations of total Hg, Se and As were highest in the (northern and southern) Beaufort Sea area and lowest in (western and southern) Hudson Bay area and Chukchi/Bering Sea. In contrast, concentrations of Cd showed an increasing trend from east to west. Minor or no spatial trends were observed for Cu, Mn, Rb and Zn. To assess temporal changes of Cd, total Hg, Se and Zn concentrations during the last decades, we compared our results to previously published data. As of 2007-2008, the temporal data suggested that the total Hg concentrations in polar bears from Canadian Arctic, other than from the Beaufort Sea, are similar to the concentrations reported from 1980s. In contrast, recent total Hg increases are suggested for East Greenland polar bears. Compared to non-adjusted concentrations, when adjusted for food web feeding position, concentrations showed reduced spatial variation for total Hg, Se and As for bears in central and eastern Canadian Arctic subpopulations, which indicated the importance of diet adjustment when assessing spatial and temporal trends. Furthermore, the relatively low concentrations of total Hg, Se and As in bears

Resume

L'ours polaire (*Ursus maritimus*) est le principal prédateur de l'écosystème marin arctique. Il représente également une composante intégrale de la culture des Inuits et des habitants du Nord au Canada. En raison de la position des ours polaires tout en haut de la chaîne alimentaire marine, les niveaux de polluants organiques persistants (POP) et de métaux lourds décelés chez eux sont parmi les plus élevés observés dans l'Arctique. Les résultats à ce jour pour 2010-2011 ont porté sur les tendances spatiales et sur la comparaison, au fil du temps, des changements aux éléments traces sélectionnés dans le tissu hépatique des ours polaires faisant partie des sept différentes sous populations au Canada, de même que de sous populations en Alaska et dans l'est du Groenland. Les tendances spatiales de neuf éléments traces (arsenic [As], cadmium [Cd], cuivre [Cu], mercure total [Hg], Mn, plomb [Pb], rubidium [Rb], soufre [Se] et zinc [Zn]) ont fait l'objet d'analyses à partir de 136 échantillons prélevés de 2005 à 2008 sur des ours faisant partie de ces dix sous populations. Les concentrations de Hg total, de Se et d'As étaient plus élevées dans la région de la mer de Beaufort (partie nord et sud) et plus basses dans la région de la baie d'Hudson (partie ouest et sud) et de la mer de Béring (Tchouktche). Par contre, on a constaté une tendance à la hausse des concentrations de Cd, d'est en ouest. On a observé des tendances spatiales mineures ou l'absence de tendances dans le cas du Cu, du Mn, du Rb et du Zn. Afin d'évaluer les changements temporels aux concentrations de Cd, de Hg total, de Se et de Zn au cours des dernières décennies, nous avons comparé les résultats de nos recherches aux données publiées précédemment. En 2007-2008, les données temporelles laissaient croire que les concentrations de Hg total chez les ours polaires de l'Arctique canadien, ailleurs que dans la mer de Beaufort, étaient similaires aux concentrations relevées dans les années 1980. Par contre, les études récentes ont révélé une augmentation de Hg total chez les ours polaires de l'est du Groenland. En comparaison avec les concen-

from Hudson Bay may be ascribed to what level they feed at in the marine food web rather than regional contaminant differences. Conversely, the relatively high levels of total Hg, Se and As for Beaufort Sea bears may be due to more to regional contamination rather than dietary sub-population differences. This work is of significant value to northerners, whose cultural lifestyle depends on subsistence foods that polar bears prey on, as well as polar bears in the Inuit diet.

trations non rajustées, dans le cas où l'on effectuait un rajustement en raison de ce qu'ils mangent dans la chaîne alimentaire, les concentrations ont indiqué une réduction de variation spatiale de Hg total, de Se et d'As chez les ours faisant partie des sous-populations du centre et de l'est de l'Arctique canadien. Ces résultats ont ainsi démontré l'importance du rajustement du régime alimentaire dans le cadre de l'évaluation des tendances spatiales et temporelles. De plus, les concentrations relativement faibles de Hg total, de Se et d'As chez les ours de la baie d'Hudson peuvent être attribuables à ce qu'ils mangent dans la chaîne alimentaire marine, plutôt qu'à des différences régionales de contaminants. Réciproquement, les niveaux relativement élevés de Hg Total, de Se et d'As chez les ours de la mer de Beaufort peuvent être attribuables à la contamination régionale, plutôt qu'à des différences du régime alimentaire chez les sous-populations. Ce travail revêt une grande importance pour les habitants du Nord dont le mode de vie ancestral repose sur des aliments de subsistance dont les ours polaires sont les prédateurs, ainsi que sur les ours polaires eux-mêmes qui font partie du régime alimentaire des Inuits.

Key Messages

- Concentrations of total Hg, Se and As were highest in the (northern and southern) Beaufort Sea area and lowest in (western and southern) Hudson Bay area and Chukchi/Bering Sea.
- Concentrations of Cd showed an increasing trend from east to west, whereas minor or no spatial trends were observed for Cu, Mn, Rb and Zn.
- As of 2007–2008, the temporal data suggest that the total Hg concentrations in polar bears from Canadian Arctic, other than from the Beaufort Sea, are similar to the concentrations reported from 1980s, although in contrast, recent total Hg increases are suggested for East Greenland polar bears.
- Compared to non-adjusted concentrations, when adjusted for effects of the position of feeding in marine food web, reduced spatial variation was observed for total Hg, Se and As for bears in central/

Messages clés

- Les concentrations de Hg total, de Se et d'As sont plus élevées dans la région de la mer de Beaufort (partie nord et ouest) et plus faibles dans la région de la baie d'Hudson (partie ouest et sud) et de la mer de Béring (Tchoukche).
- Les concentrations de Cd indiquent une tendance croissante d'est en ouest, alors que l'on a observé des tendances mineures ou l'absence de tendances spatiales dans le cas du Cu, du Mn, du Rb et du Zn.
- En 2007-2008, les données temporelles semblaient indiquer que les concentrations de Hg total chez les ours polaires de l'Arctique canadien, autres que ceux de la mer de Beaufort, étaient similaires aux concentrations relevées dans les années 1980, bien qu'au contraire, des augmentations récentes de Hg total aient été relevées chez les ours polaires de l'est du Groenland.
- En comparaison des concentrations non ajustées, dans le cas où des ajustements par rapport aux conséquences liées au niveau de leurs proies dans la chaîne alimentaire marine, on a observé une

eastern Canadian Arctic, which indicated the importance of diet adjustment when assessing spatial and temporal trends.

- Relatively low concentrations of total Hg, Se and As in bears from Hudson Bay may be ascribed to diet rather than regional contamination differences. Conversely, the relatively high levels of Hg, Se and As for Beaufort Sea bears may be due to more to regional contamination rather than dietary subpopulation differences.

variation spatiale réduite de Hg total, de Se et d'As chez les ours du centre et de l'est de l'Arctique canadien. Ces résultats démontrent l'importance de l'ajustement de l'alimentation dans le cadre de l'évaluation des tendances spatiales et temporelles.

- Des concentrations relativement faibles de Hg total, de Se et d'As chez les ours de la baie d'Hudson peuvent être attribuées à leur alimentation plutôt qu'à des différences régionales en matière de contamination. Réciproquement, les niveaux relativement faibles de Hg, de Se et d'As chez les ours de la mer de Beaufort peuvent être imputables à la contamination régionale, plutôt qu'à des différences d'alimentation chez les sous-populations.

Objectives

Overall

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

Specific and shorter term

1. To determine the spatial and ongoing temporal trends of legacy and emerging POPs (e.g., brominated flame retardants (BFRs) and perfluorinated compounds (PFCs)) and degradation products, precursors and/or isomers, and metals/elements (e.g., Hg) in polar bears using the appropriate tissues collected in communities within the western and southern Hudson Bay management zones in the Canadian Arctic, using appropriate tissues (fat or liver).
2. To use carbon and nitrogen SIs and FAs as ecological tracers of trophic levels and diet, and determined in polar bear tissues (muscle or fat) from selected management locations (assessed in (1)) to examine the influence of diet and trophic level as confounding factors on POP spatial and temporal trends, in addition other influential factors such as sex, age, time of collection, and lipid content.
3. To identify and determine emerging chlorinated, brominated and fluorinated POPs that may persist in the tissues of polar bears, are not necessarily listed as a NCP, LRTAP or Stockholm Convention priority POP, and can be monitored for as part of or with little deviation from analytical methods applied for determination of the NCP priority POPs.
4. To provide information in a timely manner to each Inuit community participating in the study, on the levels and trends of POPs in polar bears. This would include translation of documentation and deliverables into Inukituk.
5. To archive the remaining polar bear tissue samples that were collected as part of this project, in Environment Canada's National Wildlife Specimen Bank (EC-NWSB) located at the NWRC, Carleton University, Ottawa.

Introduction

Like humans, polar bears are at the top of the Arctic marine food web, circumpolarly distributed, and thus are an ideal sentinel/monitoring species for contaminants in the Arctic. Through the process of biomagnification, it continues to be shown that polar bears achieve some of the highest (legacy and emerging) contaminant concentrations in their tissues of any arctic species or any species on the planet (e.g., Butt et al. 2010; de Wit et al. 2010; Letcher et al 2010a).

Spatial trends of legacy OC contaminants in Canadian polar bears, such as PCBs, methyl sulfone (MeSO2) PCB metabolites and OC pesticides, were last assessed for 2001–2002 collected samples (Verreault et al. 2005). Levels of legacy OC contaminants, such as PCBs and chlordanes, have been monitored in the WHB polar bear population consistently through the 1980s and 1990s (Norstrom et al. 1998). We recently completed studies on longer-term temporal trends (1991–2007) of legacy organics as well as PBDEs and other BFRs, and the influence of changes of sea-ice conditions and diet shifts of bear from the western Hudson Bay populations (McKinney et al. 2009; McKinney et al. 2010). In 2010–2011 we continued to build on an annual basis, on temporal trends studies on POPs for bears from the Hudson Bay subpopulations.

The emergence of PFCs and their precursors as ubiquitous environmental contaminants is recent, including in the Arctic (Butt et al. 2010; Houde et al. 2006, 2011; Letcher et al. 2010a). We showed in 2001–2002 collected samples that several emerging POPs such as PFCs (e.g., perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA)) accumulated in the liver of bears spanning the Canadian arctic (Smithwick et al. 2005a, 2005b). Up until the present studies, there was only one known study on the temporal trends of PFCs in polar bears for any North American bear population. In liver samples of bears collected in 6 years between 1972 and 2002 from one Canadian location (Northern Baffin Island) and Barrow, Alaska, concentrations of PFOS and perfluorinated carboxylates (PFCAs) with carbon chain lengths from C9 to C11 were reported to be exponentially increasing at both locations with doubling times ranging from 3.6 ± 0.9 years for perfluorononanoic acid in the eastern group to 13.1 ± 4.0 years for PFOS in the western group (Smithwick et al. 2006).

Up until the present studies, there was a dearth of temporal data for BFRs in polar bears (de Wit et al. 2010; Letcher et al. 2010a). We had previously reported on PBDEs in the fat of bears collected in 2001–2002 from all Canadian (Nunavut and NWT) management zones (Muir et al. 2006). PBDEs have also been reported in Arctic biota with increasing frequency; however the focus has generally been on Br4 to Br8 PBDE congeners, which largely comprise the PentaBDE and OctaBDE technical mixtures, which are now largely phased out from commercial use. Much less is known about in Arctic biota about higher brominated PBDEs, and especially BDE-209, which is the major constituent of the unregulated DecaBDE technical mixture. Up until the present study, other important and bioaccumulative BFRs such as hexabromocyclododecane (HBCD; total and not isomer-specific) had not yet been determined in Canadian polar bears (Letcher et al. 2010a). Clearly more spatial and temporal studies on HBCDs are necessary for Canadian bears. Furthermore, there are other numerous and current-use non-PBDE BFRs that may also be of environmental relevance to the Arctic and present in polar bears, such as hexabromobenzene (HBB), 1,2-bis(2,4,6-tribromophenoxy)ethane (BTBPE), pentabromoethylbenzene (PBEB) and pentabromotoluene (PBT) (Gauthier et al. 2007, 2009).

Three international agreements have been implemented to regulate the production use and release of POPs and heavy metals (e.g., Pb, Cd and Hg). These include the United Nations Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution (UN-ECE LRTAP) Protocols on POPs and heavy metals and the global United Nations Environment Programme (UNEP) Stockholm Convention on POPs. Both of these conventions recognize that the presence of a given chemical in the Arctic environment represents the strongest evidence that the chemical is a POP and subject to long-range transportation. Heavy metals, and particularly Hg, also exhibit the potential to be transported over long distances to be deposited in the Arctic. Currently, there is no global agreement to reduce Hg emissions; however, the United Nations Environment Programme has recently initiated an intergovernmental Negotiating Committee to develop a legally binding global agreement by 2013. Up until the present studies, the last examination of spatial trends of metals in Canadian polar bears was carried out on 2001–2002 collected samples (Rush et al. 2008). Rigét et al. (2011) recently reviewed the current state of knowledge on the temporal trends on Hg in the Arctic, and noted for polar bears such recent trends are lacking.

Ecological tracers such as fatty acids (FAs) and stable nitrogen and carbon isotopes (SIs) are stable chemical or biochemical compounds that can be used to trace the movement of energy and contaminants through food webs, or between predator (polar bears) and prey (ringed seals and possibly other prey) (Iverson et al. 2004, 2006; Thiemann et al. 2008). Some FAs cannot be synthesized with high efficiency in higher trophic level organisms. Instead, these essential FAs are formed by primary producers and are passed up the food chain. Nitrogen and carbon SIs are routinely used in ecotoxicological studies. They can define organism trophic position, food source, and the chemical characteristics of habitats used by wildlife.

Activities in 2010–2011

Sample collections

This is an ongoing multi-year NCP project, and the current phase was initiated in 2010–2011. That is, this is the start of a new NCP IV, 5-year monitoring cycle, and fat, liver and muscle samples were obtained from SHB bears (n=22) and WHB bears (n=12). These samples were collected from bears in the late winter/early spring harvests of participating communities, HTAs, hunters and Nunavut collaborators in Hudson Bay. Hudson Bay polar bear monitoring on an annual basis allows for optimal temporal assessment of contaminants and thus the statistical power of temporal datasets. This also allows for annual monitoring for bears from Hudson Bay where sea-ice change (Arctic warming) appears to be most acute and where sea-ice conditions are measured annually (McKinney et al. 2009). Although outside the scope of the Canadian focus of this NCP core monitoring project, for international (formerly IPY) partners from Denmark, in 2010–2011 we also had collected fat, liver, muscle, kidney, and testes or reproductive tract samples collected from Hudson Bay bears for ongoing POP effects studies in comparison to bears from East and West Greenland.

Organic contaminants

Analysis of the legacy POPs, polybrominated diphenyl ethers (PBDEs), HBCD, PFCs and total Hg and other elements were carried out in the OCRL or by Lab Services at the NRWC. OC analysis for the legacy POPs were carried out by gas chromatography using a mass selective detector (GC/MSD) according to NWRC Method No. MET-CHEM-OC-06B. Analysis of the 47 standard PBDE congeners, total-α-HBCD and numerous other new BFRs was be carried out using GC-low resolution MS run in negative ion chemical ionization (NCI) mode according to ORG RES Method No. MET-NWRC-OCRL-BFR-07 and reported elsewhere (McKinney et al. 2010, 2011). PFCs were determined using LC-MS/MS in negative electrospray mode (ESI-) according to MET-NWRC-OCRL-PFC-02 and reported elsewhere (Chu and Letcher 2008; Gebbink et al. 2009). PFCs analyzed included 10 saturated and linear, C6-C15 PFCAs, 4 saturated and linear (C4, C6, C8 and C10) PFSAs, PFOSA and NMeFOSA, and the precursor 6:2, 8:2 and 10:2 fluorotelomer alcohols, and 6:2, 8:2 and 10:2 fluorotelomer unsaturated acids. In 2010–2011, numerous papers were published in peer-reviewed, scientific journals, on the screening and characterization of emerging BFRs, in vitro metabolism of major PBDEs/BFRs, and spatial and temporal trends of PBDEs, BFRs, OCs and PCBs in Canadian polar bears with samples collected in 2007–2008 (McKinney at al. 2011a, 2011b, 2011c). Longer term temporal trends of the same organic contaminants were reported for bears from WHB and sampled 1991–2007 (McKinney et al. 2009, 2010).

Metals/elements

As reported in Rush et al. (2008) in assessments of metals and elements in polar bear (liver) from Canadian bears collected in 2001–2002, a total of 21 elements were determined (essential elements: As, Cd, Co, Cr, Cu, Li, Mn, Mo, Ni, Se, V and Zn; and non-essential elements: Ag, Ba, Ga, La, Pb, Rb, Sr, Hg and Pt). However, only the 15 elements Ag, As, Ba, Cd, Cu, Ga, Hg, Mn, Mo, Pb, Rb, Se, Sr, V and Zn were included in the spatial trend and Hudson Bay temporal assessments, as Cr, Li, Ni, Tl, U, Sb, Pd, Pt,Co and La were previously found to be below detection limit in more than 20% of the samples (Rush et al. 2008). Therefore, in 2010–2011 polar bear liver samples, Ag, As, Ba, Cd, Cu, Ga, Mn, Mo, Pb, Rb, Se, Sr, V and Zn were determined by ICP-MS (NWRC) and total Hg by atomic absorption spectrometry (AAS) (EC-NWRC) according to established methods (Routti et al. 2011a, 2011b). Total Hg was analyzed using an Advanced Mercury Analyzer (AMA-254) according to NWRC Method No. MET-CHEM-AA-03G.

Polar bear sample and dietary and ecological tracers
Age determinations for all bears for which a tooth had been collected are being determined by labs (A. Coxon) of the Government of Nunavut in Igloolik. However, this age data is not available at the time of writing this synopsis report. For all polar bear (fat) samples collected in 2010, at NWRC the analysis of a suite of 37 saturated and polyunsaturated, C6-C24 fatty acids were completed (McKinney et al. 2011a). SIs of nitrogen and carbon were also determined by the EIL (University of Waterloo) using polar bear fat and muscle tissues.

Quality assurance of chemical analysis
Quality assurance/quality control (QA/QC) for all PCB and OC analyses were in accordance with accreditation through the CALA-SCC. To ensure inter-comparability of all contaminant data, EC-NWRC (Lab Services and Letcher/OCRL) labs have participated in the NCP III 1, 2, 3, 4 and 5 QA/QC Program (coordinated by the Ontario Ministry of the Environment's Laboratory Services Branch in cooperation with Environment Canada) for PCBs, OCs, PBDEs and metals/elements, and in the case of annual evaluations in 2008–2009, 2009–2010 and 2010–2011, participated for PFCs. For PCBs, OCs, PBDE, PFCs and metals/elements, EC-NWRC has committed to participate in the NCP Phase IV QA/QC rounds (for 2011–2012 the results are due in 2011). For FA determinations, EC-NWRC has been participating in an interlab QA/QC exercise with EC-WSD (Burlington; M. Arts) and the Great Lakes Institute for Environmental Research (University of Windsor). For carbon and nitrogen SI analysis, the EIL at the U. of Waterloo follows strict QA/QC guidelines.

Data analysis and dissemination of results
Statistical analysis of the all POP data (including degradation products, precursors and isomers) takes into account such factors as location, age, sex, diet and trophic level and other available information on the bears. NCP funding also facilitated the continued dissemination of the collected contaminant data in the form of manuscripts that have been submitted or published in peer-reviewed scientific journals. For large scale spatial trends studies on samples over 2007–2008, all POPs data sets have been finalized. In 2010–2011, all of this data with the exception of PFCs has been fully published or submitted for publication in peer-reviewed, scientific journals. McKinney (PhD student, Carleton University) completed, finished and successfully defended her PhD thesis in 2010–2011. Dr. Heli Routii also completed her PDF in this present reporting year.

Sample archiving
As stipulated in the 2010–2011 NCP Blueprint (Section 5.5), it is important that all tissue samples collected during the course of these studies be properly archived for future use. The collected polar bear liver, fat and muscle samples that were collected in 2010–2011 were sent frozen and directly to NWRC. All remaining polar bear tissue samples were archived and are stored in the Environment Canada's National Wildlife Specimen Bank (EC-NWSB) located at the NWRC at least at -40°C, all with individual temperature monitoring and alarms. All 2007–2008 (and 2001–2002) polar bear tissue samples from the previous NCP studies are also currently archived in the EC-NWSB at NWRC. Polar bear samples collected in 2010–2011 are part of the all important polar bear tissue archive that will be available for future research initiatives. For 2007–2008 contaminant analyzed samples, we have also archived the sample extracts (as best we can) as is encouraged by NCP.

Capacity building, communications and traditional knowledge
In 2010–2011, this project cooperated in building expertise in scientific sampling during the late winter/early spring 2010 harvests in Hudson Bay. In this research year, the four participating communities and HTAs were directly involved and led in the organization and collection of

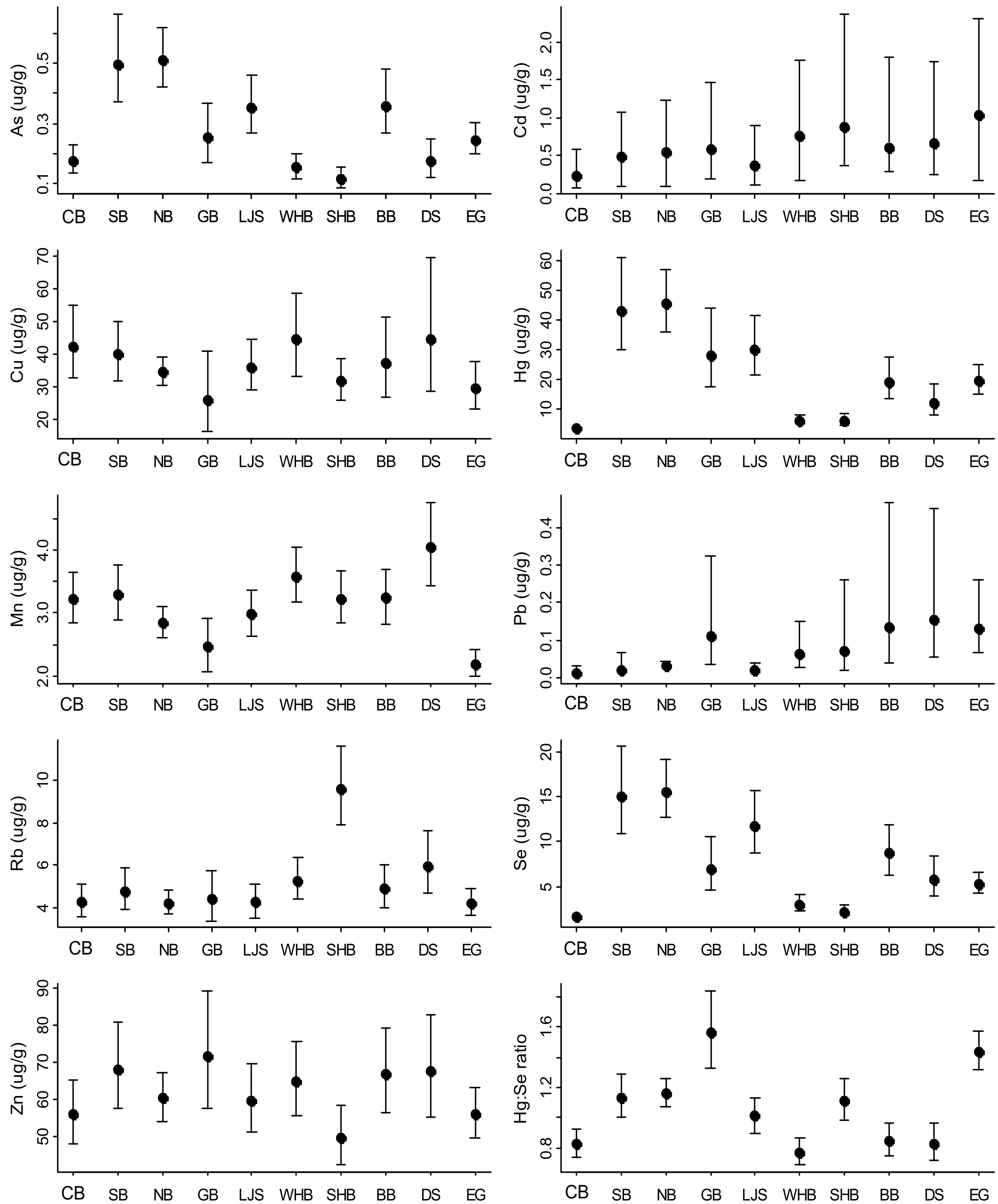


Figure 1. Geometric mean concentrations (µg•g^{-1} (or µg/g) wet weight ± 95% confidence intervals) of As[a], Cd, Cu, total Hg[a], Mn[b], Pb, Rb[b], Se[a] and Zn[b], and molar ratio of Hg : Se[c] in polar bear liver from Alaska, Canada and Greenland in 2005–2008. Concentrations are adjusted for sex and age (a), age (b) or for sex (c) (Adapted from Routti et al. 2011a).

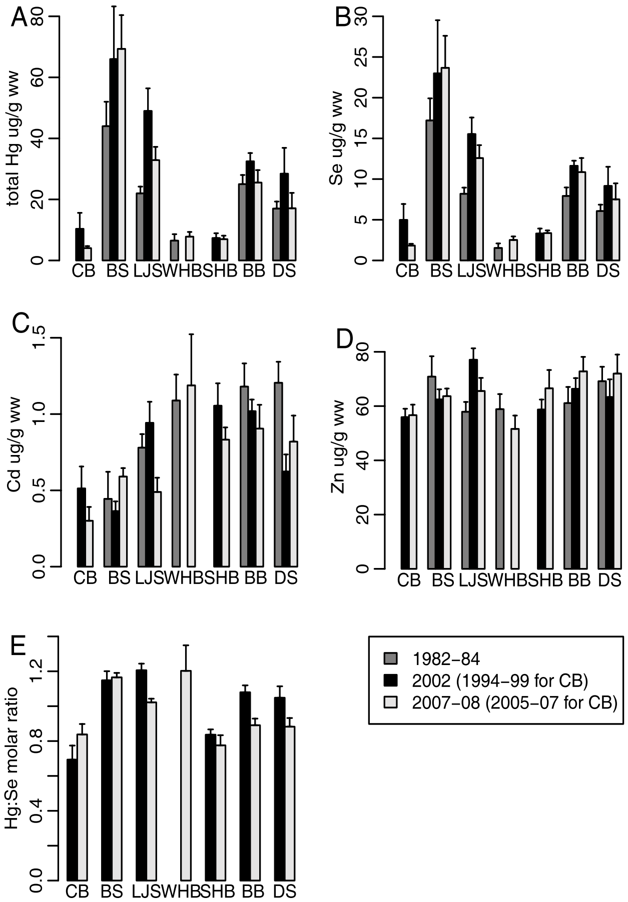
fat, liver and muscle samples. As detailed in an approved 2010 Nunavut Wildlife Research Permit, and in cooperation with the Dr. Stephen Atkinson and Angela Coxon in the Department of Environment, Government of Nunavut, Dr. Letcher arranged and sent directly to the COs in each community a cooler complete with a suitable number of sampling kits that coincides with the number of bears required for these management zones and within the allowable hunting quota for that community. Also, Letcher established with S. Atkinson and M. Fredlund (Government of Nunavut, Dept. of Environment) an Agreement of Cooperation and Contribution, which embodies this research Environment Canada-Government of Nunavut partnership. For the hunters in each community, each cooler contained simple and easy to read sampling instructions in both English and Inuktitut. Therefore, when the COs distributed the kits to the hunters, it was as easy as possible for them to sample correctly. Sampling instructions were also sent to the NAC who assessed whether the right questions being asked with regards to the traditional knowledge (e.g., sex, age and health).

For new POP data that had become available in 2009–2010, presentations and dissemination were made at the 2010 NCP Results Workshops held in late September/early October in Whitehorse, Yukon Territory. With the completion of journal publications and reports, these documents were provided to Nunavut partners and the NAC for further distribution. Whenever it was necessary, the PI responded to any inquires or concerns of the participating communities. The PI also made

Table 1. Sampling area, year, number of individuals, and median age of polar bears investigated for spatial trends and time point comparisons. M: male; F: female; U: Unknown.

	Chukchi/ Bering Sea (CB)	N. Beaufort Sea (NB)	S. Beaufort Sea (SB)	Gulf of Boothia (GB)	Lancaster/ Jones Sound (LS)	W.Hudson Bay (WH)	S. Hudson Bay (SH)	Baffin Bay- N.E. Baffin Is. (BB)	Davis Strait- S.E. Baffin Is. (DS)	E. Greenland/ Scoresby Sound (EG)
Year	2005–07	2007	2007	2007	2007–08	2007–08	2007–08	2007–08	2008	2006
n(M:F:U)	12(7:5:0)	11(7:4:0)	27(18:9:0)	6(4:2:0)	13(11:2:0)	11(8:3:0)	14(10:4:0)	14(11:3:0)	8(8:0:0)	20(14:6:0)
Age (range):U	8(2-22):0	6(4-24):1	9(3-20):1	9(3-24):0	6(3-11):1	7(3-29):0	9(3-22):2	5(2-10):4	5(3-6):1	7(3-19):0
Year			2002[a]		2002[a]		2002[a]	2002[a]	2002[a]	1999–2000[a]
n (M:F:U)			11(8:3:0)		13(3:1:9)		11(5:6:0)	12(7:5:0)	13(7:5:1)	22(9:13:0)
Age (range):U			3(0-25):1		9(5-14):6		4(3-7):7	7(5-13):7	7(2-18):7	6(3-23):9
Year	1994–99									1987–90[a]
n (M:F:U)	6(0:6:0)									29(16:13:0)
Age (range):U	12(5-19):0									4(2-18):19
Year		1982[b]	1982[b]		1982[b]	1984[b]		1984[b]	1984[b]	1983–86[a]
n (M:F:U)		7(6:1:0)	7(4:3:0)		22(16:6:0)	10(7:3:0)		8(3:5:0)	11(7:4:0)	24(13:11:0)
Age (range):U		U(4-14):2	U(4-20):3		U(2-14):2	U(1-18):1		U(4-19):0	U(2-21):0	6(2-10):14

[a] reference 29; [b] reference 32



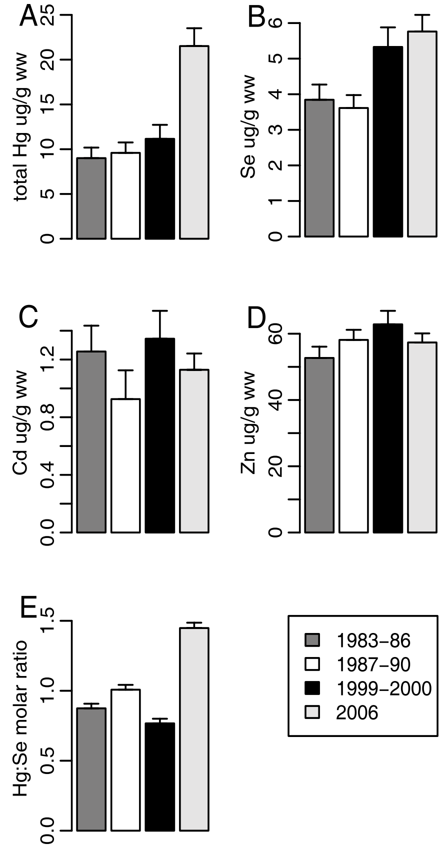


Figure 2. Geometric mean concentrations (μg•g-1 (or μg/g) wet weight ± standard error) of total Hg (A), Se (B), Cd (C) and Zn (D) and molar ratio of Hg:Se (E) in polar bear liver from East Greenland in 1983–2006 (Adapted from Routti et al. 2011a).

Figure 3. Geometric mean concentrations (μg•g-1 (or μg/g) wet weight ± standard error) of total Hg (A), Se (B), Cd (C) and Zn (D), and molar ratio of Hg: Se (E) in polar bear liver from Alaska in 1994–2007 and Canada in 1982–2008. CB: Chukchi/Bering Sea; BS: Beaufort Sea; LJS: Lancaster/Jones Sound; WHB: western Hudson Bay; SHB: southern Hudson Bay; Baffin Bay (BB), DS: Davis Strait (Adapted from Routti et al. 2011a).

every reasonable effort to communicate in person with the RCC representatives and COs and hunters in each participating community. Regular communications continued with Dr. S. Atkinson (Government of Nunavut) and well as with E, Solski (NAC, Nunavut). Also, and because NWT will be involved in polar bear sampling in future years of this project, Ms. M. Branigan (NWT), Ms. L. Skinner (NWT RCC) and Ms. S. O'Hara (NWT, Inuit Research Advisor) were regularly updated. INAC was also informed as well as others associated with these participating departments. All publications that result from the NCP core-monitoring research are being provided to pscowen@ucalgary.ca for inclusion in the NCP Publications Database.

As in past sampling for this core monitoring project, the 2010–2011 collection of samples was carried out exclusively by hunters in the participating Hudson Bay communities and in coordination with the PI and involved agencies in Nunavut. This project worked within the guidelines of the allowable hunting quotas for each of the HTAs and communities. The project therefore relied heavily on the knowledge and experience of these hunters for the sampling and for the ecological information on behaviour, condition and population numbers they provide to wildlife COs and biologists. The traditional knowledge of polar bears and their food web continues to enhance and is critically needed for this monitoring and research initiative. Via the sampling exercise and the priority of the samples that are collected for the determination of contaminants, local communities are learning more about how contaminants are manifested in a top predator organism, which is representative of human exposure as polar bears are consuming country food at the same level of people in the communities.

Results

Spatial trends of metals and elements

As we recently detailed in Routti et al. (2011a), concentrations of Hg in bears from the northern and southern Beaufort Sea subpopulations were higher than in any other populations except the adjacent areas of Lancaster/Jones Sound and the Gulf of Boothia (Table 1, Figure 1).

Bears from western and southern Hudson Bay had lower concentrations of Hg compared to the other areas except the Davis Strait and Chukchi/Bering Sea. Despite being an essential element, Se concentrations, similar to Hg, were higher in Beaufort Sea polar bears compared to the subpopulations from Chukchi/Bering Sea, Hudson Bay, Davis Strait and East Greenland. The lowest Se concentrations were found in bears from Chukchi/Bering Sea and Hudson Bay. However, Se concentrations in bears from southern Hudson Bay did not differ from those from Davis Strait and East Greenland. Concentrations of Cd were lower in Chukchi/Bering Sea population compared to all other populations except Lancaster/Jones Sound and southern Beaufort Sea (Figure 1). Concentrations of Cd were higher in East Greenland bears compared to bears from the (northern and southern) Beaufort Sea and Lancaster/Jones Sound. Concentrations of Pb were in general low compared to the other trace elements under study. The concentrations were higher in polar bears from East Greenland compared to those from Lancaster/Jones Sound, Beaufort Sea and Chukchi/Bering Sea. In addition, Pb concentrations in bears from Chukchi/Bering Sea were lower compared to those from Gulf of Boothia, western Hudson Bay, Baffin Bay and Davis Strait. Concentrations of As were higher in the Beaufort Sea compared to Chukchi/Bering Sea, Hudson Bay, Davis Strait and East Greenland (Figure 1). Southern and western Hudson Bay bears showed lower concentrations of As compared to those from Lancaster/Jones Sound and Baffin Bay. Bears from western Hudson Bay showed the highest concentrations of Rb in relation to any other bear population except Davis Strait. Otherwise, no geographical trends in Rb concentrations were observed. Minor geographical trends were observed for Mn concentrations in polar bears (Figure 1). Mn concentrations in bears from East Greenland were lower compared to those from Canadian Arctic or Chukchi/Bering Sea except the bears from Gulf of Boothia. Within the Canadian Arctic, Mn concentrations in Davis Strait were higher compared to those from northern Beaufort Sea. No geographical trends were observed for Zn or Cu concentrations (Figure 1).

Temporal trends of metals and elements

As detailed in Routti et al. (2011a), concentrations of total Hg in polar bear livers from East Greenland and sampled in 2006 were substantially higher than those sampled over the period of 1999–2000 (Figure 2). In bears from the Beaufort Sea an increasing trend in Hg concentrations was observed between 1980s and 2002 (Figure 3a). The result of the present study suggests that no changes in Hg concentrations were observed between 2002 and 2007–2008 in the bears from the Beaufort Sea (Figure 3a). The results of the present study suggest that the total Hg concentrations in polar bears from Canadian Arctic, other than from the Beaufort Sea, are similar to the concentrations reported from 1980s (Figure 3a). Hg concentrations in polar bears from Chukchi/Bering Sea showed a decreasing trend (Figure 3a). Concentrations of Se did not increase in concert with Hg in East Greenland polar bears (Figure 2b) resulting in an increased molar ratio of Hg:Se (Figure 2e). In contrast, the increase in Hg concentrations in the bears of the present study from the Beaufort Sea was consistent with the increase of Se (Figure 3b), leading to stable Hg:Se molar ratio over time in this subpopulation (Figure 3e). Cd concentrations in polar bears showed a decreasing trend in Lancaster/Jones Sound and Davis Strait since 1980s (Figure 3c).

Discussion and Conclusions

Spatial trends of metals and elements

Similar to our recent study (Routi et al. 2011a), previous studies in polar bears from the Canadian Arctic have reported total Hg concentrations being highest in the Beaufort Sea and lowest in the western Hudson Bay (Braune et al. 1991; Norstrom et al. 1986; Rush et al. 2008). The observed subpopulation dependence on the total Hg distribution in the present polar bears may be related to both abiotic and biotic factors. The high concentrations of Hg in marine mammals from Beaufort Sea are potentially a consequence of the Hg input by the Mackenzie River (Leitch et al. 2007; Andersson et al. 2008). However, time trend analysis in polar bear hair have shown an increase by up to 20 since the onset of industrial revolution indicating that geological signals in polar bear tissue may be of minor importance (Dietz et al. 2011). Furthermore, recent studies have pointed to the importance of food web structure on Hg concentrations in polar bears (Cardona-Marek et al. 2009).

Previous studies have reported strong correlations and thus similar geographical trends between Hg an Se in polar bears from the Canadian Arctic (Braune et al. 1991; Norstrom et al. 1986; Rush et al. 2008). The molar ratio of Hg:Se has been found 1:1 in tissues of marine mammals with high Hg concentrations suggesting that Hg and Se are complexed in those species. Se may reduce the toxicity of Hg by forming a stable equimolar tiaminite complex that binds to several proteins (Ikemoto et al. 2004). Interestingly, the molar ratio of Hg:Se was approximately 1.5 in the present bears from Gulf of Boothia and East Greenland, and close to one in the other areas (Figure 1). Because Hg concentrations were only moderate in the bears from Gulf of Boothia and East Greenland, the high Hg:Se ratios in these populations may be due to limited intake of Se. This excess of total Hg concentration relative to Se suggests that the bears from Gulf of Boothia and East Greenland may be at greater risk from exposure to Hg and any mediated effects.

The spatial trends in Cd concentrations in the present polar bears for the different subpopulations could be a function of the differences in the bear diets (e.g. ringed seals versus other seal species) and/or may be related to differences at lower trophic levels in polar bear food web. A complementary study showed the influence of diet difference for bears among these subpopulations was contaminant-specific for various chlorinated and brominated POPs, e.g., PCBs and PBDEs (McKinney et al. 2011c). Interpretation of bear diet-food web influence on trace element spatial trends has been detailed in a complementary paper (Routti et al. 2011b). Concentrations of Pb were in general low compared to the other trace elements under study. The geographical trends of Pb concentrations in the present polar bears should be interpreted with caution, because 40% of the polar bear liver samples showed Pb concentrations below the practical detection limit. The high concentrations of As in polar bears from the Beaufort Sea are in agreement with previous findings (Rush et al. 2008). Concentrations of As followed similar spatial trends to Hg and Se, which may be explained by Se forming an equimolar complex with As. No geographical trends in Rb, Zn and Cu concentrations and minor trends for Mn were observed, which are similar to previous results (Rush et al. 2008).

Temporal trends of metals and elements

The results of the present study suggest that the total Hg concentrations in polar bears from Canadian Arctic, other than from the Beaufort Sea, are similar to the concentrations reported from 1980s (Figure 3a) (Routti et al. 2011a). Similarly, temporal trends in Hg concentrations were not observed in arctic char (Salvelinus alpinus) from north-eastern Canadian Arctic (Gantner et al. 2009) or in ringed seals from several locations in the Canadian Arctic (Braune et al. 2005). Increasing Hg concentrations in ringed seals have only been observed in ringed seals from Pond Inlet (Baffin Bay) (Braune et al. 2005). Hg concentrations in polar bears from Chukchi/Bering Sea showed a decreasing trend (Figure 3a). However, these two-point temporal trends should be interpreted with caution, because data from 1994–99 included only six individuals (all males) (Table 1).

The recent increase in Hg concentrations in the East Greenland polar bears is consistent with global changes of Hg emissions, which have increased from 2128 to 2480 mg/yr between 1996 and 2006 (Streets et al. 2009). Increased Hg concentrations in ringed seal teeth from Greenland were also attributed to global changes in environmental Hg concentrations (Aubail et al. 2010). Furthermore, a mass balance of Hg in the Arctic Ocean is likely to be associated with climate warming (Outridge et al. 2008). Climate change including the reduction of ice cover, changes in first- and multiyear ice and timing of ice melt, melting of permafrost and increased coastal erosion, may lead to changes of Hg cycle in the Arctic Ocean (MacDonald et al. 2008; Outridge et al. 2008), which may further alter Hg concentrations in species of the Arctic marine food web. In addition, melting of multi-year ice may have a major impact on Hg uptake in Arctic marine ecosystems (Chaulk et al. 2011). Recent changes in Hg concentrations in arctic biota have also been proposed to depend on top-down processes i.e. the rate of uptake and trophic transfer of Hg by marine food webs (Outridge et al. 2008).

Concentrations of Se did not increase in concert with Hg in East Greenland polar bears (Figure 2b) resulting to an increased molar ratio of Hg:Se (Figure 2e). In contrast, the increase in Hg concentrations in the bears of the present study from the Beaufort Sea was consistent with the increase of Se (Figure 3b), leading to stable Hg:Se molar ratio over time in this subpopulation (Figure 3e) (Braune et al. 1991).

Cd concentrations in polar bears showed a decreasing trend in Lancaster/Jones Sound and Davis Strait since 1980s (Figure 3c). These results are parallel with generally stable or declining concentrations of Cd in abiotic and biotic arctic environment.

As detailed in Routti et al. (2011a), the present studies indicates that different trace elements have different trends across the Arctic. In general, the concentrations of total Hg, Se and As were highest in the Beaufort Sea area and lowest in (southern and western) Hudson Bay area and Chukchi/Bering Sea. In contrast, concentrations of Cd increased from east to west. Minor or no spatial trends were observed for Cu, Mn, Rb and Zn. The geographical trends of trace elements observed in the present study may be related to river output of trace elements, local differences in geology or in the food webs of polar bears. Time-point comparisons suggest that total Hg concentrations in East Greenland polar bears have recently increased. This increase may be related to changes in Hg emissions or climate-induced changes in Hg cycle or changes in polar bear food web. The increase of Hg:Se molar ratio in concert with Hg concentrations may suggest enhanced Hg-mediated toxicity in the East Greenland population.

In a recent complementary study (Routti et al. 2011b), we investigated using dietary chemical tracers (i.e., nitrogen isotope ratios (trophic level [TL]), carbon isotope ratios and fatty acid profiles) and thus the role of diet on regional differences in trace element concentrations including As, Cd, Cu, Hg, Mn, Pb, Rb, Se and Zn, in livers of the same polar bears from ten subpopulations from Alaska, Canadian Arctic and Greenland (n=121). Compared to non-adjusted concentrations, TL-adjusted concentrations showed reduced spatial variation for total Hg, Se and As for bears in central and eastern Canadian Arctic subpopulations, which indicated the importance of diet adjustment when assessing spatial and temporal trends. Relatively low concentrations of total Hg, Se and As in bears from Hudson Bay may be ascribed to their trophic position rather than regional contaminant differences. Conversely, the relatively high levels of Hg, Se and As for Beaufort Sea bears may be due to more to regional contamination rather than dietary subpopulation differences.

This is an ongoing core monitoring project, and assessments will continue into 2011–2012 and beyond. In 2010–2011, all spatial and 2–point temporal trends of metals and total Hg in polar bears have been published or submitted for publication (Routti et al. 2011a, 2011b). In 2011–2012, all PFC, PFOS isomer, and endosulfan and metabolite data (via D. Muir and his PhD student A. Morris) will be fully interpreted, including examination of the role of diet on spatial trends, and will be written up and published in several journal papers. In 2011–2012, and as detailed in the formal, five-year Government of Nunavut-Environment Canada agreement on polar bears contaminants research, a renewed (2012) Nunavut Wildlife Research Permit will be obtained for sampling (liver, fat and muscle) of harvested bears from communities in WHB and SHB as well as in Baffin Bay.

NCP Performance Indicators (in 2010–2011 only)

The number of northerners engaged in this project: (n=46)

The number of northerners (directly and indirectly) involved in or engaged in this project is large, including:

NWT and Nunavut team members: 4 (Peacock, Atkinson, Coxon, Branigan)

Community Conservation officers: 14 (at least one for each of the 14 participating Nunavut communities)

HTA representatives: 14 (at least one for each of the 14 participating Nunavut communities)

Community hunters: 14 (at least one for each of the 14 participating Nunavut communities)

The number of meetings/workshops for this project held in the North:

Since early 2010, Dr. Letcher has been in communication with the interim polar bear biologist in the government of Nunavut, Dr. Stephen Atkinson, as to the possibility of arranging a meeting and information exchange sometime in 2011–2012. Such details are enshrined in a 5–year MOU that commenced in 2009–2010, between Dr. Letcher (Environment Canada) and Dr. Atkinson (Government of Nunavut).

The number of students (both northern and southern) involved in this NCP project: (n=4)

The students involved in this project in 2009–2010 have been southerners or international, and are presently listed:

Ms. Melissa McKinney: PhD candidate, Carleton University, Dr. Letcher as supervisor

Ms. Alana Greaves: MSc candidate, Carleton University, Dr. Letcher as supervisor

Dr. Heli Routti: Postdoctoral Fellow, via Carleton University, Dr. Letcher as supervisor.

Mr. Adam Morris: PhD candidate, University of Guelph, Dr. Derek Muir and Dr. Keith Solomon as supervisors (Dr. Letcher, PhD thesis committee member)

The number of citable publications: (n=28)

a) Domestic/international journals, book chapters, etc.

The number of citable publications, book chapters, etc. from or related to this project as of 2010–2011 is currently 17 (Houde et al. 2011;Jaspers et al. 2010; Jenssen et al. 2010; Kirkegaard et al. 2010a, 2010b, 2010c; Letcher and Tomy 2010; Letcher et al. 2010a, 2010b; McKinney et al. 2010, 2011a, 2011b, 2011c ; Peacock et al;. 2010; Pilsner et al. 2010; Routti et al. 2011a, 2011b).

b) Conference and workshop presentations

The number of conference and workshop presentations made in 2010–2011 that were related to this project is presently 11, and are listed below:

Morris, A.D., D.C.G. Muir, K.R. Solomon, R.J. Letcher, A.T. Fisk, G.T. Tomy, C. Teixeira, J. Epp and X. Wang. 2010. Current use pesticide bioaccumulation and trophodynamics in Canadian Arctic marine mammal food webs. 31st Annual Society of Environmental Toxicology and Chemistry (SETAC) Meeting, Nov. 7–11, Portland, OR, U.S.A.

Letcher, R.J., M.A. McKinney, G.T. Tomy, S.G. Chu, R. Dietz, C. Sonne, D.C.G. Muir, C. Butt and S. De Guise. 2010. Differential perfluorooctane sulfonate (PFOS) levels in Arctic marine top predators and the influence of biotransformation of PFOS precursors. 31st Annual Society of Environmental Toxicology and Chemistry (SETAC) Meeting, Nov. 7–11, Portland, OR, U.S.A.

Letcher, R.J., M.A. McKinney, I. Stirling, N.J. Lunn and E. Peacock. 2010. The role of diet on longer-term concentration and pattern trends of brominated and chlorinated contaminants in western Hudson Bay polar bears. 31st Annual Society of Environmental Toxicology and Chemistry (SETAC) Meeting, Nov. 7–11, Portland, OR, U.S.A.

Letcher, R.J. and G.T. Tomy. 2010. New contaminants in Arctic biota. 18th Annual Results Workshop of the Northern Contaminant Program (NCP), Canadian Arctic Contaminants Assessment Symposium, Sept. 28–30, Whitehorse, Yukon, ON, Canada.

Letcher, R.J., G.T. Tomy, M.A. McKinney, S. Chu, D.C.G. Muir and C. Butt. 2010. In vitro biotransformation of precursors of perfluorooctane sulfonate (PFOS) using liver of polar bear, ringed seal and beluga whale. 18th Annual Results Workshop of the Northern Contaminant Program (NCP), Canadian Arctic Contaminants Assessment Symposium, Sept. 28–30, Whitehorse, Yukon, ON, Canada.

Muir, D.C.G. and R.J. Letcher. 2010. Levels, trends and processes of mercury in ringed seal and polar bear. 18th Annual Results Workshop of the Northern Contaminant Program (NCP), Canadian Arctic Contaminants Assessment Symposium, Sept. 28–30, Whitehorse, Yukon, ON, Canada.

Letcher, R.J., M.A. McKinney, E.W. Born, M. Branigan, R. Dietz, T.J. Evans, G.W. Gabrielsen, E. Peacock, D.C.G. Muir and C. Sonne. 2010. Flame retardant and legacy contaminants in polar bears from Alaska, Canada, East Greenland and Svalbard: Spatiotemporal trends and the role of diet. 30th International Symposium on Halogenated Persistent Organic Pollutants (DIOXIN 2010), Sept. 12–17, San Antonio, TX, U.S.A.

McKinney, M.A., D. Andriashek, E.W. Born, M. Branigan, R. Dietz, T.J. Evans, G.W. Gabrielsen, N. Lunn, E. Peacock, C. Sonne, I. Stirling and R.J. Letcher. 2010. Regional differences, temporal trends and the influence of diet in organohalogen contaminants in polar bears. International Polar Year-Oslo Science Conference. June 8–12, Oslo, Norway.

Sonne, C., R.J. Letcher, JO. Bustnes, R. Dietz, B.M. Jenssen, E.H. Jørgensen, J. Verreault, M.M. Vijayan, G.W. Gabrielsen, E.W. Born, N. Basu. 2010. An overview of the potential health effects from long-range transported pollutants in Arctic wildlife and fish. International Polar Year-Oslo Science Conference. June 8–12, Oslo, Norway.

Jenssen, B.M., G.D. Villanger, E.I. Smette, R.J. Letcher, C. Sonne and R. Dietz. 2010. Identification of testosterone disrupting organohalogenated compounds in polar bears (Ursus maritimus) (Ursus maritimus). 3rd Norwegian Environmental Toxicology Symposium, April 14–16, Bergen, Norway.

Wong, C.S., M.S. Ross, R.J. Letcher; M.A. McKinney, C. Sonne and R. Dietz. 2010. Comparison of the enantiomer distribution of chiral organochlorine contaminants in captive West Greenland sledge dogs and East Greenland polar bears. Annual 2010 Meeting of the American Chemical Society, March 21–25, San Francisco, CA, U.S.A.

Expected Project Completion Date

All aspects of the pan-Canadian spatial trends phase of this project and based on the 2007 and 2008 pan-Canadian/circumpolar sample collections (e.g., data generation, data compilation and interpretation, data interpretation and writing of papers) are expected to be fully completed by the end of 2011. The new and continuing phase of this core contaminant monitoring project began in 2009–2010 and will continue in this NCP 5 year cycle, with the collection of new polar bear (fat, liver and muscle) samples from individuals for longer-term and annual temporal trends assessments of bear in priority subpopulation in Hudson Bay.

Acknowledgments

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

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Temporal Trends of Contaminants in Arctic Seabird Eggs

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M. Mallory; Environment Canada (Iqaluit)
K. Hobson; Environment Canada (Saskatoon)

Abstract

Contaminants have been monitored in arctic seabird eggs collected from Prince Leopold Island in the Canadian High Arctic since 1975. For comparative purposes, we have also been monitoring thick-billed murre eggs from Coats Island in northern Hudson Bay since 1993. In order to examine inter-year variation in the temporal trend data series, annual egg collections have been made since 2005 for two species of seabirds (thick-billed murre, northern fulmar) from Prince Leopold Island. Concentrations of most of the legacy organochlorines (e.g. PCBs, DDE) have decreased in those two species at Prince Leopold Island since 1975 whereas levels of total mercury and some perfluorinated compounds (e.g. perfluorinated carboxylic acids) have increased. Shifts in diet are affecting the Hg temporal trend reflected in eggs of thick-billed murres breeding in northern Hudson Bay.

Résumé

Depuis 1975, on surveille les concentrations de contaminants dans les œufs des oiseaux marins de l'Arctique à partir d'œufs récoltés sur l'île Prince Leopold dans l'Extrême-Arctique canadien. À des fins de comparaison, on surveille aussi ces éléments chez le guillemot de Brünnich de l'île Coats, dans le nord de la baie d'Hudson, depuis 1993. Dans le but d'étudier les variations d'une année à l'autre dans les séries de données temporelles, on procède, depuis 2005, à la collecte d'œufs chez deux espèces d'oiseaux marins (guillemot de Brünnich et fulmar boréal) à l'île Prince Leopold. Depuis 1975, les concentrations de la plupart des composés organochlorés anciennement utilisés (p. ex., BPC, DDE) ont diminué chez ces deux espèces sur l'île Prince Leopold alors que les concentrations de mercure total et de certains composants perfluorés (p. ex., acides carboxyliques perfluorés) ont augmenté. Des changements dans les habitudes alimentaires ont des effets sur la tendance temporelle de la concentration de mercure, visibles dans les œufs du guillemot de Brünnich qui s'accouple dans la baie d'Hudson.

Key Messages

- Total mercury (Hg) concentrations in eggs of two arctic seabird species, the thick-billed murre and northern fulmar, have increased significantly since 1975 at Prince Leopold Island.
- Dietary shifts are affecting the Hg temporal trend reflected in eggs of thick-billed murres breeding in northern Hudson Bay.
- Perfluorinated carboxylic acids (PFCAs) have been increasing since 1975 in eggs of both northern fulmars and thick-billed murres whereas perfluorooctane sulfonate (PFOS) levels do not show any discernible trend.

Messages clés

- Les concentrations de mercure (Hg) total dans les œufs de deux espèces d'oiseaux marins de l'Arctique, le guillemot de Brünnich et le fulmar boréal, ont grandement augmenté à l'île Prince Leopold depuis 1975.
- Des changements dans les habitudes alimentaires ont des effets sur la tendance temporelle de la concentration de mercure, visibles dans les œufs du guillemot de Brünnich qui s'accouple dans la baie d'Hudson.
- Depuis 1975, on remarque une hausse de la concentration des acides carboxyliques perfluorés dans les œufs du fulmar boréal et du guillemot de Brünnich alors qu'on ne discerne aucune tendance pour ce qui est des concentrations de perfluorooctanesulfonate.

Objectives

In order to examine annual variation in the temporal trend data series, eggs have been collected annually since 2005 for contaminant analyses from each of two species of seabirds (northern fulmar, thick-billed murre) from Prince Leopold Island. 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.

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. Past sampling of arctic seabird eggs for contaminant analyses has been opportunistic but collections have been standardized to every five years since 1988. Most of the legacy persistent organic pollutants or POPs (e.g. PCBs, DDT) have been declining whereas total mercury (Hg) has been increasing (Braune 2007), as have the perfluorinated carboxylic acids (PFCAs) and, until relatively recently, the polybrominated diphenyl ethers (PBDEs) (Braune 2008).

One of the objectives of the core monitoring component of the NCP Blueprint for Environmental Monitoring and Research 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 confidence level of 95%. 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 annually since 2005. For comparative purposes, we have also been making annual collections of thick-billed murre eggs from Coats Island in northern Hudson Bay (our Low Arctic monitoring colony since 1993) in parallel with the High Arctic collections. Eggs are analyzed for the normal suite of legacy POPs and total Hg, and the murre and fulmar eggs from Prince Leopold Island are analyzed for PBDEs, hexabromocyclododecane (HBCD), polychlorinated dibenzo-p-dioxins (PCDDs), dibenzofurans (PCDFs), coplanar PCBs, and perfluorinated compounds (PFCs), as well.

Activities in 2010–2011

Sample collection/analysis: Eggs (n=15) were collected on the basis of one egg per nest from each of two species of seabirds (northern fulmar, thick-billed murre) from Prince Leopold Island (74°02'N, 90°05'W) in Lancaster Sound as well as from thick-billed murres on Coats Island (62°30'N, 83°00'W) in northern Hudson Bay. Eggs were analyzed for the normal suite of legacy POPs (e.g. PCBs, DDT, chlordanes, chlorobenzenes, etc.), PBDEs, HBCD, and PFCs in pools of 3 eggs each (15 eggs per collection=5 pools of 3 eggs each). Murre and fulmar eggs from Prince Leopold Island are 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 are 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, PFCs and total Hg are carried out at the National Wildlife Research Centre (NWRC) laboratories at Carleton University in Ottawa, Ontario. The legacy POPs are analyzed by gas chromatography using a mass selective detector (GC/MSD) according to NWRC Method No. MET-CHEM-OC-06B. Analyses of the standard 14 PBDE congeners and total-α-HBCD are carried out using GC-low resolution MS run in negative ion chemical ionization (NCI) mode also according to NWRC Method No. MET-CHEM-OC-06B. PFCs are analyzed using HPLC/MS/MS in negative electrospray mode (ESI-) according to NWRC Method No. MET-WTD-ORG-RES-PFC-02. PFCs analyzed include 10 PFCAs (including PFOA), 4 PFSAs (including PFOS), 3 FTUCAs, PFOSA and 3 FtOHs. Total mercury (Hg) is analyzed using an Advanced Mercury Analyzer (AMA-254) equipped with an ASS-254 autosampler for solid samples according to NWRC Method No. MET-CHEM-AA-03G. 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 CALA. Both the NWRC and RPC labaoratories have participated in the NCP's QA/QC Program. Stable isotope (C, N) analyses are carried out through the Environment Canada lab at PNWRC in Saskatoon with isotopic measurements made at the Department of Soil Science, University of Saskatchewan, Saskatoon. All samples are archived in the National Wildlife Specimen Bank housed at the NWRC in Ottawa.

Capacity Building: The contaminants monitoring program at Prince Leopold Island in the Canadian High Arctic is part of a long-term, integrated seabird monitoring program which has been investigating seabird population trends and relationships with climate change and contaminants for over 30 years. In 2010, we had one Inuk field assistant, Valerie Amarualik from Resolute Bay, work at the Prince Leopold Island field site. As well, an Inuk assistant, Josiah Nakoolak from Coral Harbour, was hired to help with the field work at Coats Island, as has been the case for more than 20 years at that site.

Communications: Presentations on the work that Environment Canada is doing on arctic birds are given regularly in Resolute Bay. A brief, unofficial meeting with some Resolute Bay HTA members was held in August 2010, followed by a presentation to the Resolute Bay HTA in late March 2011. Similar presentations are given at the school and elsewhere in Coral Harbour about every two years. Presentations were made to the Coral Harbour HTO in April 2009 and again in April 2011. A presentation was also made in Kuujjuaq in November 2010, and a one hour talk was given to the Nunavut Wildlife Management Board in March of 2010, in Iqaluit. The residue data along with a plain language summary of the findings from this project is submitted to the Niqiit Avatittinni Committee (Nunavut) for their review and recommendation as to the most appropriate communications strategy back to the northern communities. Annual reports of the results to date are made to the NCP. The results will continue to be published in a peer-reviewed scientific journals.

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 is being compiled as part of a Ph.D. thesis, the results of which should be available later in 2011. In 2010, we initiated interviews on local knowledge of other seabirds, including Arctic terns, which some communities tell us are in decline. To date, results suggest that Inuit have observed declines in populations of shorebirds and terns, and increases in goose populations, but no trends or obvious differences in other marine bird abundance or distribution. These data provide potentially useful information for how to assess whether environmental stressors (e.g. contaminants, climate change) may be affecting northern migratory bird populations.

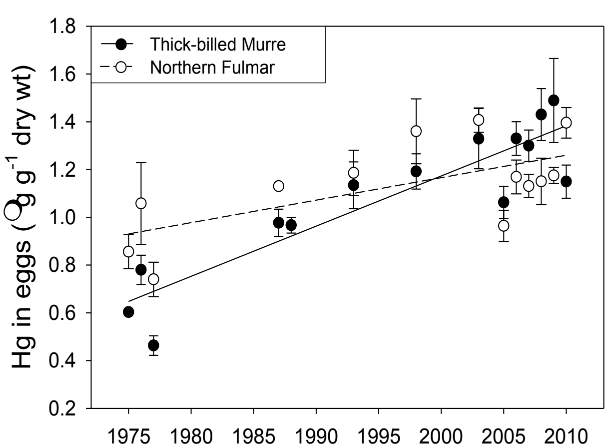

Figure 1. Mean concentrations (± standard error) of total Hg ($\mu g\ g^{-1}$ dry wt) in eggs of northern fulmars and thick-billed murres collected from Prince Leopold Island, 1975–2010.

Results

Total Hg concentrations have increased significantly in eggs of thick-billed murres (n=60, r=0.74, p<0.00001) and northern fulmars (n=61, r=0.50, p<0.00005) between 1975 and 2010 at Prince Leopold Island (Figure 1). Therefore, the increase in Hg levels seems to be continuing, although annual monitoring after 2005 indicates a degree of inter-annual variation. While total Hg levels in eggs of thick-billed murres have been increasing at Prince Leopold Island in the High Arctic, there is no clear Hg trend at the Coats Island murre colony in northern Hudson Bay (Figure 2, top graph). Although we have not yet received stable isotope data for the seabird eggs collected in 2010, adjusting the egg Hg concentrations up to 2009 from both murre colonies for trophic variations in diet as represented by δ15N resulted in little change in the trend at Prince

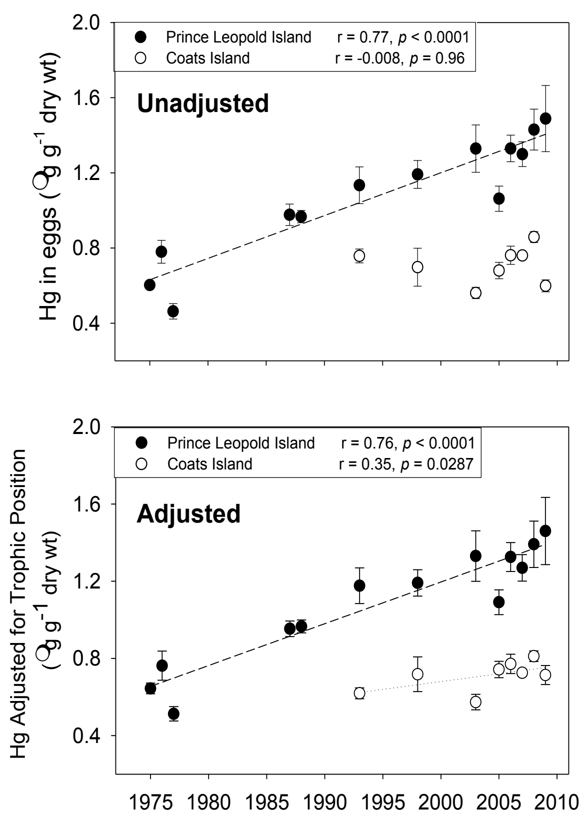

Figure 2. Unadjusted (top graph) mean concentrations (± standard errors) of total Hg in eggs of thick-billed murres from Prince Leopold Island (1975-2009) and Coats Island (1993–2009) vs Hg concentrations adjusted for trophic position (bottom graph).

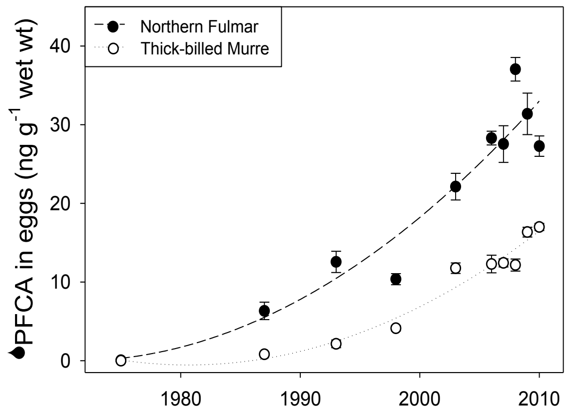

Figure 3. Mean annual concentrations (± standard error) of total PFCAs (ΣPFCA) in eggs of thick-billed murres and northern fulmars from Prince Leopold Island, 1975–2010. ΣPFCA=C_6 to C_{15} inclusive.

Leopold Island whereas the adjusted data from the Coats Island colony changed to a significantly increasing Hg trend (Figure 2, bottom graph).

Concentrations of total polyfluorinated carboxylates (ΣPFCA) have increased from 1975 to 2010 in eggs of both northern fulmars ($n=47$, $r=0.89$, $p<0.00001$) and thick-billed murres ($n=45$, $r=0.89$, $p<0.00001$) from Prince Leopold Island (Figure 3) but perfluorooctane sulfonate (PFOS) levels have not changed significantly ($p>0.05$) over the same time period. C11 (PFUA) and C13 (PFTriA) were the predominant perfluorinated carboxylic acids (PFCAs) in eggs of both species. PFOS was the major perfluorosulfonic acid (PFSA) measured, and perfluorooctane sulfonamide (PFOSA) was detected at very low concentrations in only a few samples. No fluorotelomer alcohols (6:2 FTOH, 8:2 FTOH, 10:2 FTOH) were detected in any of the samples, and fluorotelomer unsaturated acids (6:2 FTUA, 8:2 FTUA, 10:2 FTUA) were detected in only a few samples but could not be quantified.

Discussion and Conclusions

Major organochlorines, such as total PCBs (ΣPCB) and DDT metabolites (ΣDDT), in eggs of both thick-billed murres and northern fulmars from Prince Leopold Island have decreased since 1975 but now appear to be levelling off, albeit with some inter-annual fluctuation (Braune 2008). However, total Hg concentrations seem to continue increasing. The increasing Hg trends in Canadian Arctic seabirds supports the west-to-east circumpolar gradient in the occurrence of recently increasing Hg trends which is based on a higher proportion of marine time-series in the Canadian and Greenland region of the Arctic showing significant Hg increases than in the North Atlantic Arctic (Rigét et al., in press). 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.

Thick-billed murres breeding on Coats Island in northern Hudson Bay have been monitored for contaminants since 1993 (Braune et al., 2002). A decrease in trophic position, as indicated by δ15N, has occurred in eggs of thick-billed murres breeding at Coats Island, whereas murre eggs from Prince Leopold Island have not shown any consistent change over time (Braune, 2009). Dietary studies have shown that there has been a shift from arctic cod and benthic fish species to capelin and sandlance in the diet of thick-billed murres at Coats Island (Gaston et al., 2003). Adjusting the egg Hg concentrations for trophic position at the Coats Island colony changed the trend to a significant increase which indicates that the shift in diet which occurred in the murres at Coats Island has affected the temporal Hg trend for that colony.

Total PFCAs are increasing in the murre and fulmar eggs from Prince Leopold Island whereas PFOS concentrations are showing no significant change over time. Compared with eggs of glaucous gulls (Larus hyperboreus) from the Norwegian Arctic (Verreault et al. 2005) and eggs of guillemots (common murre – Uria aalge) from the Baltic Sea (Holmström et al. 2005), the PFOS concentrations in the eggs of the northern fulmars and thick-billed murres are relatively low. Fluorotelomer unsaturated acids were also not detected in glaucous gull eggs from the Norwegian Arctic (Verreault et al. 2005). Butt et al. (2007), however, did detect the 8:2 and 10:2 FTUAs in livers of northern fulmars and thick-billed murres from Prince Leopold Island.

NCP Performance Indicators

- In 2010–11, two northerners participated in the field work (see Capacity Building).
- There were three meetings held in the North in 2010–11 (see Communications).
- In 2010–11, two students participated in the project. One northern student was involved in the field work and one southern student assisted with sample processing in the lab.
- In 2010–11, data were included in one review paper submitted to The Science of the Total Environment, one government report (NCP Synopsis Report), a book chapter, a conference proceedings, and seven presentations.

Expected Project Completion Date

March 31, 2015.

Acknowledgements

Thanks to D. Nettleship, A. Gaston, M. Mallory, G. Grant and all of the field crews for their collection of the seabird eggs over the years. Sample preparation and chemical analyses were carried out by the Laboratory Services personnel at the National Wildlife Research Centre in Ottawa. Stable-nitrogen isotope analyses were coordinated by K. Hobson of Environment Canada in Saskatoon. Funding over the years has been provided by Environment Canada and the Northern Contaminants Program of Indian and Northern Affairs Canada. Logistical support out of Resolute Bay is provided by the Polar Continental Shelf Program, Natural Resources Canada.

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Interspecies Sensitivity of Arctic Marine Birds to Methylmercury Exposure

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Abstract
Mercury (Hg) has been increasing in some marine birds in the Canadian Arctic over the past several decades. However, there is a lack of information on the effects of Hg exposure on avian reproduction. The most bioavailable and toxic form of Hg is methylmercury (MeHg) and nearly 100% of the Hg transferred by breeding female birds to their eggs is MeHg. Given that reproduction is one of the most sensitive endpoints of MeHg toxicity, we brought eggs of arctic terns into the laboratory where they were dosed with graded concentrations of MeHg to determine the relative sensitivity of the developing embryo to MeHg. Preliminary results suggest that the arctic tern has an intermediate sensitivity to MeHg exposure, similar to that of other tern species.

Résumé
Le taux de mercure (Hg) s'est accru chez quelques oiseaux de mer de l'Arctique canadien au cours des dernières décennies. Toutefois, nous manquons d'informations quant aux effets de l'exposition au Hg sur la reproduction avienne. La forme de Hg la plus biodisponible et la plus toxique est le méthylmercure (MeHg) et près de 100 % du mercure transmis par les oiseaux femelles gestantes à leurs œufs est du MeHg. Étant donné que la reproduction est l'un des critères d'évaluation de la toxicité du MeHg les plus sensibles, nous avons apporté des œufs de sterne arctique dans le laboratoire où nous leur avons administré des doses de concentrations progressives de MeHg afin de déterminer la sensibilité relative de l'embryon en croissance au MeHg. Les résultats préliminaires semblent indiquer que la sterne arctique a une sensibilité moyenne à l'exposition au MeHg semblable à celle des autres espèces de sterne.

Key Messages
- Preliminary results suggest that the arctic tern has a medium sensitivity to methylmercury exposure, similar to that of other tern species.

Messages clés
- Les résultats préliminaires semblent indiquer que la sterne arctique a une sensibilité moyenne à l'exposition au méthylmercure semblable à celle des autres espèces de sterne.

Objectives

- To determine the relative sensitivities to methylmercury (MeHg) exposure for arctic marine bird species based on the most sensitive life stage, embryonic development.
- Based on the MeHg sensitivity, predict when environmental Hg exposure levels may reach critical thresholds for reproductive impairment in the species tested.
- To determine the effects of MeHg exposure on the neuro-signaling pathways of the developing avian brain using changes in neurochemical parameters (e.g. neuroreceptor concentrations) as a biomarker of Hg exposure; and relate neurochemical changes to decreased hatchability following MeHg exposure in ovo.
- In 2010/11, the research focussed on the arctic tern.

Introduction

Based on information available for the last Canadian Arctic Contaminants Assessment Report, Fisk et al. (2005) recommended that biological effects research in Canadian arctic species other than polar bears is needed, and Wiener et al. (2003, p. 434) have suggested that "obtaining information on the reproductive sensitivity of wild, fish-eating birds to methylmercury exposure is perhaps the most pressing research need concerning the avian ecotoxicology of mercury."

Total mercury (Hg) has been increasing in marine birds and mammals in some regions of the Canadian Arctic and in West Greenland over the past several decades (Braune 2007, Braune et al. 2005a,b, Rigét et al. in press). Mercury biomagnifies up the food chain (Atwell et al. 1998, Campbell et al. 2005) making those species feeding at high trophic positions more vulnerable to Hg exposure via their diet. Canadian arctic marine bird species which feed at higher trophic levels include the glaucous gull (Larus hyperboreus), ivory gull (Pagophilia eburnea), northern fulmar (Fulmarus glacialis) and thick-billed murre (Uria lomvia) (Campbell et al. 2005) as well as the arctic tern (Sterna paradisaea) (Akearok et al. 2010). Although the status of the arctic tern is poorly known, large population declines have been reported in Greenland (Hatch 2002) and population declines have also been noted over the past decade by various communities in the eastern Canadian Arctic (M. Mallory, CWS-Iqaluit, personal communication, January 2010). Consequently, the Kivalliq Region of Nunavut has identified "research on Arctic terns" as a regional priority (Nunavut Wildlife Management Board 2007). Arctic terns, which breed in the Canadian Arctic, are primarily piscivorous placing them at a comparable trophic position with other seabird species monitored for contaminants by the NCP (see Akearok et al. 2010). However, total Hg concentrations measured in first-laid eggs of arctic terns collected from a small island (Tern Island) just north of Cornwallis Island are higher than Hg measured in eggs of most other seabird species, except glaucous gulls, collected from Prince Leopold Island and Resolute in 2008 (Table 1).

Mercury is an extremely potent embryo toxicant, and dietary Hg is rapidly transferred to avian eggs on a dose-dependent basis, making reproduction one of the most sensitive endpoints of Hg toxicity (Wolfe et al. 1998). The most bioavailable and toxic form of Hg is methylmercury (MeHg) and nearly 100% of the Hg transferred to eggs is MeHg with the majority (about 85–95%) being deposited into the albumen (Wiener et al. 2003). Therefore, Hg concentrations found in the egg are a good indicator of Hg risk to avian reproduction (Wolfe et al. 1998). Some of the documented effects of Hg on avian reproduction include reduced hatchability due to increases in early mortality of embryos, reduced clutch size, and embryonic deformity (Thompson 1996, Wolfe et al. 1998). Embryotoxic thresholds for Hg based on captive breeding studies are often used generically for a wide range of avian species even though there is no reason to believe that the embryos of all birds are equally sensitive to the harmful effects of MeHg (Heinz et al. 2009). Therefore, Heinz et al. (2006) developed a protocol by which the eggs of wild birds could be brought into the laboratory and injected with graded concentrations of MeHg chloride to determine threshold levels of harmful effects. MeHg dose-response relationships have now been generated for 26 avian species (Heinz et al. 2009) including three species of terns, the common tern (Sterna hirundo), royal tern (S. maxima) and Caspian tern (S. caspia). Heinz et al. (2009) categorized

Table 1. Total Hg concentrations (μg g^{-1} dry wt) in seabird eggs collected from the Canadian Arctic in 2008.

Species	Location	N	Total Hg	Hg Range	Source[a]
Arctic tern	Tern I.	17	2.11	1.35–3.08	1
Black guillemot	Prince Leopold I.	9	1.79	1.10–2.36	2
Thick-billed murre	Prince Leopold I.	15	1.43	0.96–2.15	2
Northern fulmar	Prince Leopold I.	15	1.15	0.61–1.80	2
Black-legged kittiwake	Prince Leopold I.	15	0.80	0.65–1.16	2
Glaucous gull	Prince Leopold I.	9	2.31	1.43–3.94	2
Glaucous gull	Resolute	5	0.89	0.53–1.80	2

[a] 1: Akearok et al. (2010); 2: Braune, unpublished data

all three tern species as having medium sensitivity to MeHg although sample sizes were low for all three species.

Studies have shown that neurochemical parameters, such as neurotransmitter concentrations of acetylcholine and glutamate, are significantly affected by low-level dietary exposure to MeHg in adult birds and mammals; thus there is a potential to use specific neurochemical changes as biomarkers of Hg exposure and effects in wildlife (Basu et al. 2006, 2007; Scheuhammer et al. 2008). These two neurotransmitter receptors play important roles in the regulation and control of reproductive hormones and, therefore, their perturbation may signify early impacts to reproductive potential. Because low doses of MeHg are generally more toxic in developing embryos than in adults, it is of considerable interest to determine the effects of MeHg exposure on the neuro-signaling pathways of the developing brain, and to relate these changes to more commonly used endpoints of toxicity, such as decreased hatchability.

Activities in 2010–2011

Sample collection/experimental: In early July 2010, we collected 125 fresh, unincubated arctic tern eggs from a colony of 300–350 arctic tern nests on a small island unofficially named Tern Island (75°49'N, 96°18'W) just north of Cornwallis Island in the Canadian High Arctic. Eggs were collected within 24 hours of being laid and were stored in foam-lined coolers in the field at 6°–16° C until they could be transported to the National Wildlife Research Centre (NWRC) laboratories in Ottawa. Eggs were cleaned and randomly assigned to artificial incubators (Brinsea Z6 contact incubators) but due to incubator difficulties, eggs were transferred to a Petersime incubator on incubation day 2. On incubation day 4, eggs were assessed for viability and randomly assigned to 8 dose groups of 12 eggs each plus 17 control eggs and 12 vehicle controls. Eggs were dosed with environmentally-relevant graded concentrations of MeHg chloride (methylmercury (II) chloride, PESTANAL®, analytical standard from Sigma-Aldrich) dissolved in safflower oil as follows: control (not injected but same handling as other eggs), vehicle-control (injected with undosed safflower oil (vehicle)), and dose groups of 0.05, 0.1, 0.2, 0.4, 0.8, 1.6, 3.2, 6.4 $\mu g\ g^{-1}$ MeHg on a wet-weight (ww) basis in the egg following the protocol of Heinz et al. (2009). Heinz et al. (2006) demonstrated that the MeHg dose introduced into the air cell of an egg passes through the inner shell membrane and into the albumen, and those authors concluded that air cell injections are a safe way to get good dose-response results. Therefore, the dissolved MeHg was injected into the air cell through a hole drilled in the egg and subsequently sealed with surgical tape. After dosing with MeHg, eggs were returned to the incubator and allowed to develop. During incubation, egg viability was assessed periodically by candling and/or use of an Avitronic digital egg monitor. Survival to 90% of development was used as the endpoint measurement to compare embryo survival of the control eggs and eggs injected with graded concentrations of MeHg. Those embryos which survived to pipping (starring of eggshell indicating beginning of hatch) were euthanized by decapitation. All embryos were examined for any gross anatomical anomalies. Embryos (including the fecal sac and chorioallantoic membrane) were then weighed, homogenized and analyzed for total Hg (THg). MeHg was analyzed in three carcasses from each dose group in order to determine the proportion of MeHg:THg. We also harvested brain tissue from 56 arctic tern embryos for measurement of the neurotransmitters acetylcholine (muscarinic [mACh]) and glutamate (N-methyl-D-aspartic acid [NMDA]). The brains were removed, weighed and stored in liquid nitrogen for individual analysis of NMDA and mACh receptor density and THg. MeHg is being analyzed for three brains (pooled) from each dose group in order to determine the ratio of MeHg:THg.

Analytical methods: THg is analyzed in freeze-dried samples using a direct Hg analyzer (Milestone DMA-80), according to a standardized protocol (NWRC Method No. MET-CHEM-AA-03G) as described in detail by Weech et al. (2004). The method employs direct combustion of solid samples in an oxygen-rich atmosphere. Organic Hg (primarily present as MeHg in biological tissues) is quantified by extraction of organomercurials into toluene followed by back-extraction into sodium thiosulphate and measurement of total Hg in the final extract using a direct Hg analyzer (DMA-80) as described in Scheuhammer et al. (1998). NMDA and mACh receptor levels are assayed in embryonic brain tissue homogenates using methods described previously for adult birds and mammals (Basu et al. 2006, 2007; Scheuhammer et al. 2008). In brief, receptors are labelled with tritiated compounds having high specific affinity for these receptors, and their concentrations quantified by beta-counting (Perkin-Elmer microplate liquid scintillation counter).

Capacity Building: Two Inuit students from northern communities were hired to help with the field work at Tern Island in 2010. One student (Valerie Amarualik) was from Resolute Bay and the other (Terry Noah) was from Grise Fiord.

Communications: Resolute Bay is the nearest community to Tern Island. Presentations on the work that Environment Canada is doing on arctic birds are given regularly in Resolute Bay. A brief, unofficial meeting with some Resolute Bay HTA members was held in August 2010, followed by a presentation to the Resolute Bay HTA in late March 2011. The residue data along with a plain language summary of the findings from this project will be submitted to the Niqiit Avatittinni Committee (Nunavut) for their review and recommendation as to the most appropriate communications strategy back to the northern communities. Annual reports of the results are made to the NCP. The results will be published in a peer-reviewed scientific journal.

Traditional Knowledge: Population declines of the arctic tern have been noted over the past decade by various communities in the eastern Canadian Arctic (e.g. Sanikiluaq, Whale Cove, Rankin Inlet, Chesterfield Inlet, and Resolute Bay) (M. Mallory, CWS-Iqaluit, personal communication, January 2010) leading the Kivalliq Region of Nunavut to identify “research on Arctic terns” as a regional priority (Nunavut Wildlife Management Board 2007). This contributed to the selection of the arctic tern as a candidate species for this study.

Results

Of the 124 eggs incubated, 56 (45%) reached at least 90% development. One egg was removed because of content loss through a hairline crack in the shell. Organic Hg averaged 94.7% ± 1.2% of THg in the embryo carcasses or undeveloped eggs with no significant difference among dose groups (ANOVA: n=30; $F_{0.05(1),8,21}=0.65$; p=0.74). There was a sharp decrease in survival of tern embryos to 90% of development between the 0.2 and 0.4 $\mu g\ g^{-1}$ ww dose groups and a second drop between the 1.6 and 3.2 $\mu g\ g^{-1}$ ww dose groups

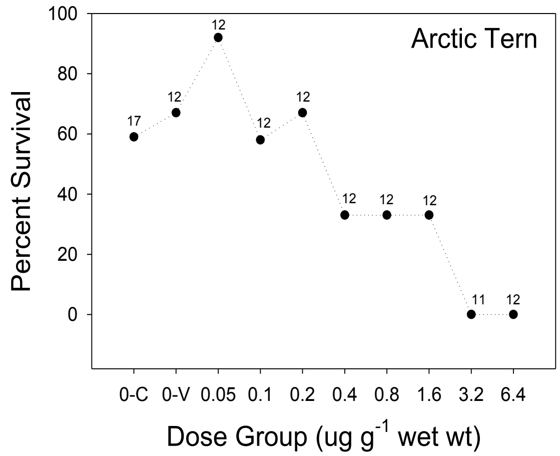

Figure 1. Preliminary dose-response results for survival of arctic tern embryos through 90% of development. Results not corrected for maternally-deposited Hg. Sample size for each dose group is indicated on the graph. One egg was removed from the second highest dose group because of content loss through a hairline crack in the shell.

(Figure 1). We also harvested brain tissue from 56 arctic tern embryos for measurement of neurotransmitter receptors. Measurements of NMDA and mACh receptor density are currently underway.

Discussion and Conclusions

It has been shown that reproductive success in birds can decrease by 35–50% due to dietary MeHg exposure insufficient to cause obvious signs of toxicity in adults (Wolfe et al. 1998). Based on a recent evaluation of published field and laboratory studies for nonmarine birds, the range of egg Hg concentrations associated with no adverse effect is 0.7-1.6 $\mu g\ g^{-1}$ ww while the range of egg Hg concentrations associated with adverse effects is 0.8-5.1 $\mu g\ g^{-1}$ ww (Shore et al. 2011). Using the data generated by Heinz et al. (2009) for species sensitivity to the embryotoxic effects of Hg, Shore et al. (2011) have proposed an indicative Hg value of 0.6 $\mu g\ g^{-1}$ ww in eggs as being protective for most (95%) of species. The uncorrected data for the arctic terns showed that there was a sharp decrease in survival of tern embryos to 90% of development between the 0.2 and 0.4 $\mu g\ g^{-1}$ ww dose groups and a second drop between the 1.6 and 3.2 $\mu g\ g^{-1}$ ww dose groups. To put those concentrations into a real-world context, the average THg concentration measured in first-laid (early) arctic tern eggs collected from Tern Island, just north of Cornwallis Island, in 2008 averaged 0.49 $\mu g\ g^{-1}$ ww (Akearok et al. 2010). However, it should be noted that results shown in Figure 1 have not yet been corrected for maternally-deposited Hg, which would increase the concentrations at which effects were observed. Also, Heinz et al. (2009), who developed the protocol we are using, suggested that MeHg injected into the egg is two to four times more embryotoxic than maternally-deposited MeHg, although the sensitivity relative to other species was the same whether the MeHg was injected or deposited naturally by the mother.

The study by Heinz et al. (2009), in which eggs of 26 species of birds were dosed with MeHg, demonstrated that the sensitivity of avian embryos to MeHg can vary dramatically among species with median lethal concentrations (LC50) ranging from 1 $\mu g{\cdot}g^{-1}$ ww or higher in eggs of the low sensitivity group to <0.25 $\mu g{\cdot}g^{-1}$ ww in eggs of those species exhibiting high sensitivity. Based on a calculated LC50 ranging between 0.25 and 1 $\mu g\ g^{-1}$ ww of Hg, Heinz et al. (2009) categorized three tern species (common, royal, Caspian) as having medium sensitivity to MeHg. Using these sensitivity categories, preliminary interpretation of the uncorrected data suggests that arctic terns would probably also fall into the medium sensitivity group.

NCP Performance Indicators

- In 2010–11, two northerners, both students, participated in the field work (see Capacity Building).
- There were two meetings held in the North in 2010–11 (see Communications).
- In 2010–11, five students participated in this study. Two northern students (see Capacity Building) and one southern student helped with the field work, and two southern students assisted with sample processing in the lab.
- No peer-reviewed publications have, as yet, been produced. In 2010, preliminary data were included in one departmental report (NCP Synopsis Report) and the data have been included in the CACAR III Mercury Assessment.

Expected Project Completion Date

March 31, 2011.

Acknowledgements

Thanks to M. Mallory for his help in coordinating the field work, and A. Scheuhammer and S. Kennedy for their help in coordinating the lab work. Thanks to K. Boadway, J. Boadway, C. Vallerand, V. Amarualik, and T. Noah for their help in the field, and S. Jones, D. Crump, E. Porter, F. St-Louis, D. Bond and E. Neugebauer for their work in the lab. Funding was provided by the Northern Contaminants Program of Indian and Northern Affairs Canada.

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A Genomics-Based Health Study of Ringed Seals (*Phoca hispida*) along the Labrador Coast: Health in the Face of Global and Local PCBs

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Abstract

Saglek Fjord has been the site of a military radar station since the late 1950s. Due to historical operations in Saglek Bay, high PCB (polychlorinated biphenyls) levels have been measured in surface sediments, marine invertebrates, fish, seabirds, and ringed seals (*Phoca hispida*). Preliminary data indicate that PCB levels in 24% of ringed seals exceed adverse health effects thresholds established in harbour seals (*Phoca vitulina*), underscoring the potential for local population impacts. Our study is designed to examine whether these elevated PCB levels are affecting the health of ringed seals. Since

Résumé

Depuis les années 1950, une station radar militaire est installée dans le fjord Saglek. En raison d'opérations historiques dans la baie Saglek, des niveaux élevés de BPC (diphényles polychlorés) ont été relevés dans les sédiments de surface, dans les invertébrés marins, les poissons, les oiseaux de mer et les phoques annelés (Phoca hispida). Les données préliminaires indiquent que les taux de BPC relevés dans 24 pour cent des phoques annelés sont supérieurs au seuil établi pour les phoques communs (Phoca vitulina) au-delà duquel il peut y avoir des effets néfastes sur la santé, et par conséquent des répercussions sur la population locale. Notre étude vise à déterminer si

obtaining samples for health assessments is challenging, we devised two methods to obtain samples conducive to our study objectives: i) live-captures of sub-adult and adult ringed seals during our concurrent telemetry program, and ii) samples obtained in cooperation with local harvesting practices. In 2010–11, we successfully obtained samples from 31 ringed seals (live-captures n=6; harvested n=25) for our study. Trends in concentrations of PCBs, polybrominated diphenyl ethers (PBDEs), and total mercury (THg) were also studied using ringed seals from Saglek Fjord (n= 13) and reference fjords (n= 18; Nachvak Fjord, Okak Bay, and Anaktalak Bay). Average concentrations of ΣPBDEs in 2010 male seals from the reference fjord group was significantly greater (11–fold) than concentrations from Saglek Fjord. On the other hand, average concentrations of ΣPCBs in 2010 male ringed seals from Saglek Fjord were significantly greater (3–fold) than concentrations from reference fjords. Average mercury concentrations measured in seals muscle did not vary between Saglek Fjord and reference fjord concentrations. PCBs and PBDEs were correlated in reference fjord (Nachvak Fjord, Okak Bay, Anaktalak Bay) seals, suggesting similar source, transport and fate processes for the two contaminants. PCBs were elevated in many ringed seals from Saglek Fjord, suggesting that these seals have been exposed to the local PCB sources. Over the coming year, we will complete genomic extractions for blubber, skin, muscle, and kidney tissues at the University of Victoria and IOS and the expression of 11 target genes for all tissues will be investigated using quantitative real-time polymerase chain reaction (*q*RT-PCR) and relative quantification (based on the best housekeeping gene).

The relationship between contaminant levels and the expression of a variety of health endpoints will be evaluated

ces taux élevés de BPC ont des effets sur la santé des phoques annelés. Comme l'obtention d'échantillons aux fins d'évaluation de la santé constitue en soi un défi, nous avons adopté deux méthodes pour obtenir des échantillons adéquats : i) la capture vivante de phoques annelés sous-adultes et adultes dans le cadre de notre programme concurrent de télémétrie; ii) l'obtention d'échantillons au moyen de pratiques de chasse locales. En 2010–2011, nous avons réussi à obtenir des échantillons prélevés sur 31 phoques annelés (capture vivante au nombre de 6, capture au moyen de pratiques de chasse au nombre de 25) pour les fins de notre étude. Nous avons également examiné les tendances en ce qui a trait aux concentrations de BPC, d'éthers diphényliques polybromés (EDP) et de mercure total (THg) chez les phoques annelés du fjord Saglek (au nombre de 13) et des fjords de référence (au nombre de 18; le fjord Nachvak, la baie Okak et la baie Anaktalak). En 2010, les concentrations moyennes de ΣEDP chez les phoques mâles du groupe de fjords de référence étaient beaucoup plus élevées (11 fois) que celles relevées chez les phoques du fjord Saglek. Par ailleurs, en 2010, les concentrations moyennes de ΣBPC relevées chez les phoques annelés mâles du fjord Saglek étaient beaucoup plus élevées (3 fois) que celles relevées dans les échantillons en provenance des fjords de référence. Nous n'avons relevé aucune variante entre les taux moyen de concentration de mercure mesurés dans le tissu musculaire des phoques du fjord Saglek et des phoques des fjords de référence. Nous avons établi des corrélations entre les taux de BPC et d'EDP chez les phoques des fjords de référence (fjord Nachvak, baie Okak et baie Anaktalak). Ces résultats semblent indiquer que la source, le transport et les processus intervenant dans le devenir des deux contaminants sont similaires. En effet, le taux de BPC était élevé chez plusieurs phoques annelés du fjord Saglek, ce qui semble indiquer qu'ils ont été exposés à des sources locales de BPC. Au cours de la prochaine année, nous compléterons les extractions génomiques sur le tissu du petit lard, de la peau, des muscles et des reins à l'université de Victoria et à l'Institut des sciences de la mer. On y examinera l'expression de 11 gènes cibles pour l'ensemble des tissus au moyen du système quantitatif de la réaction en chaîne par polymérase en temps réel (PCR en temps réel) et de la mesure relative (basée sur le meilleur gène domestique).

On évaluera le rapport entre les taux de contaminants et l'expression d'une variété de paramètres de santé.

Key Messages

- Samples were successfully obtained from 31 ringed seals (live-captures n=6; harvested n=25) in 2010–11 using a variety of capture and sampling methods.
- 59 ringed seal blubber samples (Saglek Fjord n=25; Reference fjords n=34) from 2009–11 were analyzed for contaminants, including PCBs, PBDEs, and mercury (THg) at the Great Lakes Institute for Environmental Research (GLIER) in Windsor, ON.
- PCBs and PBDEs were correlated in reference fjord seals, suggesting similar source, transport, and fate processes for the two contaminants.
- PCBs were higher than expected in many ringed seals from Saglek Fjord, suggesting that these seals have been exposed to local PCB sources.
- Newly developed genomics-based techniques specific for ringed seals are currently being validated and applied to samples in support of health assessments.
- Circulating thyroid hormone concentrations related to age and did not relate to PCB concentrations.
- $\delta^{13}C$ values in ringed seals collected from reference fjords were elevated relative to Saglek Fjord seals, suggesting that reference fjord seals were feeding on more benthic or inshore prey than seals in Saglek.
- Saglek Fjord seals had higher $\delta^{15}N$ values compared with reference fjords seals, suggesting that Saglek Fjord seals were feeding at higher trophic levels than seals from reference fjords.
- None of the ringed seals analyzed had *Trichinella* (0% infection rate) or active infections of *Otostrongylus circumlitus* (lungworm) and *Acanthocheilonema spirocauda* (heartworm), while 10% were infected with anisakid nematodes.

Messages clés

- En 2010–2011, nous avons réussi à obtenir des échantillons prélevés sur 31 phoques annelés (captures vivantes au nombre de 6, captures provenant de pratiques de chasse au nombre de 25) au moyen d'une panoplie de méthodes de capture et d'échantillonnage.
- Nous avons analysé, dans les laboratoires du Great Lakes Institute for Environmental Research (GLIER) de Windsor, en Ontario, 59 échantillons prélevés en 2009–11 et provenant du petit lard de phoques annelés (au nombre de 25 en provenance du fjord Saglek et de 34, de fjords de référence) afin d'y déceler des traces de contaminants, notamment de BPC, d'EDP et de mercure (THg).
- Nous avons établi des corrélations entre les taux de BPC et d'EDP chez les phoques des fjords de référence (fjord Nachvak, baie Okak et baie Anaktalak), ce qui semble indiquer que la source, le transport et les processus intervenant dans le devenir des deux contaminants sont similaires.
- Le taux de BPC dépassait nos prévisions pour bon nombre de phoques annelés du fjord Saglek, ce qui semble indiquer qu'ils ont été exposés à des sources locales de BPC.
- Les techniques basées sur la génomique récemment mises au point et spécifiques à l'étude des phoques annelés sont en cours de validation et appliquées aux échantillons en vue de l'évaluation de la santé de ces animaux.
- Les taux d'hormones thyroïdiennes en circulation étaient liés à l'âge et non aux concentrations de BPC.
- Les valeurs de la signature isotopique $\delta^{13}C$ chez les phoques annelés des fjords de référence étaient élevées par rapport à celles des phoques du fjord Saglek, ce qui semble indiquer que les phoques des fjords de référence se sont nourris de proies plus benthiques ou côtières que ceux de Saglek.

- En comparant les valeurs de la signature isotopique $\delta^{15}N$ plus élevées relevées dans les échantillons prélevés sur les phoques du fjord Saglek avec celles relevées sur les phoques des fjords de référence, il nous a semblé que les phoques du fjord Salek s'alimentent à des niveaux trophiques plus élevés que les phoques des fjords de référence.
- Aucun des phoques annelés examinés n'était atteint de trichinella (taux d'infection nul) ou d'infections actives causées par l'otostrongylus circumlitus (strongle pulmonaire) ou par l'acanthocheilonema spirocauda (filaire des chiens), alors que 10 pour cent d'entre eux avaient des infections causées par les nématodes anisakidés.

Objectives

i. Develop/adapt and validate techniques to measure the health of ringed seals using methods established in harbour seals.

ii. Assess the health of ringed seal using physiological, biochemical and molecular biomarker measurements.

iii. Determine organic contaminant (PCBs, PBDEs, OC pesticides) and mercury levels in ringed seal and report on the associations found between contaminant exposure and changes in biomarkers in ringed seal from the north Labrador coast.

iv. Incorporate local Inuit concerns into our study and communicate our results to the communities of Nunatsiavut through several avenues, including the kANGIDLUASUk base camp (jointly operated by Parks Canada and the Nunatsiavut Government) and regular updates and reports to the Nunatsiavut Government.

Introduction

Elevated PCB concentrations in ringed seal from the northern Labrador coast could represent a serious threat to the health of ringed seals, local wildlife that prey on ringed seals (e.g. polar bears) and humans. Marine mammals are especially vulnerable to elevated exposure of persistent organic pollutants as a result of their high trophic level, low detoxification capacity, large lipid reserves, and long life span (Boon et al. 1992; Nyman et al. 2003; Mos and Ross 2002). Because these compounds are persistent they accumulate through the food chain, reaching their highest levels in upper trophic organisms, like ringed seal (Assunção et al. 2007; Wolkers et al. 2008). Marine mammals, such as ringed seal can serve as a 'sentinel species' of marine ecosystem contamination (Ross 2000). Through this study, we will be reporting on levels and trends of contaminants in ringed seals, which will both support the assessment of ecological and human health risks and provide Inuit with important health information regarding a valued component of their traditional diet.

PCB concentrations in ringed seals of the same age and sex from the northern Labrador coast range from Arctic background (< 1,000 ng/g ww) to 15,000 ng/g (ww) (Kuzyk et al. 2005; ESG 2008; Muir et al. 2006). Organochlorine contaminants, including PCBs, were more recently measured in ringed seals from the Labrador coast as part of our coastal food-web study, and contaminant data to date have shown that elevated PCB levels in ringed seals still persist along the coast (Brown et al. 2009). PCB levels at the upper end of this range exceed all previously reported concentrations in ringed seals from northern Canada and exceed established health effects thresholds in another pinniped species, the harbour seal (*Phoca vitulina*). As such, some of the ringed seals from the north Labrador coast may be at risk for toxic effects including the disruption of vitamin A, retinoic acid receptor RARα expression levels, thyroid hormone physiology and immune function (Mos et al. 2006; Mos et al. 2007; Tabuchi et al., 2006). The disruption of such physiological processes may lead to developmental, reproductive, and immunological impacts, ultimately impacting the health of local populations. This wide range of exposure provides a near-unique opportunity to evaluate the effects of PCBs on the health of a wild marine mammal, as the concentrations of this chemical dominate those of other POPs. In this study, we will assess the exposure levels and health status of ringed seals using established biomarkers. We have chosen a suite of biomarkers that appear to elicit a response or have been correlated with, organochlorine exposure in studies of other pinnipeds.

Activities in 2010–2011

The summer sampling program was extremely successful in meeting its objectives for collecting samples from both live-captured ringed seals during our satellite telemetry program and harvested animals on an opportunistic basis. With the help from Joey Angnatok, Chesley Webb, Joe Webb, Bill Webb, Leo Angnatok, and Samuel Ittulak we successfully obtained samples from 31 ringed seals (live-captures n=6; harvested n=25) for our study. Five ringed seal were collected via harvesting from Nachvak Fjord, 13 ringed seals were collected via harvesting and live-captures from Saglek Fjord, 11 ringed seals were collected via harvesting and live-captures from Okak Bay and 2 ringed seals were collected via harvesting from Anaktalak Bay. Science personnel in the field included Tanya Brown (PhD student, University of Victoria, ESG), Peter Ross (DFO), Becky Sjare (DFO), James Loughlin (DFO), and Mary Denniston (NG). Also assisting with the collections were Dorothy Angnatok (Research Assistant, Nain, Labrador) and five kANGIDLUASUk student interns from Nunatsiavut and Nunavik (Jason Dicker, Samantha Lyall, Jennifer-Rose Campbell, Charlie Annanack and Lissie Unatweenuk). Field work and tissue sample collections were supported by funds from ArcticNet, DND, NCP and FCSAP (Federal Contaminated Sites Action Plan).

Live-captured Ringed Seals: Collections consisted of skin/blubber biopsies and blood (plasma and serum). Skin/blubber biopsies for genomics were place in RNALaterTM solution and stored at -20°C. Blubber samples were submitted to the LEACA lab for analysis of PCBs, PBDEs, and OCPs. The plasma and serum samples were analyzed for circulatory vitamin A (retinol and retinyl palmitate), vitamin E (α-tocopherol) and thyroid hormones (TT4, FT4, TT3, FT3) at IOS. Serological testing for protozoan *Toxoplasma gondii* was completed at the CFIA (Canadian Food Inspection Agency).

Harvested Ringed Seals: Collections consisted of blood (plasma, serum, RBCs), liver, muscle, kidney, heart and lungs, gonads, stomach, blubber and skin, tooth/lower jaw, vibrissae, claws, and the left fore-flipper. Samples of the skin, liver, muscle, brain, and kidney were collected, placed in RNALaterTM solution and stored at -20°C. Genomic extractions were completed for liver and extractions for blubber, skin, muscle, and kidney tissues are underway at the University of Victoria and IOS. The plasma and serum samples were analyzed for circulatory vitamin A (retinol and retinyl palmitate), vitamin E (α-tocopherol) and thyroid hormones (TT4, FT4, TT3, FT3) at IOS. Serological testing for protozoan *Toxoplasma gondii* was completed at the CFIA. The heart and lungs were examined for heartworm (*Acanthocheilonema spirocauda*) and lungworm (*Otostrongylus circumlitus*) at the Institut Maurice-Lamontagne. The All tooth aging was conducted by Matson Labs (Milltown, MT). Testing for *Trichinella* sp. infection using four different muscles (tongue, masseter, diaphragma, and left fore-flipper) was completed at the CFIA. Liver will be analyzed for phase I and II enzyme activities. The radius bone of the left fore-flipper will be analyzed for bone mineral density at the Centre for Bone and Periodontal Research, Montreal, Quebec. Blubber samples were submitted to the GLIER lab for analysis of PCBs, PBDEs, and OCPs. Muscle samples were submitted to the GLIER for analysis of THg. Muscle and RBC samples were sent to the GLIER for stable isotope ($\delta^{13}C$ and $\delta^{15}N$) analysis. Blubber samples were sent to Dalhousie University for fatty acid analysis.

Complementary Studies – marine food web & ringed seal satellite telemetry: The marine food web study and ringed seal satellite telemetry study are sub-projects within our ArcticNet Nunatsiavut Nuluak program, but will have direct implications to understanding the contaminant exposure and health effects in ringed seals from the north Labrador coast. These two studies complement the ringed seal health study by controlling for some of the confounding factors (e.g. feeding ecology and behaviour) that may influence ringed seal health and the effects measured.

During the summer and fall of 2010, benthic invertebrates, zooplankton, and fish were collected for our marine food web study in Nachvak, Saglek, Okak, and Anaktalak Fjords (Figure 1). Sampling for benthic invertebrates and fish during the summer was completed from a longliner vessel (MV *Whats Happening*) and sampling for pelagic phytoplankton (using a CTD-rosette system), zooplankton (using zooplankton tows) and fish (using the Agassiz and Rectangular Mid-Water Trawls) during the fall was completed from the CCGS *Amundsen*. Fish and invertebrate fatty acid, stable isotope and contaminant analyses are on-going at Dalhousie University and GLIER.

Satellite Platform Transmitter Terminals (PTTs) were deployed on five ringed seals during September 2010. A PTT and data logger (both in a single unit) were attached to the dorsal fur (between the scapulae) of each ringed seal with fast-setting epoxy glue. Each satellite PTT will relay location and diving behaviour data for 4–8 months. Standard morphometric measurements, a blood sample, and two or three fat biopsies (one or two 3.5 mm and one 8.0 mm) were taken on each animal.

Figure 1. Location of the study areas in Nunatsiavut (Nachvak, Saglek, Okak and Anaktalak Fjords). Note: Although long range transport is the primary source of contaminants to Nunatsiavut, local sources of PCBs also exist at Saglek Bay due to historical operations at the former military radar site.

Capacity Building and Training: In 2010, Dorothy Angnatok (Research Assistant, Nain, Labrador) and five kANGIDLUASUk student interns from Nunatsiavut and Nunavik (Jason Dicker, Samantha Lyall, Jennifer-Rose Campbell, Charlie Annanack and Lissie Unatweenuk) worked with the scientific personelle and the captain and crew of the *MV* Whats Happening on several of the Nunatsiavut Nuluak research programs, including the ringed seal health study and the marine food web study. The kANGIDLUASUk student intern program has helped to develop capacity, promote environmental education, training and careers, primarily amongst youth, in Nain and other Nunatsiavut and Nunavik communities. Dorothy progressed from a kANGIDLUASUk student intern to a research assistant, and in doing so took on a leadership role in many of our Nunatsiavut Nuluak projects during 2010. The tools and skills (both personal and professional) that Dorothy gained through her leadership role within the Nunatsiavut Nuluak program have proven extremely valuable in shaping her future endeavors. Dorothy fostered close relationships with scientists that have continued past the summer field season and in Dorothy's case has sparked a strong interest in the field of biology and scientific research. She is currently completing her degree in the Sport and Leisure Management Program at Holland College and hopes to apply to Memorial University for a bachelors degree in Biology.

Communications: Short summary reports for each of the programs within ArcticNet Nunatsiavut Nuluak (ANN), including the ringed seal health study were provided to the Nunatsiavut Government, and Parks Canada in the fall/winter of 2010. The reports summarized field work, major outcomes/results and detailed next steps.

From June 1–4, 2010 we attended the Tukisinnik Community Research Forum in Nain, Labrador. We presented background information, current research and preliminary results for our ringed seal health study, the marine food web study, and the ringed seal satellite telemetry study. This information was communicated to the Nunatsiavut Government, community members, Parks Canada, Industry, Torngat Joint Fisheries Board, and the Torngat Wildlife and Plants Co-Management Board. Open discussions concerning existing research activities were held across the three days. We also participated in a youth forum and put together a session that introduced youth to scientists leading the Nunatsiavut Nuluak research programs, our research, and the relevance of our research in Nunatsiavut. As part of the youth session we included a hands-on activity highlighting some of the work we do in the field, how we do it, and the equipment we use. A plain-language summary (in English and Inuktitut) of the ANN work was handed out at the forum and circulated around to Nunatsiavut communities and government offices.

On June 16, 2011 we held our annual Saglek Stakeholder Meeting in St. John's, NL. Results of our ArcticNet Nunatsiavut Nuluak research programs, including the ringed seal health study were communicated to the stakeholders, including Inuit organizations.

Traditional Knowledge: The kANGIDLUASUk base camp that we operate from during July and August provides the opportunity for the integration of Inuit Knowledge in the Nuluak project, including the ringed seal health study. The base camp, and more importantly the Inuit connections that it fosters, anchors all facets of our project and strongly engages northerners in the scientific process through the bilateral exchange of knowledge, technology, and training. Traditional knowledge and Inuit concerns were partly responsible for the genesis of this program and will continue to be extremely important to the program in the future. We have heard concerns from Inuit at base camp and during the Tukisinnik Community Research Forum about possible health effects that elevated levels of contaminants may be having on ringed seals in this and other areas (e.g. Hopedale and Lake Mellville). Consequently, we are considering expanding our ringed seal research further south along the Labrador coast. This health study will allow us to address these concerns.

An NCP funded project entitled, "Tukisimakatigennik (understanding together): Inuit Knowledge and scientific inquiry into contaminants trends in Nunatsiavut" complements our ringed seal health, ringed seal telemetry, and marine food web studies in Nunatsiavut. While working alongside hunters in the field, project team members of the ringed seal health and TK studies carried out interviews in Anaktalak Bay and Saglek Fjord during the summer of 2010. This information, along with information collected during interviews with local hunters from Nain in the winter of 2010 is being used to document Nunatsiavimmiut Knowledge of ringed seal ecology.

Results and Discussion

Morphometrics

We collected samples from 28 and 31 ringed seals from four fjords (Nachvak Fjord, Saglek Fjord, Okak Bay, and Anaktalak Bay) for health assessments and contaminant analyses in 2009 and 2010, respectively. Of the 28 seals sampled in 2009, 17 were female (average weight=50 kg ± 23 kg; average blubber thickness=4.4 cm ± 2.4) and 11 were male (average weight=42 kg ± 24 kg; blubber thickness=2.4 cm ± 2.4 cm). Of the 31 seals sampled in 2010, 16 were female (average weight=54 kg ± 24 kg; average blubber thickness=3.4 cm ± 3.0 cm) and 15 were male (average weight=46 kg ± 22 kg; average blubber thickness=3.1 cm ± 1.6 cm). 2009 female and male seal ages ranged from 0 to 23 years (median 10 years) and 0 to 24 years (median 2 years), respectively. 2010 ringed seals are currently being aged at Matson Labs (Milltown, MT).

Table 1. Average percent contribution of the top six PCB and PBDE congeners in ringed seals from Saglek Fjord and reference fjords.

	Saglek Fjord		Reference fjords	
	congener	% contribution	congener	% contribution
PCBs	153	26.7	153	24.2
2009	138/163	15.2	138/163	12.7
	180	10.7	180	11.4
	118	4.8	170/190	4.5
	170/190	4.8	118	4.4
	99	4.2	92/84/101	3.8
2010	153	25.2	153	26.5
	180	18.6	138/163	14.4
	138/163	13.2	180	10.5
	170/190	7.5	170/190	4.6
	187/182	3.7	118	3.7
	183	2.7	99	3.5
PBDEs	47	52.3	47	71.0
2010	28	25.1	49	10.1
	49	6.9	99	5.6
	66	6.0	28	3.9
	100	4.3	100	2.7
	99	4.2	66	1.8

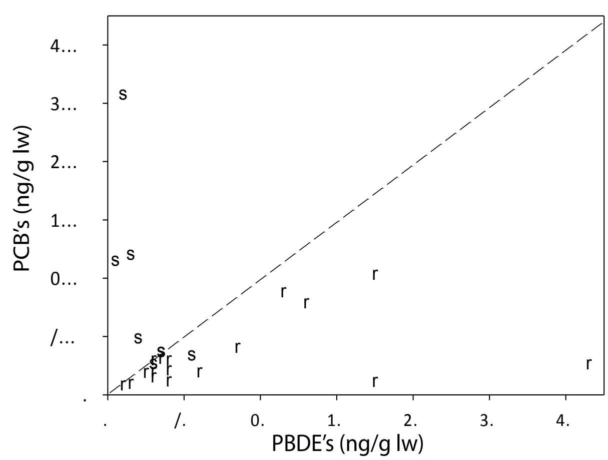

Figure 2. Total PCB and PBDE concentrations in male and females ringed seals from Saglek Fjord (s) and reference fjords (r) sampled in 2010. Reference fjord concentrations (R^2= 0.90; p>0.001); Saglek Fjord concentrations (R^2=0.43; p=0.16).

Concentrations of PCBs, PBDEs and mercury in ringed seals

Concentrations of ΣPCB (62 congeners) compounds significantly increased with age for 2009 male ringed seals (p=0.02). No significant differences (p>0.05) were found among age and concentrations of ΣPCBs for 2009 female ringed seals. Concentrations of ΣPCBs in 2009 seals were significantly different between sexes, with males having nearly two times the concentrations of PCBs than females (p=0.032; male PCBs 909 ng/g lw ± 656; female PCBs 511 ng/g lw ± 328). Concentrations of ΣPCBs did not differ between sexes for 2010 ringed seals. However, concentrations of ΣPBDEs (22 congeners) in 2010 seals differed significantly between sexes, with males having three times the concentrations of PBDEs than females (p=0.018; male PBDEs 18.7 ng/g lw ± 17.5; female PBDEs 5.6 ng/g lw ± 2.7). Concentrations of total mercury (THg) in 2009 ringed seals did not differ significantly between sexes or with age (p>0.05).

After removing the influence of sex, average concentrations of ΣPBDEs in 2010 male seals were significantly greater in the reference fjord seals (11–fold) than concentrations from Saglek Fjord (p=0.006; Saglek 2.3 ng/g lw ± 1.3; other fjords 22 ng/g lw ± 17). No significant differences were found between average concentrations of ΣPBDEs in 2010 female seals and location (p>0.05; Saglek 6.0 ng/g lw ± 3.2; reference fjords 5.2 ng/g lw ± 2.5 ng/g lw). On the other hand, average concentrations of ΣPCBs in 2010 male and female ringed seals from Saglek Fjord were significantly greater (3–fold and 4–fold, respectively) than concentrations from reference fjords (male: p=0.02; Saglek 2,375 ng/g lw ± 76; reference fjords 825 ng/g lw ± 668; female: p=0.03; Saglek 1,488 ng/g lw ± 1813; reference fjords 413 ng/g lw ± 191). Concentrations of THg in 2009 Saglek Fjord ringed seals were not significantly different from reference seals (p>0.05; Saglek 0.224 μg/g ww ± 0.064; reference fjords 0.207 μg/g ww ± 0.106). THg levels in the muscle tissue of ringed seals from northern Labrador fjords were similar to previously reported values from ringed seals collected in Nunatsiavut and Nunavik from 1998 to 2000 (Muir et al. 2001).

PCB congeners 153, 180, 138/163, 170/190, 99, 183, 187/22, 92/84/101 were the top six congeners for Saglek and reference fjord ringed seals and accounted for 60 to 70% of the total PCB concentration (Table 1). PCB 153, 138/163 and 180 were consistently the top three congeners in both Saglek Fjord and reference fjord ringed seals. The top six congeners and percent contribution for reference fjord seals was similar between years and to the 2009 Saglek Fjord seals (Table 1). On the other hand, for the 2010 Saglek Fjord ringed seals the top six congeners varied from reference fjord and 2009 Saglek Fjord seals, with the 2010 Saglek seals including a greater proportion of congeners dominant in Aroclor 1260 commercial mixtures (PCB 187/182 and 183 were among the top six), the source of PCBs at Saglek (Pier et al. 2003). The top six PBDE congeners (47, 28, 49, 66, 100, 99) in ringed seals from Saglek Fjord and reference fjords accounted for 95 to 98%. The dominating congener among Saglek Fjord and reference fjord ringed seals was BDE-47 (52.3% and 71%, respectively). BDE-47 was also the most dominant congener in ringed seals from East Greenland (75.4%) and other marine mammal species and seabirds (Rigét et al. 2006).

There was a significant correlation between PCBs and PBDEs in ringed seals from the reference fjord group, but not for seals from Saglek Fjord (Figure 2). These results further suggest that Saglek Fjord ringed seals have been exposed to local PCB sources, in addition to PCBs and PBDEs associated with long-range transport (i.e. background).

Diet and Condition

Stable Isotopes

For seals collected in 2009 and 2010, there were no sex-related differences in $\delta^{15}N$ and $\delta^{13}C$ values (p>0.05). For reference fjord seals collected in 2010, both females and males were enriched in $\delta^{13}C$ values over reference seals collected in 2009 (p=0.01 and p=0.01, respectively). For female and male Saglek and reference fjord seals, no significant differences between years were found for $\delta^{15}N$ values (p>0.05). 2009 reference fjord seals had higher $\delta^{13}C$ values compared with Saglek Fjord seals (p=0.007), suggesting that the reference fjord seals were feeding on more benthic or inshore prey than seals in Saglek. 2009 and

Table 2. Average carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope values vary by location suggesting that there may be differences in the feeding patterns of ringed seals in Saglek Fjord and reference fjords.

Group		N	$\delta^{15}N$	$\delta^{13}C$
Saglek Fjord				
2009	Females	1	13.6	17.7
	Males	3	17.0 ± 3.3	9.9 ± 9.1
	All	4	16.1 ± 3.2	11.8 ± 8.4
2010	Females	7	15.1 ± 1.3	18.1 ± 0.8
	Males	2	14.4 ± 0.3	17.9 ± 0.4
	All	9	14.9 ± 1.2	18.1 ± 0.7
Reference Fjords				
2009	Females	13	13.9 ± 1.1	17.9 ± 0.4
	Males	3	13.3 ± 0.5	17.3 ± 0.1
	All	16	13.8 ± 1.0	17.8 ± 0.5
2010	Females	6	14.1 ± 0.9	18.6 ± 0.6
	Males	11	14.0 ± 0.9	18.4 ± 0.7
	All	17	14.0 ±0.9	18.5 ± 0.7

Table 3. Circulating TH concentrations in ringed seals from Saglek Fjord and four reference fjords (Nachvak Fjord, Okak Bay, Anaktalak Bay) in Northern Labrador.

	Saglek Fjord		Reference Fjords	
	n	Concentration	N	Concentration
TT_4 (nmol/L)	12	54.8 ± 30.2 (28.5-128.1)	15	52.2 ± 66.6 (2.2-260.9)
FT_4 (pmol/L)	12	17.4 ± 4.2 (11.6-25.1)	15	14.0 ± 3.9 (6.2-23.0)
TT_3 (nmol/L)	12	1.3 ± 0.44 (0.46-1.9)	16	0.71 ± 0.28 (0.32-1.5)

2010 Saglek Fjord seals had higher $\delta^{15}N$ values compared with reference fjords seals (p=0.01 and p=0.03, respectively), suggesting that Saglek Fjord seals were feeding at higher trophic levels than ringed seals from reference fjords. Our preliminary results suggest there may be differences in the feeding patterns of ringed seals in Saglek Fjord and reference fjords, which may have potential implications for the transfer of contaminants to the species.

Thyroid hormones

The concentrations of free circulating T_4 and total T_3 and T_4 were measured in serum collected from the 2009 ringed seals (Table 3). The concentrations of TT_4, FT_4, and TT_3 did not differ between sexes (p>0.05). Among the seals sampled from the two location groups, Saglek Fjord seals had significantly greater FT_4 and TT_3 compared with reference fjord seals (p=0.03; p<0.001). TT_3 levels had a significant negative trend with age (Figure 3). After removing the influence of age, adult (>4 years) seals TT_3 did not vary between the two location groups. On the other hand, sub-adult (≤ 4 years) seals from Saglek Fjord had significantly greater TT3 compared with reference fjord seals (p=0.006; Saglek 1.5 ± 0.25 nmol/L; reference fjords 1.0 ± 0.29 nmol/L). Thyroid concentrations did not relate to ringed seal PCB concentrations (p>0.05). These results may suggest that contaminant levels may not be elevated enough to disrupt thyroid hormone homeostasis. However, these results are preliminary and may be confounded by other variables, such as a small sample size, age, sex, and condition.

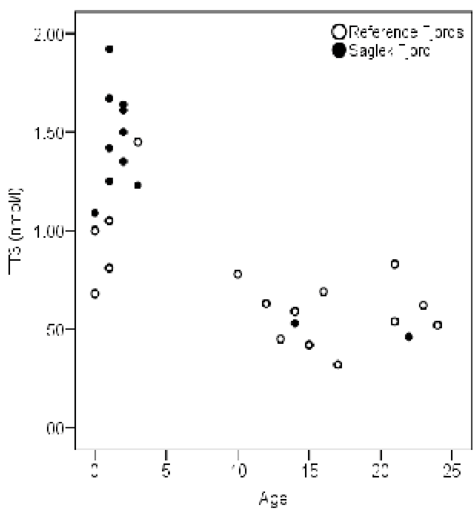

Figure 3. Total T3 concentrations in 2009 ringed seals varied with age (r^2=0.56, p<0.001) and sample location (≤ 4 years; p=0.006).

Parasites

Muscle samples from 33 (2009, n=10; 2010, n=23) ringed seals were tested for *Trichinella*. Of the 33 ringed seals tested, none had trichinellosis, i.e. an infection rate of 0%. Ringed seal samples collected from all four fjords were analyzed for anisakids: 9 of the 95 (10%) were infected. The incidence of anisakid infection from the four fjords was 23% in Anaktalak, 17% in Okak, 3.6% in Nachvak, and 0% in Saglek. Of the 44 ringed seals analyzed for *Otostrongylus circumlitus* (lungworm) and *Acanthocheilonema spirocauda* (heartworm) in 2009 and 2010, none had active infections. Two ringed seal from 2009, however, had calcified worms in the lungs indicative of previous infections of *O. circumlitus*. Work is in progress to complete serological testing for anti-*Toxoplasma* antibodies.

Conclusions

The combination of long range "background" and a local PCB "hotspot" on the Labrador coast affords us an invaluable opportunity to examine the effects of PCBs on the health of a marine mammal population, as the concentrations of this chemical dominate those of other POPs. Our project has delivered a series of new health assessment tools for ringed seals, which is being used to generate insight into the effects of PCBs on their health. This study has provided new information on the levels of PCBs, PBDEs, and THg in Labrador ringed seals. Results for ringed seal PCB concentrations are being incorporated into a human health risk assessment for Saglek Fjord. The ringed seal health study has bearing on the health of the ringed seal population in Labrador, in addition to those community members that rely on this species as important country food. The marine food web study and ringed seal satellite telemetry study are complementary studies within our ArcticNet Nunatsiavut Nuluak program, and have direct implications to understanding the contaminant exposure and health effects in ringed seals from the north Labrador coast. These two studies are helping to control for some of the confounding factors (e.g. feeding ecology and behaviour) that may influence ringed seal health and the effects measured.

Expected Project Completion Data

Year 1 (2009–10): Pilot year for the Labrador ringed seal health program. The objectives of the first year were to design and apply a field sampling programme conducive to health assessments, and to initiate the development of a new genomics tool box to measure health of ringed seals.

Year 2 (2010–11): Second year of sampling using two strategies (live-capture during a concurrent telemetry study and samples from harvested sub-adults and adults), continue with method development, and begin analyses.

Year 3 (2011–12): Complete health measurements on samples and holistic interpretation of the data.

Year 4 (2012–13): Complete publications in scientific journals and report results back to Nunatsiavut communities.

Acknowledgments

We thank NCP, ArcticNet, DND, and FCSAP for supporting this project, the MV Whats Happening and Robert Bradford captain and crew, and Dorothy Angnatok, James Loughlin, Mary Denniston and the kANGIDLUASUk student interns (Jason Dicker, Samantha Lyall, Jennifer-Rose Campbell, Charlie Annanack and Lissie Unatweenuk) for their support of the sampling.

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Characterizing Contaminant-Related Health Effects in Beluga Whales (*Delphinapterus leucas*) from the Western Canadian Arctic

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Abstract

Beluga whales (Delphinapterus leucas) in the Arctic may be vulnerable to the combined effects of contaminants and a changing climate. We have been pioneering new methods to measure the health of beluga whales in close collaboration with Inuvialuit community members from Tuktoyaktuk and with other researchers working in the area. Our beluga whale health research enters its final year, with investment in field sample collections between 2007 and 2010, methods development in the laboratory, the application of these new methods to samples collected, and the completion of laboratory-based tests to determine the effects of mercury on white blood cells from beluga. The 2010 field season was challenged by poor weather and reduced sample size. Despite logistical and technical challenges in the field and in the laboratory, we have made considerable progress in being able to measure the health of beluga whales, and to explore the ways in which both contaminants and climate change

Résumé

Les bélugas (Delphinapterus leucas) de l'Arctique peuvent être vulnérables aux effets combinés des contaminants et des changements climatiques. Nous avons élaboré de nouvelles méthodes pour évaluer la santé des bélugas en collaboration étroite avec les membres de la collectivité Inuvialuit de Tuktoyaktuk et d'autres chercheurs travaillant dans le domaine. Notre étude sur la santé des bélugas entre dans sa dernière année; les travaux ont porté sur la collecte d'échantillons sur le terrain entre 2007 et 2010, l'élaboration de méthodes en laboratoire, l'application de ces nouvelles méthodes aux échantillons prélevés et la réalisation d'essais en laboratoire pour déterminer les effets du mercure sur les globules blancs des bélugas. La recherche sur le terrain en 2010 a représenté un grand défi en raison du mauvais temps et de la quantité réduite d'échantillons. Malgré les défis logistiques et techniques sur le terrain et en laboratoire, nous avons fait des progrès considérables dans notre capacité à évaluer la santé des bélugas et à analyser les façons dont les effets combinés des

are affecting health. Results from this year exemplify the impacts of climate on research, both in terms of field logistics and in terms of research findings. Our results indicate that persistent environmental contaminants appear to affect a variety of health endpoints at the molecular level. Further work will clarify the extent to which these observations may be influenced by such factors as age, sex, condition or feeding ecology. Impacts of climate change and/or contaminants are of concern if it translates into reduced stock abundance for community harvesters or diminished quality. There has been strong interest by community members of Tuktoyaktuk, and the student training program is engaging a new generation of northerners. This project represents a collaboration between the Northern Contaminants Programme (NCP – INAC) and Fisheries and Oceans Canada (Ecosystem Research Initiative and National Headquarters).

contaminants et des changements climatiques affectent leur santé. Les résultats de cette année illustrent les répercussions du climat sur la recherche, tant du point de vue de la logistique sur le terrain que de celui des résultats de la recherche. Ces résultats indiquent que certains contaminants persistants de l'environnement semblent affecter différents paramètres de la santé sur le plan moléculaire. Des recherches approfondies nous aideront à déterminer dans quelle mesure des facteurs tels que l'âge, le sexe, l'état de santé et les relations trophiques peuvent influer sur ces caractéristiques. Les répercussions des changements climatiques et des contaminants sont préoccupantes si elles se traduisent par une abondance réduite des stocks pour les exploitants des collectivités ou par une diminution de la qualité. Les membres de la collectivité de Tuktoyaktuk se sont montrés très intéressés et le programme de formation à l'intention des étudiants engage une nouvelle génération d'habitants du Nord. Ce projet est mené en collaboration avec le Programme de lutte contre les contaminants dans le Nord (PLCN – AADNC) et Pêches et Océans Canada (projet de recherche sur l'écosystème et administration centrale nationale).

Key Messages

- A fourth year of field sampling was completed, with the participation of team members, collaborators and community members;
- For the first time the project partnered with the new TEK program led by M. Pokiak and R. Pokiak who were based out of Tuktoyaktuk;
- Poor weather in July 2010 reduced sample collections to 10 beluga whales (from the planned 20) at Hendrickson Island. All whales were male;
- A comparison of blubber and liver PCB and PBDE concentrations in 10 beluga showed significant, positive correlations between liver and blubber tissue concentrations;
- New and/or refined laboratory techniques have been validated for the measurement of fatty acids and lipid classes; a pattern analysis approach using Principal Components Analysis (PCA) found a positive relationship between Factor 1 and PCB concentrations; further evaluation is underway to determine whether this is due to age, metabolism, feeding ecology and/or toxicity;

Messages clés

- Une quatrième année d'échantillonnage sur le terrain s'est terminée avec la participation de membres de l'équipe, de collaborateurs et de membres de la collectivité;
- Pour la première fois, nous nous sommes associés au nouveau programme axé sur la science et les connaissances écologiques traditionnelles dirigé par M. Pokiak et R. Pokiak qui étaient situés à l'extérieur de Tuktoyaktuk;
- Le mauvais temps au mois de juillet 2010 a réduit la collection d'échantillons à 10 bélugas (comparativement aux 20 prévus) à l'île Hendrickson. Toutes les baleines étaient des mâles;
- La comparaison des concentrations de BPC et d'EDP dans la graisse et dans le foie de 10 bélugas indique une corrélation positive importante entre les concentrations dans les tissus du foie et celles dans les tissus adipeux;
- Des techniques de laboratoire nouvelles ou perfectionnées ont été validées pour l'examen des acides gras et des classes de lipides; une approche fondée sur l'analyse des tendances

- Some gene expression endpoints correlate negatively with PCBs for samples from earlier study years, and genomic evaluation for 2009–10 is underway;
- Circulating hormones such as vitamin A and thyroid hormones appear generally less sensitive to toxicological alteration than genomics, perhaps partly due to the confounding factors;
- In vitro experiments using fresh blood obtained from Vancouver Aquarium belugas suggest that mercury is toxic to white blood cells at concentrations observed in some free-ranging populations of beluga.

au moyen de l'analyse en composantes principales (ACP) a permis de trouver une relation positive entre le facteur 1 et les concentrations en BPC; un examen approfondi est en cours pour déterminer si cette relation est attribuable à l'âge, au métabolisme, aux relations trophiques ou à la toxicité;

- Des paramètres de l'expression génétique sont en corrélation négative avec les concentrations de BPC détectées dans les échantillons de recherches menées au cours des années antérieures et l'évaluation génomique de 2009–2010 est en cours;
- Les hormones circulantes telles que la vitamine A et les hormones thyroïdiennes paraissent généralement moins sensibles aux changements toxicologiques qu'à ceux de nature génomique, ce qui est peut-être partiellement attribuables aux variables confusionnelles;
- Des expériences in vitro où du sang frais obtenu des bélugas de l'Aquarium de Vancouver a été analysé semblent indiquer que le mercure est toxique pour les globules blancs aux concentrations observées chez des populations de bélugas en liberté.

Objectives

Overarching Objective: Characterize health risks associated with dietary intake, accumulation and metabolism of persistent contaminants in beluga whales.

1. Carry out a small field sampling program to strengthen our understanding of temporal changes in beluga whale health observed over the past four years. Work closely with the community of Tuktoyaktuk and train youth in sampling techniques for future capacity development (research and/or monitoring);
2. Complete genomic, endocrine and physiologic tool measurements to characterize the health of beluga (final QA/QC of species-specific genomics toolbox and all related measurements) using 2010 samples;
3. Conduct laboratory-based in vitro toxicity experiments to evaluate effects of mercury (Hg) and other priority contaminants on beluga health (in collaboration with the Vancouver Aquarium);
4. Focus on data analysis and publications, communication with Hunters and Trappers Committee (HTC) in Tuktoyaktuk, the Fisheries Joint Management Committee (FJMC), the Northern Contaminants Programme secretariat, and the international scientific community.

Introduction

Beluga whales are at the top of the Arctic food web, rendering them vulnerable to contamination by a variety of persistent environmental contaminants that are transported from distant sources. Our research has demonstrated that complex environmental mixtures of POPs are affecting the health of free-ranging pinnipeds, and present a tangible risk to cetaceans, in several areas of southern Canada (Ross 2006; Mos et al. 2006; Tabuchi et al. 2006). Concerns about contaminants in the Canadian Arctic emanate, in part, from studies which demonstrate possible health effects in subsistence-oriented humans, polar bears and beluga whales (Dallaire et al. 2004; White et al. 1994; Braathen et al. 2004). Technical and logistical challenges have generally precluded health assessments in Arctic marine mammals, but new and emerging technologies provide an opportunity to build on past efforts and shed light on an important facet of Arctic contamination (Stern et al. 2005; Lockhart et al. 2005; Muir et al. 1999).

A complicating juxtaposition in the way of climate change may add a layer of stress to beluga whales, by altering contaminant pathways, or by reducing the condition of beluga whales (Macdonald 2005). Despite the wealth of information about pathways and fate of different classes of environmental contaminants over time and space in the Arctic little is known about adverse health effects associated with these contaminants in vulnerable species, including beluga whales.

Changes in Arctic sea ice cover, temperature profiles, food web productivity, and beluga distribution and feeding ecology may profoundly change the course of contaminant fate in the Arctic environment, as well as the condition and health of beluga. Climate change has the potential to confound our understanding of mechanistic linkages between contaminant exposure and health effects, but may also have serious implications for the health of beluga whale populations. Our programme is designed to characterize condition and nutritional status of belugas in order to generate insight into the relationship between climate, contaminants and health of beluga.

Activities in 2010–2011

Another full sampling year took place at Hendrickson Island. Similar to previous years all Hendrickson Island personnel worked as a team to sample whales efficiently, in addition to helping hunters remove beluga tissues for later processing. Science personnel in the field included Lisa Loseto (DFO), Stephen Raverty (BC Animal Health Center), Marie Noel (PhD student, University of Victoria), Sonja Ostertag (UNBC). Also at our field camp were three students from the Inuvialiut Settlement Region (R. Walker, K. Snow and B. Voudrack) for a youth mentoring program (NCP TEK funded). Camp was set up July 1, 2010 and shut down July 22, 2010.

Frank and Nellie Pokiak and their family were on site for tissue sample collections for G. Stern (DFO). Two FJMC monitors and their families participated in collecting beluga hunt data. In addition to mentoring the three students from Tuktoyaktuk, additional youth (as well as others on the island) participated opportunistically in our field program.

Samples analysed by the Fisheries and Oceans Canada (DFO) Laboratory of Expertise for Aquatic Chemical Analysis (LEACA, Sidney BC) for PCB and PBDE analysis. Lipid analysis and extractions for fatty acids were completed in Sidney and samples were sent to the FWI for fatty acid analysis. Liver and muscle samples were sent to the University of Winnipeg for stable isotopic analysis. Genomic extractions have been completed for blubber and QA/QC for new tissues is underway. Measurements of thyroid hormones, testosterone, cholesterol, vitamin A and E, and isoprostanes are currently underway at the DFO Marine mammal toxicology laboratory (IOS); data are not reported here but previous year data are presented in the 2009 Report. Finally, in vitro Hg toxicity tests were carried out on fresh beluga blood collected from the Aquarium.

Results

Morphometrics

While only 10 whales were sampled for complete health assessment, an additional 10 were taken by F. Pokiak as he remained on Hendrickson two additional weeks. The additional ten taken were analyzed for fatty acids and lipid classes. Of the whales harvested, all were male (mean length=408 cm; σ=44 cm) and there were no differences in length from previous years ($p=0.52$; $r=0.17$). Blubber thickness averaged 8 cm which did not differ from previous years ($p=0.71$; $r=0.1$).

Age data for whales from 2007 and 2008 were reanalyzed to validate the new laboratory, and ageing was completed for 2009 and 2010 samples.

Diet and Condition

Stable Isotopes

Given the small sample size in 2010, evaluating stable isotopic trends with length was constrained. Stable isotopes of carbon and nitrogen had trends with length that were not significant (Table 1). Trends with PCBs and PBDEs and stable isotopes were not significant, however a negative relation with δ13C was present ($r=0.6$; $p=0.08$). Significant trend was present with Hg concentrations in liver and δ15N ($r=0.7$; $p=0.03$).

Lipid classes

Current methods to measure lipid classes are somewhat qualitative and lack specificity needed to examine trends within one class of lipids (TLC-FID). In attempt to better quantify lipids we developed new methods to measure the carbon groups within triglycerides (TAG), a high energy story of lipid. These efforts are being directed as a means to examine condition and nutritional status in beluga whales. Quantifying the lipid classes is not only complementary to the fatty acid research and data, but it will yield important data on food web energetics and ecosystem health. Method development on a GC/MS and GC/FID was recently completed. Figure 1 shows a chromatogram of the groups of TAG measured in beluga blubber. The developed method on the GC/FID allowed for us to detect 14 different TAG groups and nearly 100 peaks. These groups being CN 28, CN 30, CN 32, CN 34, CN36, CN 38, CN 40, CN 42, CN 44, CN 46, CN 48, CN 50, CN 52 and CN 54. Along with the identified TAG groups, cholesterol was also detected.

The CN 40 group dominated the TAG lipid groups at just over 20% of the total. Differences among in inner, middle and outer blubber layers did not differ in profiles of TAG groups. However concentrations did vary by layer whereby the inner layer had lowest concentrations (final estimates being validated against standards). A PCA was used to summarize data into two variables (PC 1= 43%, PC 2=22%) and evaluate trends with biological data. Significant relations were found with the lipids and length of whales ($r=0.7$; $p=0.003$).

Table 1. Mean carbon and nitrogen stable isotopes (per mil) for beluga liver and muscle samples. Correlations determined for beluga length trends for carbon and nitrogen isotopic values in beluga liver and muscle.

	$\delta^{15}N$	Std Dev	Length Trend	$\delta^{13}C$	Std Dev	Length Trend
2007						
Liver	17.71	0.76	r=0.5; p=0.04	-20.2	0.57	r=-0.6; p=0.004
Muscle	16.54	0.63	r=0.1; p=0.6	-18.44	0.38	r=-0.4; p=0.2
2008						
Liver	16.85	1.2	r=0.05; p=0.8	-18.76	0.93	r=-0.5; p=0.02
Muscle	16.85	1.07	r=0.3; p=0.1	-18	0.9	r=0.3; p=0.1
2009						
Liver	16.08	2.3	r=0.001; p=0.5	-19.22	0.8	r=0.03; p=0.5
Muscle	13.39	1.5	r=- 0.24; p= 0.03	-18.25	1	r=-0.07; p=0.3
2010						
Liver	16.74	1.35	r=0.44; p=0.2	-20.23	0.46	r =- 0.32; p=0.38
Muscle	17.9	1	r=-0.29; p= 0.42	-18.73	1.1	r=-0.18; p=0.63

Fatty acid profiles

Fatty acid data was summarized for the beluga blubber using a principle component analysis (PCA) and 34 fatty acids associated with diet. Here a sample size of 20 was used (10 completed by the full health analyses team and 10 by F. Pokiak). The first and second factors explained 91% of the variation (82% PC 1; 9% PC2). As observed previously, PCA Factor 1 related to length ($r=0.57$; $p=0.0$). The relationship between PC1 was also significant with PCBs ($r=0.9$; $p<0.0001$) and PBDEs ($r= 0.72$; $p=0.002$). Significant relationships with Hg in muscle and skin were also observed ($r=0.8$; $p < 0.001$; $r=0.7$; $p=0.002$). No trend was observed with stable isotopes measured in liver and muscle, likely owing to small samples for stable isotopes ($n=10$). Further analyses an interpretation is needed to determine the extent to which these results reflect dietary, condition and/or other influences.

PCB and PBDE concentrations in beluga whales

Since only 10 samples were taken during our field study (our plan had been 20), we chose to measure PCBs and PBDEs in two tissues (liver and blubber) and compare results.

PCB concentrations in 2010 were 3171 ng/g lw ± 1374, and did not differ from concentrations measured in 2007, 2008 and 2009 ($p=0.88$; $r=0.1$). Concentrations in liver were significantly lower at 2426 ng/g lw ± 1164 than concentrations in blubber ($p<0.0001$). Concentrations in liver and blubber were positively correlated ($p<0.0001$; $r=0.97$) (Figure 2).

PBDE concentrations (sum of congeners including di- to hepta-brominated congeners) were 21.2 ng/g lw ± 2.9, which was not significantly lower than previous years ($r=0.34$; $p=0.08$). Liver and blubber concentrations were significantly related ($r=0.89$; $p=0.001$).

PCB and PBDE concentrations were significantly related ($r=0.88$; $p=0.001$).

Concentrations of PCBs did correlate with length ($r= 0.6$; $p<0.032$; Figure 3), whereas PBDEs did not ($r= 0.5$; $p=0.4$). Interestingly, Factor 1 from our PCA analysis of 34 fatty acids correlated with PCBs (Figure 4), and more exploration of this relationship will provide insight into whether this is due to feeding ecology, age, and./or contaminants.

Health endpoints: Genomics

Blubber, skin, liver, kidney and muscle samples from 54 beluga whales (24 from 2008, 20 from 2009 and 10 from 2010) at Hendrickson Island were preserved in 'RNA later' and stored at -20°C until total RNA isolation. Blubber samples were divided into inner, middle, and outer blubber in order to investigate any possible stratification of gene expression levels within the blubber layer.

Briefly, total RNA in those samples was isolated using the single-step RNA isolation method based on guanidine isothiocyanate/phenol/chloroform extraction with Trizol (Invitrogen Canada Inc., Toronto, Ontario, Canada) as a reagent. Total cDNA was produced using Superscript II RNase H- reverse transcriptase (Invitrogen Canada Inc). At present, RNA from all the 54 samples of blubber, skin, liver and muscle and 30 samples of kidney has been successfully extracted.

In order to assess the health of this beluga whale population, a total of 18 target genes have been developed and validated for beluga whales through QA/QC (in collaboration with Drs Caren Helbing and Nik Veldhoen at Uvic), including three housekeeping genes (ribosomal protein L8, Glyceraldehyde-3- phosphate dehydrogenase (GAPDH) and cytoplasmic B-actin). The performance of these primers in different tissue types is reported in Table 2.

The expression levels of those specific genes were investigated using quantitative real-time polymerase chain reaction (qRT-PCR) and relative quantification (based on the best housekeeping gene). Housekeeping genes are used to evaluate the quality of the data. Using the "crossing point method" (Pfaffl et al, 2004), L8 was found to be the most stable among the three housekeeping genes and was therefore chosen as a normalizer gene. L8 values were also used to identify outliers in the dataset.

We present here the liver and skin results for the 2008 males (Figure 5). Data from the 2009 and 2010 field sampling are currently undergoing QA/QC.

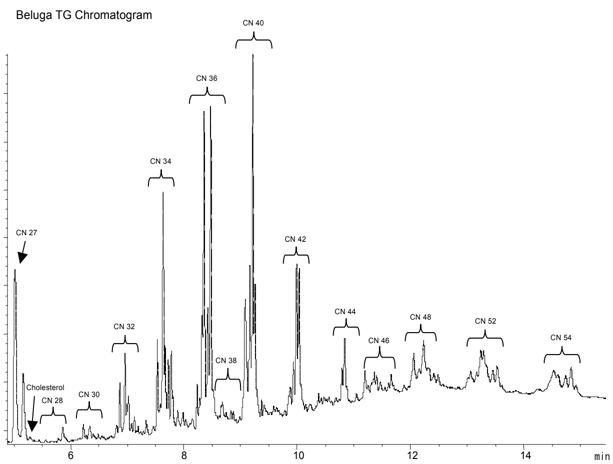

Figure 1. Chromatogram of TG groups identified within the lipids of beluga blubber analyzed on a GC/FID

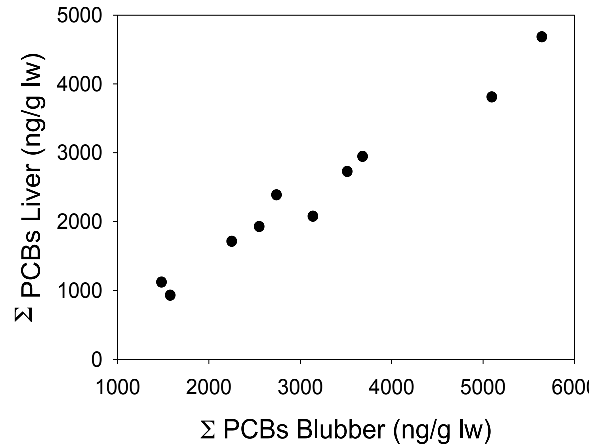

Figure 2: Total PCB concentrations in liver and blubber in 2010 belugas were significantly related ($p<0.0001$; $r=0.87$).

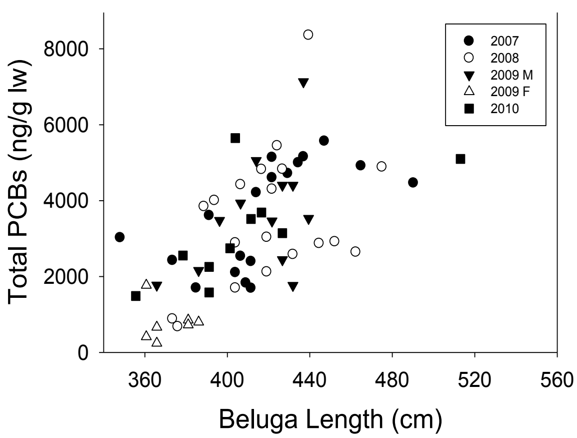

Figure 3: Total PCB concentrations correlated with total body length in 2010, similar to trends observed in 2007.

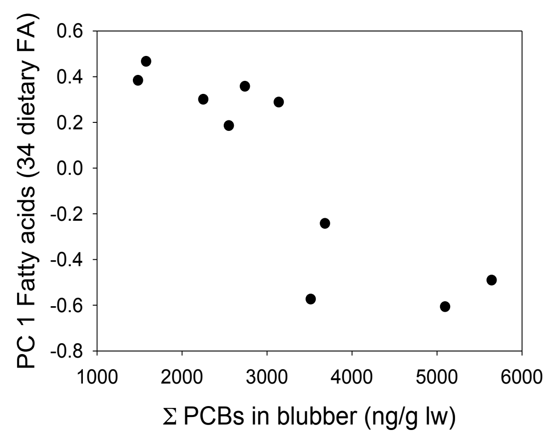

Figure 4: First principle component for fatty acids and the sum of PCB concentrations in blubber show a significant relationship similar to 2007 and 2009 data.

The expression of AhR and Cyp1A in the liver of the 2008 beluga males was not influenced by any biological variables such as age, length, or blubber thickness. Previous studies showed an increase with age of AhR expression in humans (Pitt et al., 2001) and in Baikal seals (Phoca sibirica) (Kim et al., 2005), either reflecting the higher ability of adults to metabolize contaminants or increased contaminant concentrations in older individuals. The expression of AhR and Cyp 1A increased significantly with PCB concentrations in beluga liver, which is consistent with the major role that liver plays in metabolism. Several studies have reported an increase in AhR and Cyp1A expression with exposure to dioxin-like contaminants (Pitt et al., 2001; Kim et al., 2005; Wilson et al., 2005). Jensen and Hahn (2001) also reported that the beluga AhR possesses a high affinity for dioxins, suggesting that this species might be particularly sensitive to dioxin-like compounds. This is in agreement with the present study; even though the Western Arctic belugas are exposed to relatively moderate PCB concentrations, an up regulation of AhR was still detected.

Metallothioneins are low molecular weight proteins that are able to bind to group II metals (i.e. $Hg2+$) and therefore provide protection against their toxicity. The expression of MT1 in the 2008 beluga males was not influenced by length or blubber thickness. However a significant decrease with age was observed ($r^2=0.16$; $p=0.033$; not shown) and will need to be taken into consideration when interpreting possible trends with contaminant concentrations. MT1 expression in liver was negatively correlated with PCBs ($r^2=0.45$; $p=0.009$) but no correlation was observed with mercury (results not shown). The absence of relationship with mercury suggests that metallothioneins may not be the main means of Hg detoxification process in liver which is consistent with previous observations that only 5 % of Hg was bound to metallothioneins in liver

Table 2: Beluga whale-specific primers and performance based on a three-tier evaluation of different tissue types.

Target			Blubber/ skin	Liver	Muscle	Kidney
L8	Ribosomal protein L8	Normalizer	**Pass**	**Pass**	**Pass**	**Pass**
GAPDH	Glyceraldehyde-3-phosphate dehydrogenase	Normalizer	**Pass**	**Pass**	Fail	Fail
B actin	Cytoplasmic Beta Actin	Normalizer	**Pass**	**Pass**	**Pass**	**Pass**
TRα	Thyroid receptor alpha	Endocrine disruption	**Pass**	Fail	**Pass**	**Pass***
TRβ	Thyroid receptor beta	Endocrine disruption	**Pass**	**Pass**	**Pass**	**Pass**
Erα	Estrogen Receptor alpha	Endocrine disruption	**Pass**	**Pass**	Fail	**Pass***
Vit D	Vitamin D receptor	Endocrine disruption	**Pass**	Fail	Fail	Fail
RAR	Retinoic acid receptor alpha	Endocrine disruption	Fail	Fail	Fail	Fail
AhR	Aryl hydrocarbon receptor	Organic contaminant exposure	**Pass**	**Pass**	**Pass***	**Pass**
CYP 1A	Cytochrome P450	Organic contaminant exposure	Fail	**Pass**	Fail	Fail
GR	Glucocorticoid receptor	Metal/oxidative/ general stress	**Pass**	Fail	Fail	Fail
MT1	Metallothionein 1	Metal/oxidative/ general stress	**Pass**	**Pass**	**Pass**	**Pass**
hsp70	Heat shock protein 70	Metal/oxidative/ general stress	**Pass**	Fail	Fail	**Pass**
PPARγ	Peroxisome proliferator-activated receptor gamma	Condition/metabolism	**Pass**	Fail	Fail	Fail
Adiponectin	Adiponectin	Condition/metabolism	**Pass**	Fail	Fail	Fail
Leptin	Leptin	Condition/metabolism	**Pass**	Fail	Fail	Fail
ILGF I	Insulin-like growth factor 1	Condition/metabolism	**Pass**	Fail	Fail	Fail
RXR	Retinoid X receptor alpha	Condition/metabolism	**Pass**	**Pass**	Fail	**Pass**

* Pass but must be used with caution

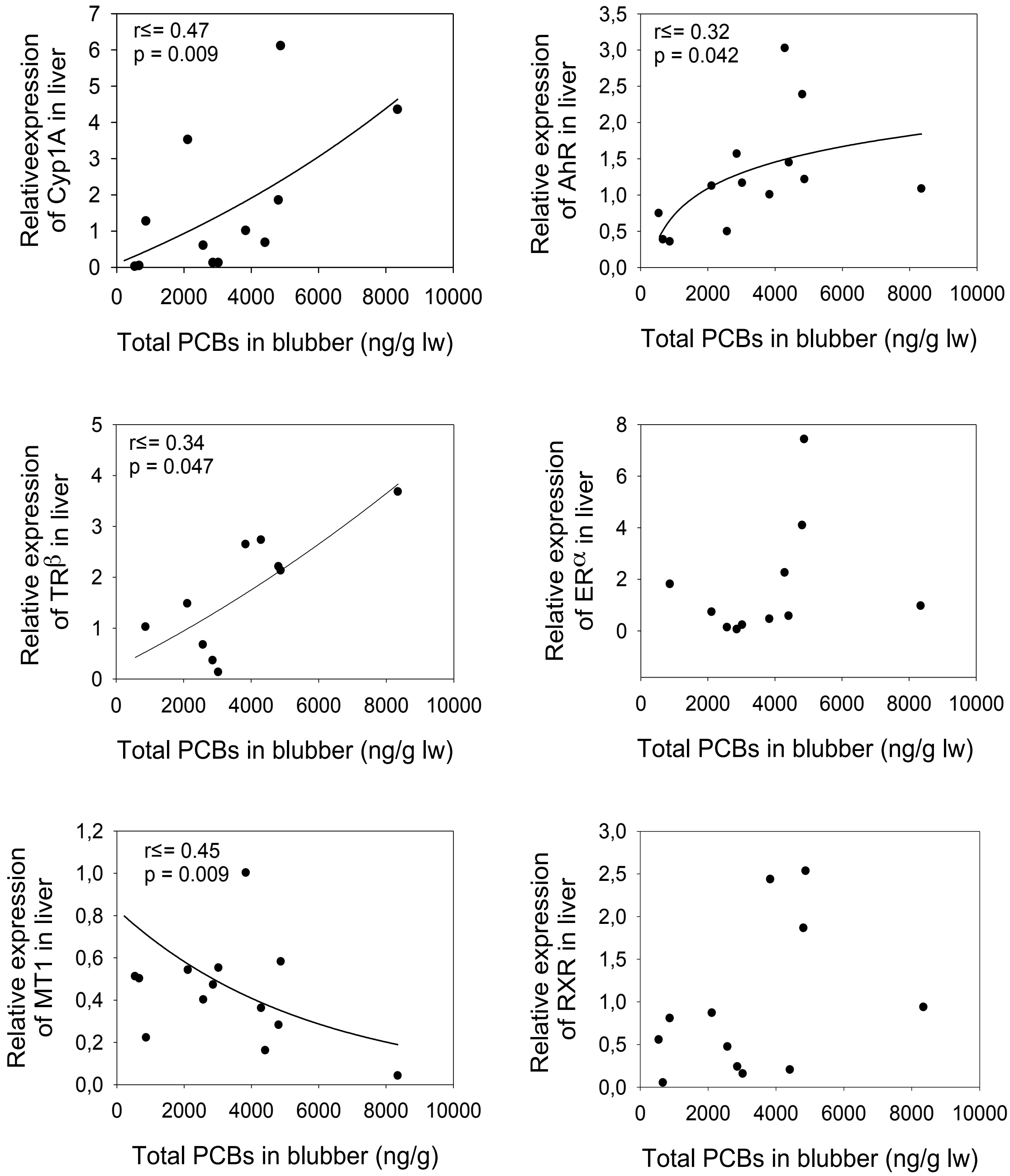

Figure 5: The expression of Cyp1A, AhR, and TRβ in liver increased with increasing PCB concentrations in beluga whales (males from 2008 presented here as final analyses are underway), while MT-1 decreased (left).

(Wagemann et al., 1986). As MT1 appeared to be negatively correlated with age, this might have influenced the present results with PCBs.

The expression of TRβ in the liver of the 2008 males was not influenced by age, length, or blubber thickness. A positive relationship was observed between TRβ expression and both PCBs and Hg (r^2=0.34, p=0.047; r^2=0.63, p=0.003, respectively). Similarly, Tabuchi et al., (2006) found a significant positive relationship between the TRα isoform and PCB concentrations in harbour seal blubber. The increase of TRβ expres-

Table 3: Correlations between endocrine endpoints and PCB concentrations in beluga whales. Further work is needed to illuminate the possible influence of feeding ecology on these results. The 2007 whales were not sampled for blood thus no data are available for thyroids. The 2009 data is presented first with males and females combined, as well as separate sexes.

	2007		2008		2009 (m=males, f=females)					
	R	p	r	p	r	p	r (m)	p (m)	r (f)	p (f)
FT3	N/A	N/A	0.003	0.99	-0.094	0.73	-0.53	0.141	0.06	0.9
FT4	N/A	N/A	0.26	0.39	0.06	0.83	-0.52	0.15	0.45	0.31
TT3	N/A	N/A	-0.37	0.25	0.06	0.82	-0.18	0.65	-0.23	0.62
TT4	N/A	N/A	<u>-0.56</u>	<u>0.05</u>	-0.14	0.6	-0.46	0.21	0.06	0.9
Ratio FT3: TT3	N/A	N/A	<u>0.82</u>	<u>0.001</u>	0.12	0.65	0.05	0.9	0.29	0.53
Ratio FT4: TT4	N/A	N/A	0.23	0.45	0.27	0.31	-0.01	0.97	0.49	0.26
Vitamin A (Blubber)	0.7	<u>0.001</u>	0.44	0.06	-0.026	0.925	0.57	0.1	0.13	0.78

sion reported in the belugas might indicate an increased risk in thyroid hormone – dependent health effects such as developmental abnormalities, neurotoxicity and impairment of key metabolic pathways.

These preliminary results show that, even though the Western Arctic beluga whale population is exposed to moderate PCB (and Hg) concentrations, we were still able to detect up-regulations of important toxicology- and stress-related genes as well as a gene coding for a key receptor involved in the thyroid hormone system. This indicates that individual whales are exposed to levels of contaminants that elicit physiological responses. The extent to which these responses may affect this population is unclear; however, our preliminary results do indicate that these whales might be at risk for adverse health effects due to chemical exposure.

Health endpoints: hormones

Measurements of circulating hormones are currently underway, and we present here the relationships between the dominant PCBs and thyroid hormones (Free- and Total- T3 and T4; ratios) and vitamin A (Table 3). There was no consistent pattern observed, but there was an association between PCBs and thyroid hormone (TT4) in 2008, the ratio of FT3: TT3 in 2008, and blubber vitamin A in 2007. The evaluation of incoming 2010 data, and a critical examination of possible confounding factors is needed to fully interpret these initial results.

Health endpoints: Mercury is toxic to white blood cells in captive beluga

While increasing anthropogenic emissions of mercury (Hg) have raised concerns about toxicity at the top of aquatic food webs, selenium (Se) is thought to confer a degree of protection to marine mammals. Objectives of this study were 1) to evaluate the effects of inorganic mercury (mercuric chloride, HgCl2) and organic mercury (methylmercuric chloride, MeHgCl) (0 to 10 μM) on the function of lymphocytes isolated from beluga whales under in vitro conditions;
2) to evaluate the protective effects of sodium selenite (Na2SeO3) on cell proliferation of HgCl2 or MeHgCl-treated beluga lymphocytes; and 3) to compare Hg and Se blood concentrations measured in Arctic beluga whales to these laboratory-derived toxicity levels.

Cell viability, T-lymphocyte proliferation, intracellular thiol levels and metallothionein induction were evaluated. A significant reduction in the lymphoproliferative response was registered

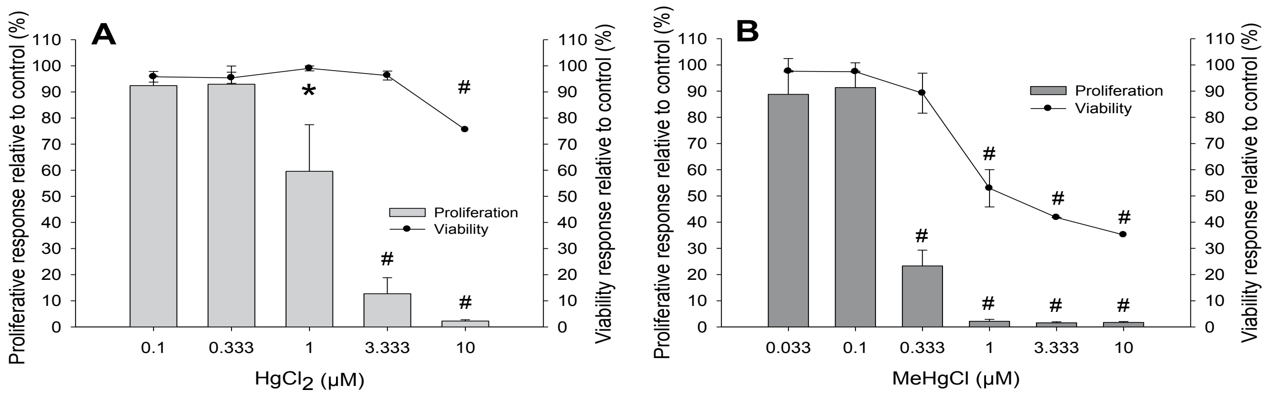

Figure 6. The proliferation of T lymphocytes (bars) and their viability (lines) following different exposures to inorganic mercury (A) and organic mercury (B). Results are expressed as a (%) of the control response (unexposed cells). (n=3 for inorganic mercury and n=4 for organic mercury per dose group; mean ± standard error). * $p \leq 0.05$, # $p \leq 0.01$. Viability was significantly decreased after a 48 hour exposure to 10 μM HgCl2 or 1 μM MeHgCl. T-lymphocyte proliferation was inhibited following a 48 hour exposure to 1 μM of HgCl2 and 0.33 μM of MeHgCl.

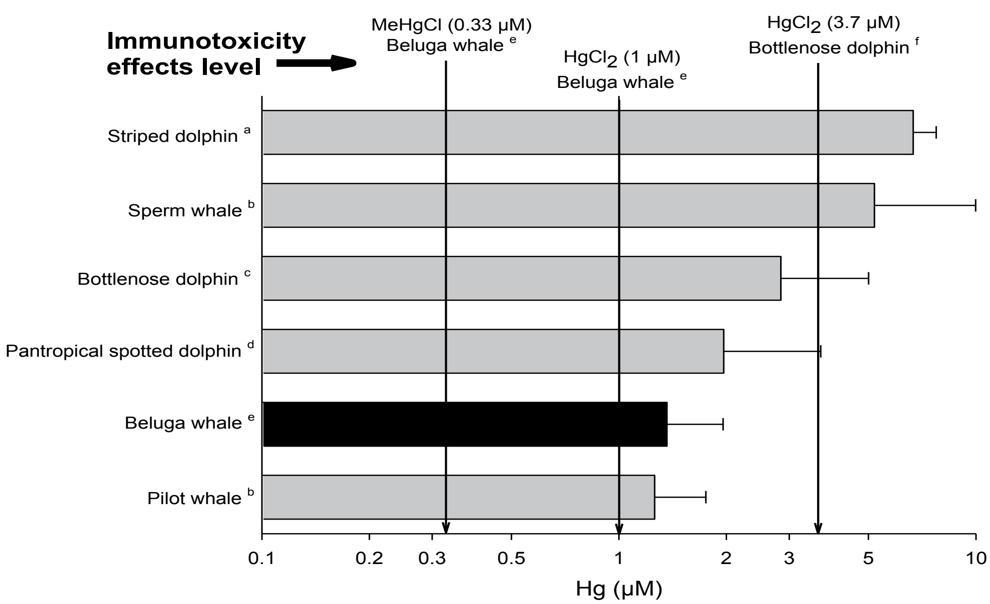

Figure 7: Mercury (Hg) concentrations (mean ± SD) reported in the blood of cetaceans compared to our lowest effects concentrations for MeHgCl or HgCl2, as assessed by a decreased proliferative response of T-lymphocytes. Hg data were cited from a: Itano et al. (1984); b: Nielsen et al. (2000); c: Woshner et al. (2008); d: André et al. (1990); e: this study and f: Camara Pellisso et al. (2008).

following exposure to 1 μM of HgCl2 and 0.33 μM of MeHgCl (Figure 6). Decreased intracellular thiol levels were also observed at 10 μM of HgCl2 and 0.33 μM of MeHgCl. Metallothionein induction was noted with the highest concentration of HgCl2 (10 μM) and with 0.33 μM of MeHgCl. Concurrent exposure of Na2SeO3 with highest concentrations of HgCl2 (3.33 and 10 μM) or highest concentration of MeHgCl (10 μM) and under conditions of Hg:Se ratios between 1:2 and 1:4 provided a relative protection against the decrease in T-lymphocyte proliferation induced by Hg. Mercury in beluga whale blood examined is almost exclusively MeHg. Although, no correlation was found between Hg and Se concentrations in beluga whale blood, the observed in vitro protection of Se against Hg toxicity may contribute to the in vivo protection in toothed cetaceans exposed to high Hg concentrations.

In general, concentrations of Hg in whole blood measured in harvested beluga whales were lower than those reported in other cetacean species from other locations (Figure 7). Despite this observation, the average concentration measured in free-ranging beluga exceeded our new immune function effects levels for both methyl (MeHgCl) and inorganic mercury (HgCl2). These in vitro-based findings suggest that, despite a protective effect associated with selenium, any increase in the concentration of Hg in Arctic beluga could reduce their defences against pathogens and lead to risk of increased morbidity or mortality. Additional work on free-ranging beluga would be of value to address the nature of this risk.

Expected Project Completion Date

Phase 1: Pilot study 2007–08: Field sampling and initial methods development.

Phase 2: Research effort 2008–09: Conduct 2nd year of sampling; continue methods development; conduct initial round of analyses. Partner with IPY and ArcticNET.

Phase 3: Research effort 2009–10: Complete development and validation of methods; conduct a 3rd year of sampling; conduct health measurements on existing samples.

Phase 4: Research effort 2010–11: Conduct health measurements on 2010 samples; confer with communities; write scientific manuscripts.

Phase 5: Completion year 2011–12: Complete all health measurements; write and submit scientific manuscripts; design outreach materials; present key findings to community members.

NCP Performance Indicators

Publications:

Loseto L. L., Ross, P.S. 2011. A legacy of risk: Organic contaminants in marine mammals. Concepts in Exposure, Toxicology and Management. 343–369. In: Environmental Contaminants in Biota: Interpreting tissue concentions. Beyer, N., Meador, J. (ed). Taylor and Francis Group, Oxford.

Presentations:

Noel M., Loseto L., Dangerfield N., Helbing C., Veldhoen N., Stern G., Ross P.S. Investigating the impacts of contaminants on the health of the western arctic beluga whale population: a genomics approach. Oral presentation, 2010 SETAC meeting.

Noel M., Loseto L., Helbing C., Veldhoen N., Stern G., Ross P.S. Are PCBs and mercury affecting the health of the Western Arctic beluga whales? Evidence at the molecular level. Poster presentation. 2010 NCP meeting.

Noel M., Loseto L., Buckman A., Helbing C., Veldhoen N., Stern G., Ross P.S. The effects of contaminants on the health of the Western Arctic beluga whales: a genomics approach. Oral presentation. 2009 Marine Mammal conference.

Pokiak, R., Pokiak, M., Loring, E., Nickels, S., Andrachuk, M., Loseto, L. Traditional Knowledge on Beluga Health in the Inuvialuit Settlement Region. ArcticNet ASM, Dec 13–17 2010, Ottawa ON, Oral presentation.

Loseto, L.L., Pokiak, N. 2009 Perspectives and Values: Lessons learned from a collaborative beluga research program in Tuktoyaktuk NT. Assistant Deputy Minister Lecture Series, Nov 27 2009, Ottawa ON Oral presentation.

Loseto, L.L., Hickie, B., Macdonald, R.W., Ross, P.S. Feeding ecology and contaminant exposure: What risks does a receding ice edge bring to the Beaufort Sea beluga whales? Biannual Marine Mammal Conference. Oct 12–16 2009, Quebec, Qc Canada; oral presentation.

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Community Presentations:
Pokiak, F., Loseto, L. and team members. Beluga Health Project: team update. Inuvialuit Final Agreement Research Day, March 04 2011

Loseto, L.L., Pokiak, F. Hendrickson Island Beluga Study: an example of a CBM program. All Inuvialuit Settlement Region communities, Feb 21–25, 2011.

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Brochures (Partnership with Beluga Health TEK project):

1) 2009 brochure: Beluga whales and Hendrickson Island.
2) 2010 brochure: Sharing knowledge on belugas and beluga health.

Field camps and students
2008 camp: science crew: Lisa Loseto, Sonja Ostertag, Marie Noel, Stephen Raverty

students: Kayla Felix and Ryan Walker from Tuktoyaktuk (help with camp duties and beluga sampling).

2009 camp: science crew: Lisa Loseto, Marie Noel, Stephen Raverty.

students: Jocelyn Noksana and Ryan Walker from Tuktoyaktuk (help with camp duties and beluga sampling).

2010 camp: science people: Lisa Loseto, Sonja Ostertag, Marie Noel, Stephen Raverty

students: Brandon Voudrach and Ryan Walker from Tuktoyaktuk; Kate Snow from Inuvik (help with camp duties and beluga sampling).

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Mercury Measurement at Alert and Little Fox Lake

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Abstract

Mercury (Hg) is a global priority pollutant and continues to be of concern in Arctic regions. The longest Arctic record of atmospheric mercury concentrations have been collected in the Canadian high Arctic at Alert, Nunavut. This time series shows distinct repeatable seasonal and annual patterns in the gaseous elemental mercury (GEM). Trend analysis of this data set reveals a decreasing trend in GEM of −0.71% per year for the period 1995 to 2009. A comparison of trends between Alert and other North American long term GEM measurements reveals that the decreases observed at Alert are much lower than those at other locations. Collection of atmospheric mercury species including Reactive Gaseous Mercury (RGM) and Particle Associated Mercury (PHg) continued in order to understand the processes of atmospheric mercury conversion and deposition in the springtime to the Arctic. GEM measurements continued to be collected in the Yukon at Little Fox Lake and the progress on those measurements will be reported. New results show that this site is impacted by regional forest fires which make attribution of long range transport events of GEM more challenging than expected.

Résumé

Le mercure (Hg) est un polluant prioritaire dans le monde entier et il continue d'inquiéter dans les régions de l'Arctique. Le registre arctique le plus ancien des concentrations de mercure dans l'atmosphère est celui tenu à Alert (Nunavut), dans l'Extrême-Arctique canadien. Cette série chronologique révèle l'existence de régimes saisonniers et annuels répétables distincts concernant le mercure élémentaire gazeux (MEG). L'analyse des tendances de cet ensemble de données révèle une tendance à la baisse du MEG de -0,71 % par an pendant la période de 1995 à 2009. Une comparaison des tendances entre Alert et d'autres mesures du MEG à long terme en Amérique du Nord révèle que les baisses observées à Alert sont beaucoup plus faibles que celles des autres sites. On a continué de recueillir des spécimens de mercure atmosphérique, notamment de mercure gazeux réactif et de mercure associé à des particules, afin de comprendre les processus de conversion et de dépôt atmosphériques du mercure au printemps dans l'Arctique. On a continué de mesurer les concentrations de MEG au lac Little Fox (Yukon) et les résultats seront publiés. De nouveaux résultats indiquent que ce site subit les effets des feux de forêt régionaux qui rendent l'attribution d'événements de transport de MEG à grande distance plus difficile que prévue.

Key Messages

- Sixteen years of atmospheric mercury measurements have been made at Alert, Nunavut. This data has been, and will continue to be, used to establish trends of atmospheric mercury in the Canadian high Arctic
- Four years of atmospheric mercury measurements have been collected at Little Fox Lake, Yukon to establish baseline levels, assess long range transport events from the Pacific Rim and the impact of regional forest fires to this area.

Messages clés

- On mesure les concentrations de mercure dans l'atmosphère depuis 16 ans à Alert (Nunavut). Ces données ont été utilisées, et continueront de l'être, pour établir les tendances du mercure atmosphérique dans l'Extrême-Arctique canadien.
- On recueille les mesures des concentrations atmosphériques de mercure depuis quatre ans au lac Little Fox (Yukon) afin d'établir les niveaux de référence, d'évaluer les événements du transport à grande distance depuis le littoral du Pacifique, et de déterminer l'impact des feux de forêt régionaux sur le secteur.

Objectives

The objectives of this project are to establish long term baseline concentrations of mercury in the Arctic atmosphere and to study the behaviour of mercury in the Canadian high Arctic. By collecting this information on concentrations of atmospheric mercury, temporal variability, transport events and trends can be established. This information will be crucial in the development of Canadian strategies for national and international pollution control objectives. For instance, this data will be part of Canada's strategy on the current UNEP global negotiations on a legally binding agreement for mercury. Currently, Alert is being considered to be 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 the chemical and physical aspects of atmospheric mercury depletion events (AMDEs) 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 have begun in the Yukon to measure the transport of mercury to this area.

Introduction

Mercury (Hg) continues to be a priority pollutant of concern in Arctic regions. This project, within the NCP, provides long term data on the temporal trends and contributes to understanding the spatial variability of mercury in the High Arctic air as well as how the behaviour of Hg may impact the pristine Arctic. Changes in the global atmospheric pool of Hg over time and the resulting concentration changes in particular regions are poorly defined. Thus, areas like the Arctic are a good place to assess such trends. Further, with global climate change expected to occur at a rapid pace in Arctic regions, the atmospheric dynamics and the impacts of pollutants such as Hg to this environment have to be well understood. Pollution of Hg in the Arctic has mainly occurred after industrialisation (Steffen, Douglas et al. 2008). While European and North American emissions of gaseous elemental mercury (GEM) have decreased since 1995, emissions in other regions such as Asia and Africa have increased (Pacyna, Pacyna et al. 2006). Circulation patterns show that air masses originating in Asia can enter the Canadian Arctic (Dastoor and Larocque 2004; Durnford, Dastoor et al. 2010) and thus the increase in Asian emissions is 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, Dastoor et al. 2010).

Annual time series of GEM have been produced and show repetitive distinct seasonal cycling of this pollutant. Through analysis of this annual cycling, it was discovered that a substantial amount of reactive mercury is present in the air and on particles during the spring time when levels of GEM in the air are very low (Schroeder, Anlauf et al. 1998; Steffen, Schroeder et al. 2003). This shift in mercury species in the air is called an atmospheric mercury depletion event (AMDE). A portion of these reactive mercury species remain in the air while a large amount is deposited onto the snow and ice surfaces (Ariya, Dastoor et al. 2004). It is possible that this conversion of mercury (and subsequent deposition) after polar sunrise may provide a pathway by which these more reactive and potentially bio-available mercury species are introduced into the Arctic environment (Lu, Schroeder et al. 2001). These data (Canadian and other) will provide important information on the atmospheric transport, transformation and deposition processes of this priority pollutant throughout the Polar Regions.

The International Polar Year (IPY) activities that have been coupled with this NCP program are now complete and the analysis of collected data is underway. Three Canadian IPY funded programs (Steffen 2009) that were undertaken to understand the transport, transformation and deposition of mercury in the Arctic will be linked with this ongoing NCP mercury research to provide a better understanding of mercury in the arctic air.

Activities in 2010–2011

Research activities

Ground-based continuous atmospheric measurements of GEM, Reactive Gaseous Mercury (RGM) and Particulate Mercury (PHg) continued at Alert. RGM and PHg concentrations were collected and the data has been quality assured. The GEM data from Alert and Little Fox Lake for 2010 have been collected and initial quality control processing has been completed. Ancillary data has been collected at Little Fox Lake for one year now and includes carbon monoxide, ozone and black carbon measurements. A robust statistical analysis of long-term trends in GEM at Alert, Kuujjuaparik, Quebec, and St Anicet, Quebec (Arctic, sub-Arctic and temperate locations, respectively), were conducted to compare trends at different latitudes. Snow samples continued to be collected on weekly samples (ground) and on a per event basis (table). The samples have yet to be analysed and will be in this FY.

Capacity Building

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

We are working with the Yukon College in Whitehorse to have the data from Little Fox Lake downloaded and kept on their server so they can access the data on site. This would allow students at the college remote access to the data and raise interest in scientific research and local environmental issues. We are working with Pat Roach to distribute information to local science students for site visits to Little Fox Lake so that they can understand how atmospheric chemistry measurements are made.

Communications

The Alert outreach brochure has been finished and has been disseminated to partners and stakeholders.

Traditional Knowledge

At this time, TK is only indirectly related to this NCP project through an IPY research project in Barrow, Alaska as discussed in the Synopsis of Research 2009–2010.

Results

Figure 1 shows the GEM measurements at Alert from 1995 to 2010 and the RGM and PHg concentrations from 2002 to 2010. Figure 2 compares monthly trends from 2000 to 2009 for the high and sub arctic (Alert and Kuujjuarapik) and temperate (St. Anicet, Quebec) locations. The trends are shown as change in concentration per year and if the change is above zero it indicates

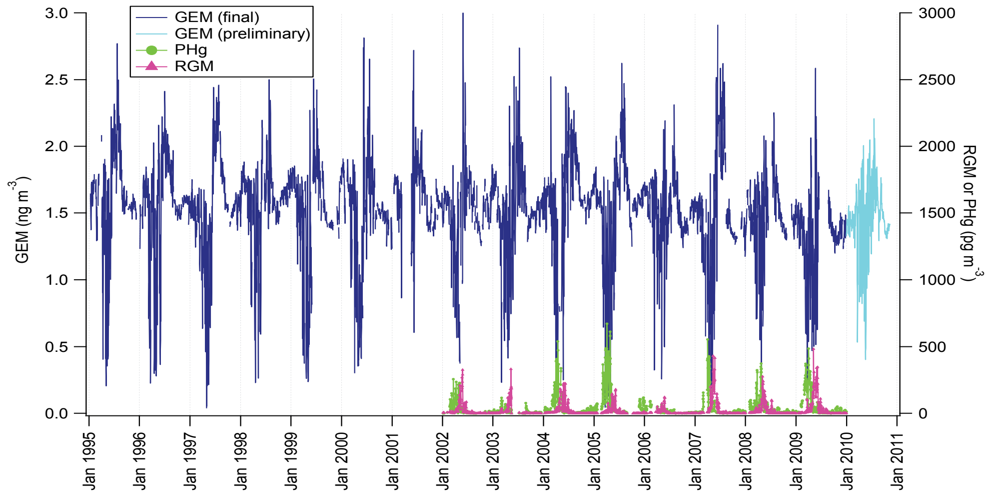

Figure 1: Daily average concentrations of gaseous elemental mercury (GEM), particulate-bound mercury (PHg), and reactive gaseous mercury (RGM) at Alert, NU.

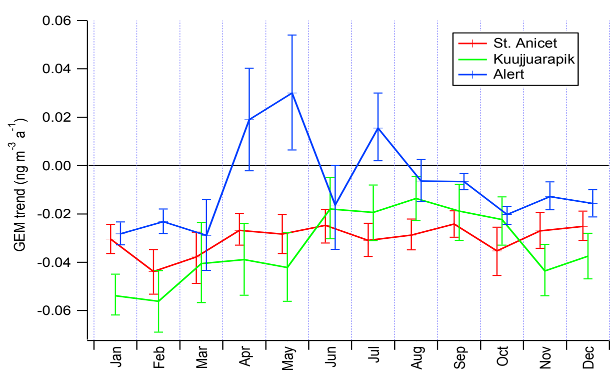

Figure 2: Rate of change of GEM concentrations over the period 2000–2009 at three Canadian sites with data separated by month. Error bars represent 95% confidence limits.

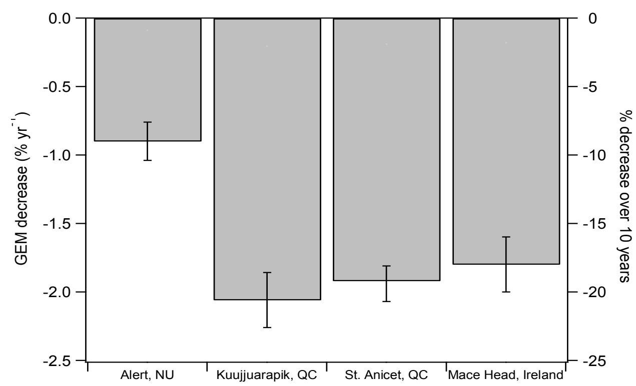

Figure 3: Overall rate of change of GEM concentrations over the period 2000–2009 at three Canadian sites and for 1996–2009 at Mace Head, Ireland (Ebinghaus et al., 2011). Error bars represent 95% confidence limits (CL) for Canadian sites and 99.9% CL at Mace Head.

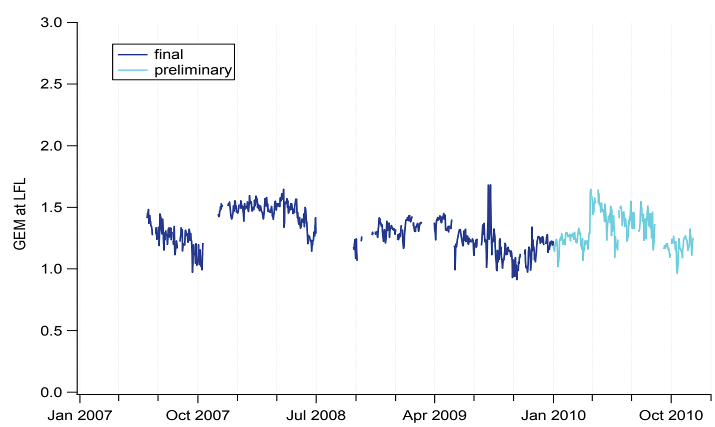

Figure 4: Daily average concentrations of gaseous elemental mercury (GEM) at Little Fox Lake, YT. Data from 2010 has been through preliminary QC but not finalized.

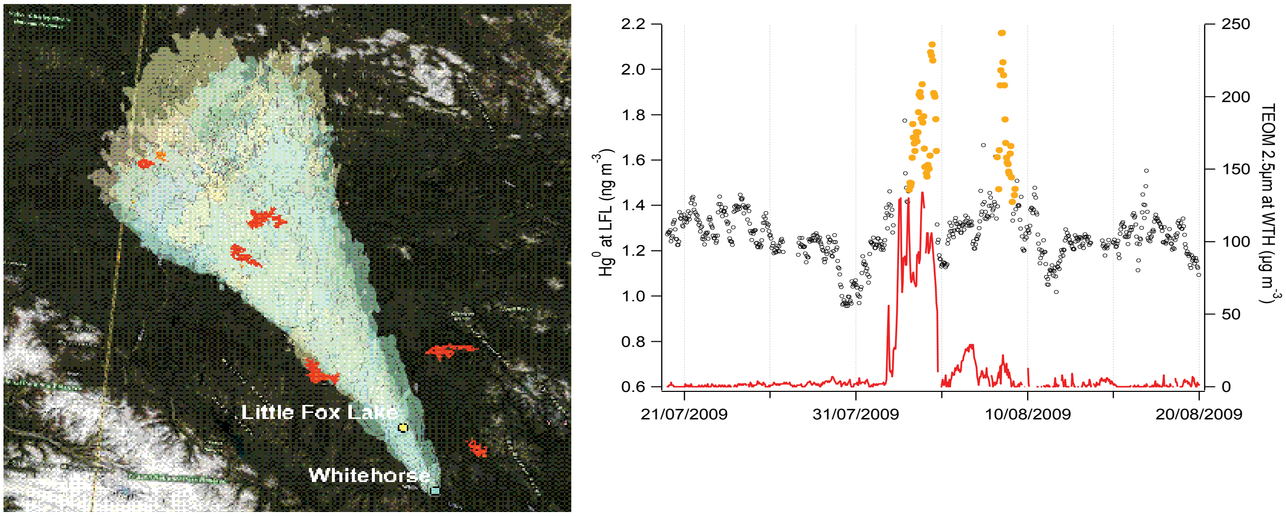

Figure 5: Graph showing high mercury levels at LFL (orange) and high particulate matter at Whitehorse (red, courtesy of National Atmospheric Pollution Service and Yukon Environment) in August 2009. Map shows that during these two days, air was coming from active forest fire areas (red patches on map) to both sites.

and increasing trend for that month and if it is below zero it indicates a decreasing trend for that month. Figure 3 shows a comparison of the overall decrease per year for the same three sites as well as published trends from Mace Head, Ireland (a temperate site) from 1996 to 2009 (Ebinghaus, Jennings et al. 2011). These 4 sites have some of the longest records of GEM in the world.

GEM measurements at Little Fox Lake from 2007 to 2010 are shown in Figure 4. Figure 5 shows the origin of air at both Little Fox Lake and Whitehorse during a period of high mercury measurements at LFL and high particulate matter at Whitehorse in August 2009.

Discussion and Conclusions

Sixteen years of GEM concentration data from Alert have now been collected. This is an impressive record of long term atmospheric mercury in the Arctic. Previous analyses of the data had shown no trends in the annual data set (Steffen et al., 2003; Temme et al., 2007). However, this data exhibits such seasonal fluctuations that a more robust investigation of the data was undertaken. From this analysis a small, yet statistically significant, trend was found showing a decrease in GEM concentrations from 1995 to 2007 at a rate of -0.0086 ng m^{-3} yr^{-1} (Cole and Steffen 2010). Extending this analysis to the end of 2009 revealed a slightly faster overall decrease of -0.011 ng m^{-3} yr^{-1}, or -0.71% yr^{-1}. Recently, the same method of trend analysis was performed on two other long term data sets in Canada for comparison, using the period 2000 to 2009 (the longest period for which data from all sites was available). The results, broken down into trends in each month, are shown in Figure 2. Both St Anicet and Kuujjuarapik demonstrate significant decreasing trends for each month. Alert shows significant increasing trends for the months of May and July over this 10–year period, though only May shows an increase over the entire measurement period (1995–2009). April and May reflect the springtime depletion active period at both Alert and Kuujjuarapik. It is interesting, then, that while both Kuujjuarapik and Alert experience similar chemistry in the springtime, there appears to be differing trends in the concentration of GEM over time at these locations. In comparison to the two sites that experience AMDE chemistry, St. Anicet has little seasonal variability and trends in various months generally agree within the 95% confidence limits.

Figure 3 shows the overall long term trends in the entire data sets, as percent decrease per year, for the three Canadian sites (Arctic, sub-Arctic, and temperate) and the trend using the same analysis method for GEM in background air masses observed at the temperate coastal site of Mace Head, Ireland, for the period 1996–2009 (Ebinghaus, Jennings et al. 2011). It is clear that the decrease at Alert is significantly slower (less than 1% per year) than at the three lower-latitude sites (1.8–2.1% per year). These changes represent significant decreases in atmospheric mercury over the last decade of 9% at Alert and 20% elsewhere. Trends at the 3 lower latitude sites are in good agreement with each other and with the trend reported in the southern hemisphere (Slemr, Brunke et al. 2011) and likely represent a change in the global or hemispheric background concentration of GEM. It should be noted that estimates of anthropogenic emissions up to 2005 (Streets, Zhang et al. 2009; Pacyna, Pacyna et al. 2010) are unlikely to account for a change of this magnitude (though these estimates do not cover the entire measurement period) and it has been suggested that changes in how mercury is retained or emitted in soils and oceans may play a crucial role in determining air concentration trends (Slemr, Brunke et al. 2011). It is notable that Alert has not seen a decrease of the same magnitude. This significant difference is likely a result of the springtime chemistry occurring at this location or over the Arctic Ocean, based on the fact that site differences between the trends are most pronounced in the spring (Figure 2). However, it is also possible that this site may be impacted to a greater extent by transport events from areas that are known to have less significant decreasing emissions (i.e. Asia and Russia), since the decreasing trend at Alert is slower compared to Kuujjuarapik and St. Anicet in all months of the year. Information collected by this research team during the OASIS-Canada IPY study suggests that the Arctic Ocean retains more deposited mercury in the springtime and can potentially impact the trends observed at this near ocean site. Further work into the impact of the ocean processes in relation to the atmospheric cycling is warranted to understand why the Alert mercury trend is significantly different than at other sub-arctic and temperate locations.

Measurements at Little Fox Lake were initiated in 2006 to monitor the concentration levels of atmospheric Hg at an Arctic background inland location in the Yukon. The data, shown in Figure 2, indicate that the atmospheric mercury concentration levels fall within what is expected for a remote location and the data also shows minimal seasonal variability including no distinct springtime chemistry. Data to the end of 2009 has been analyzed to identify high mercury episodes of more than 6 hours. Dispersion modeling and ensemble trajectories (HYSPLIT) (Draxler and Rolph 2003) were performed around these episodes to identify the source regions of air arriving at the measurement site at these times. The highest mercury episodes, one of which is shown in Figure 5, were found to be due to forest fires in the region, consistent with high levels of particulate matter in Whitehorse, 80 km downwind. Several smaller episodes were not explained by local sources, but have not yet been attributed to particular long-range sources. Additional continuous monitoring of carbon monoxide, ozone and black carbon at the site in March 2010 will provide more information to help identify pollution sources, once these data are available. As well, these data will provide the opportunity to capture emission signatures such as Hg/CO ratios from boreal forest burning in the region and thereby better estimate emissions from these fires for global mercury budgets.

Data collected under the atmospheric mercury research program is being used to study trends, sources, and processes of mercury in Arctic air. Analysis of these data not only provides invaluable insight into the long term trends and processes occurring at different sites in the arctic, but can also identify areas in which further processes research is warranted. For example, further study of processes occurring over the Arctic Ocean is needed to understand the impact of Hg deposition around this unique area.

NCP Performance Indicators

Number of northerners engaged: 0

Number of meetings/workshops held in the North: 0

Number of students involved in project: 1
(plus rotating students at Alert)

Number of citable publications: 1

Expected Project Completion Date

Ongoing.

Acknowledgements

The project team would like to thank the Global Atmospheric Watch program at Alert for supplying facilities, assistance and personnel. We would like to thank Byron Felske and Joshua Benmergui for collecting the 2009/2010 GEM data at Alert. Much appreciation to Greg Skelton for the ongoing work on compiling this large data set! Thanks to Martin Pilote for the St Anicet and Kuujjuarapik data, and to Yukon Environment and the National Atmospheric Pollution Service for PM2.5 data from Whitehorse Thanks to NCP and Environment Canada for financial support of this program.

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Mercury in Beluga, Narwhal and Walrus from the Canadian Arctic: Status in 2011

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Abstract

Additional analyses of mercury and selenium in organs of beluga were completed and added to a growing database on concentrations of these elements in arctic marine mammals, mainly beluga, narwhal and walrus. The data on these animals offer opportunities to test for differences among organs within individual animals at specific times and locations, among regions for particular organs and species and among years at locations where collections have been made repetitively. Tests for changes that relate to time or location or other variables become increasingly rigorous as future collections supply additional data. Mercury content varies among organs within an animal and among animals from a given site and time of collection. Of the organs analyzed in this study, liver typically has the highest concentrations of mercury, followed by kidney, muscle and muktuk. Mercury levels in any of the organs analyzed varied considerably from animal to animal with standard deviations often half or more of the mean value, making it very difficult to detect any differences among samples. Estimation of

Résumé

Des analyses additionnelles du mercure et du sélénium présents dans les organes des bélugas ont été effectuées et les résultats ont été ajoutés à la base de données toujours croissante des concentrations de ces éléments dans les mammifères arctiques, principalement les bélugas, les narvals et les morses. Les données sur ces animaux nous donnent l'occasion de tester les différences entre les organes des différents animaux à des moments et endroits précis, entre les régions en ce qui concerne des espèces et des organes précis et entre les années dans des endroits où des échantillons ont été prélevés de façon répétitive. La rigueur des tests portant sur les changements liés au moment, à l'emplacement ou à d'autres variables augmente au fur et à mesure que l'on obtient des données découlant de la prise de nouveaux échantillons. Le contenu en mercure varie selon les organes d'un même animal et selon les animaux situés au même emplacement et visés par une même collecte. Parmi les organes analysés dans le cadre de cette étude, c'est dans le foie qu'on trouve généralement les plus hautes concentrations de mercure, suivi des reins, muscles et muktuk. Les niveaux

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

de mercure dans les organes analysés varient considérablement d'un animal à l'autre, et les écarts types se chiffrent en général à la moitié ou plus de la valeur moyenne, ce qui complique la détection de différences entre les échantillons. Le fait que le mercure s'accumule avec l'âge et que les animaux plus âgés affichent habituellement des niveaux plus élevés que les jeunes complique l'évaluation des changements dans le temps. Le rôle de l'âge est d'autant plus complexe à évaluer chez les bélugas depuis que l'on a découvert qu'un groupe de couches de dents se forme chaque année, et non pas deux, comme on le pensait précédemment (Stewart et al, 2006). Les âges rapportés avant l'avènement de cette recherche ont été doublés et les données récentes sur l'âge tiennent compte de cette estimation d'une couche par année. Puisqu'il faut ajuster la base des comparaisons de niveaux de mercure entre différents groupes de bélugas en fonction des âges différents, les données sur ceux-ci sont cruciales. En règle générale, les analyses chimiques sont effectuées avant la détermination de l'âge; par conséquent, il y a un délai dans les interprétations. Le mercure et le sélénium présents dans le foie sont liés statistiquement, et nous présumons que ce phénomène découle de la formation de HgSe dans les tissus biologiques, qui vise possiblement à détoxifier le mercure.

Key Messages

- New data in 2010 were from beluga only; no new samples of walrus or narwhal were obtained. Beluga were obtained from Hendrickson Island (n=20) and ages were obtained for most beluga from that location taken from 2008 to 2010. Three new beluga were obtained from Pangnirtung but ages of those are not available. Eleven beluga were added from Sanikiluaq and fifteen from Arviat; none of those have been aged yet.
- The average level of mercury in liver of beluga from Hendrickson Island in 2010 was 16.3 $\mu g \cdot g^{-1}$ (wet weight), the second lowest average we have on record for whales from the Mackenzie Delta. The lowest average on file was 10.7 $\mu g \cdot g^{-1}$ from a collection of relatively young whales in 1981 and the highest was 41 $\mu g \cdot g^{-1}$ in 1995.
- The three beluga from Pangnirtung contained an average of 16.6 $\mu g \cdot g^{-1}$ of mercury in liver in 2010, the highest mean we have recorded

Messages clés

- En 2010, les nouvelles données portaient seulement sur les bélugas; aucun nouvel échantillon de tissus de morse ou de narval n'a été obtenu. Les échantillons de tissus de bélugas ont été prélevés à l'île Hendrickson (n=20) et l'âge a été déterminé pour la plupart des bélugas figurant dans les échantillons pris de 2008 à 2010. Des échantillons de trois nouveaux bélugas ont été prélevés à Pangnirtung, mais l'âge de ces animaux ne sont pas connus. Onze bélugas de Sanikiluaq et 15 d'Arviat ont été ajoutés; l'âge de tous ces animaux n'a pas encore été établi.
- En 2010, le niveau moyen de mercure dans le foie d'un béluga de l'île Hendrickson était de 16,3 $\mu g \cdot g^{-1}$ (poids frais), la deuxième moyenne la plus faible enregistrée pour des baleines du delta du Mackenzie. La moyenne la plus faible enregistrée se chiffre à 10,7 $\mu g \cdot g^{-1}$ et a été établie en 1981 à partir d'un ensemble de baleines relativement jeunes, et la plus élevée atteint 41 $\mu g \cdot g^{-1}$ et date de 1995.

from there, although it represents only three whales. The eleven beluga from Sanikiluaq in 2010 had an average of 20 $\mu g \cdot g^{-1}$ in liver, within the range of previous mean values. At Arviat, the mean levels of mercury in liver was 15.9 $\mu g \cdot g^{-1}$, the highest on record to date for that location.

- Average levels of mercury in liver in 2010 remained well above 0.5 $\mu g \cdot g^{-1}$ (the guideline used to regulate the sale of commercial fish in Canada) at all locations (means from about 16 to 20 $\mu g \cdot g^{-1}$). Even the minimum levels found exceeded the guideline. The same was true for levels of mercury in kidney samples although mean levels were lower than those in liver. Levels in muscle were lower yet with all locations having average values around 1 $\mu g \cdot g^{-1}$. Levels in muktuk were the lowest of all with three of the four locations having mean levels below 0.5 $\mu g \cdot g^{-1}$.
- As in previous years, mercury and selenium in samples of liver, kidney and muscle were usually related statistically. However there was no relationship between mercury and selenium in muktuk from the whales from Hendrickson Island, the only collection for which we have both mercury and selenium in muktuk. The muktuk showed an enhanced molar surplus of selenium over mercury relative to the other organs analyzed.
- In 2010, levels of mercury in liver were about the same in the whales from Hendrickson Island as in those from the three eastern communities. In previous years, the levels found in beluga from the Mackenzie Delta were generally higher than in those from eastern sites but those differences have diminished with the low values from Hendrickson Island in 2010.
- The question of temporal change in levels of mercury is of interest and is indeed one of the primary purposes of this study. It is complicated by a relationship between mercury in organs and the ages of the whales. We still lack age data for a number of collections reported and so attempts to describe temporal change remain preliminary. As more age data become available, improved statistical examinations will be made for temporal trends will be made

- Le niveau moyen de mercure dans le foie des trois bélugas de Pangnirtung examinés en 2010 se situait à 16,6 $\mu g \cdot g^{-1}$. Il s'agit de la moyenne la plus élevée observée depuis que nous avons commencé à prélever des échantillons à cet emplacement, même si elle n'a été établie qu'à partir de trois animaux. Les 11 bélugas de Sanikiluaq examinés en 2010 affichaient une moyenne pour le foie de 20 $\mu g \cdot g^{-1}$, ce qui s'inscrit dans la fourchette des moyennes précédentes. À Arviat, le niveau moyen de mercure dans le foie se situait à 15,9 $\mu g \cdot g^{-1}$, soit le niveau le plus élevé jamais consigné à cet endroit.
- Les niveaux moyens de mercure dans le foie mesurés dans les échantillons de 2010 prélevés à tous les emplacements sont de loin supérieurs à 0.5 $\mu g \cdot g^{-1}$ (la ligne directrice utilisée pour calculer la vente de poisson commercial au Canada), se situant entre 16 et 20 $\mu g \cdot g^{-1}$. Même les niveaux minimums dépassaient la ligne directrice. Même chose pour les niveaux de mercure dans les reins, quoique les niveaux moyens étaient inférieurs à ceux relevés dans le foie. Les niveaux mesurés dans les échantillons de muscles prélevés à tous les emplacements étaient encore plus bas, se chiffrant en moyenne autour de 1 $\mu g \cdot g^{-1}$. Les niveaux présents dans le muktuk étaient les plus bas de tous; les échantillons provenant de trois des quatre emplacements présentaient des niveaux moyens largement inférieurs à 0,5 $\mu g \cdot g^{-1}$.
- Comme pour les années précédentes, le mercure et le sélénium présents dans les échantillons de foie, reins et muscles étaient habituellement liés statistiquement. Toutefois, on ne constate aucun lien entre le mercure et le sélénium présents dans le muktuk des baleines de l'île Hendrickson, le seul endroit où des échantillons montrent la présence simultanée du mercure et du sélénium. On a observé dans le muktuk un surplus molaire accru de sélénium par rapport au mercure comparativement à tous les autres organes analysés.
- En 2010, les niveaux de mercure dans le foie étaient à peu près égaux chez les baleines de l'île Hendrickson et chez les animaux des trois collectivités de l'Est. Lors des années précédentes, les niveaux mesurés chez les bélugas du delta du Mackenzie étaient en général supérieurs à ceux mesurés chez les

(adjustments for age, transformation to reduce the correlation between means and standard deviations) but those are beyond the scope of this preliminary data report.

baleines des emplacements de l'Est, mais les différences ont diminué en raison des valeurs faibles enregistrées à l'île Hendrickson en 2010.

- La question des changements dans le temps des niveaux de mercure est intéressante et constitue en fait l'un des buts principaux de cette étude. Le lien entre le mercure dans les organes et l'âge des baleines complique l'analyse. Nous n'avons pas encore les données liées à l'âge pour certains échantillons, et les tentatives de description des changements temporels demeurent préliminaires. L'obtention de données supplémentaires sur l'âge nous permettra de réaliser des examens statistiques améliorés et d'établir des tendances temporelles (ajustements en fonction de l'âge, transformation pour réduire la corrélation entre les déviations moyennes), mais ces données dépassent la portée de ce rapport de données préliminaires.

Objectives

To provide incremental information on levels of mercury and selenium in organs of beluga, narwhal and walrus from selected locations in the Canadian Arctic, to maintain a database of this information and to assess long-term trends of mercury in these animals.

Introduction

The levels of mercury in organs of northern marine mammals have generally exceeded the guideline level of 0.5 $\mu g \cdot g^{-1}$ used to regulate the sale of commercial fish in Canada. There is no regulation governing the concentrations in marine mammals used for subsistence consumption and indeed any such guideline would be difficult or impossible to enforce. There is a published recommendation that fish consumed in a subsistence fishery not exceed 0.2 $\mu g \cdot g^{-1}$ (Health and Welfare Canada, 1979) although this recommendation has no legal status.

There are three main hypotheses about the source of the mercury to the animals. The first is that the mercury is present naturally in northern habitats and the animals there simply reflect the geology and oceanography of their feeding ranges. The second is that processes associated with climate change have altered the availability of mercury present naturally in the habitat. The third is that mercury from outside the habitat has been imported with movements of air (or water or ice) and that some of that mercury has found its way into northern animals. The extent to which these or other arguments apply is not yet clear. Studies of sediment cores suggest that more mercury has been reaching recent lake sediments than was the case when deeper, older layers of sediment were laid down (Lockhart et al., 1998) but this observation does not establish whether the excess mercury is natural mercury being mobilized from soils in the drainage basins or whether it is imported into the basin presumably with moving air masses. Studies of mercury in beluga teeth suggest that most of the mercury in contemporary beluga from the Beaufort Sea has been derived from recent anthropogenic activity (Outridge et al., 2002). However, parallel studies of mercury in teeth of walrus from Igloolik found that recent levels were not elevated over archeological samples suggesting little anthropogenic mercury in those animals (Outridge et al., 2002). Since pervious studies by Outridge et al. (2000) has shown that mercury levels in teeth are correlated with those in liver, kidney, muscle and muktuk, it seems likely that the trends reported in teeth occurred similarly in other organs.

The samples we describe here were all collected since the 1970s; Mercury has increased in air over the North Atlantic (Slemr and Langer, 1992) and mercury has been measured in air and in snow in the Arctic (Lu et al., 2001). While there is little doubt that industrial mercury is deposited in the Arctic, the ultimate fate of that mercury remains in question. Processes within the snow suggest that much of the mercury deposited to Arctic snow may be volatilized back into the air without ever reaching arctic animals. A question of great interest is whether mercury resulting from human activities is sufficient to cause changes in the levels of mercury in arctic animals. Stern and Macdonald (2005) postulated that the apparent increases of mercury in western Arctic beluga since the early 1990's may be attributed to recent changes in ice cover and distribution in the western Arctic Ocean. Gaden et al. (2009) found that levels of mercury in muscle of ringed seals collected from Holman between 1973 and 2007 showed no temporal trend but were related in a curvilinear way to the length of the ice-free season. Gaden and Stern (2010) have found that mercury levels in female beluga from Arviat decreased between the early 1980s and 2008. They used isotopic ratios of $\delta^{15}N$ and $\delta^{13}C$ to show that beluga feeding had changed over the interval. They suggested that this was likely due to the capture of prey from more offshore areas in response to the longer ice-free season over the interval. Loseto et al. (2008) have begun to look at biological variables that reflect feeding habits of Beaufort Sea beluga to help explain the levels of mercury found in them.

A previous study of mercury in northern animals pooled data from different locations in the eastern and western Arctic and reported a trend to higher levels in both regions (Wagemann et al., 1996). With growing recognition that arctic populations of marine mammals are composed of multiple stocks that are hunted separately in different communities, the need is for trend data on a stock-specific basis. Locations were considered separately by Lockhart et al., 2005, however, these and other earlier assessments will have to be repeated with the recalculated ages of beluga.

Whales may range long distances from the communities where they are hunted, but the hunting itself is usually relatively close to the communities. Here, mammals are described only by the communities where the samples were obtained. Hence two or more communities may hunt the same stock if those communities are relatively near each other.

The raw data from this and other investigations are archived in the Freshwater Institute and currently comprise records of mercury and often selenium in organs of 1195 arctic beluga, 285 walrus, 413 narwhal and 1052 ringed seals. Biologists obtain samples from hunter kills and those samples form the basis of most analyses. The archive grows through the collection and analyses of new samples and also through the analyses of archived samples from past collections. Over time, the accumulated data offer increasingly rigorous opportunities to test for changes that may relate to environmental variables. Beluga ages in the archived data have been revised in keeping with the new information on growth layer formation in beluga.

Activities in 2010–2011

This report covers data available by May, 2011. The collection of samples is done independently of this project and is not described here. The analytical methods have been described in previous reports and have been continued unchanged. Liver tissue of most animals was analyzed and kidney, muscle and muktuk were also analyzed when available. The new data are listed in Table 1. The project is concerned principally with mercury but many of the same samples were analyzed for selenium as well because of its probable relationship to the toxicology of mercury. Of the new samples reported here, ages are available only for those from Hendrickson Island.

Mercury and selenium in beluga from Hendrickson Island, 2010

Twenty beluga were obtained from Hendrickson Island in 2010, 19 males and 1 female. The unadjusted mean level of mercury in the livers of these animals was 16.3 $\mu g \cdot g^{-1}$ (Table 1). This is the lowest mean value we have found for beluga liver from the Mackenzie Delta area since 1981 when the mean level was 10.7 $\mu g \cdot g^{-1}$. The range of mercury levels found is typically broad and that remained the case in 2010 with the minimum level in liver being 3.54 $\mu g \cdot g^{-1}$ and the

Table 1. New data for mercury and selenium in organs of beluga added to the database by May, 2011

Species	Location	Year	Organ	Mean Age (yr) and number of samples	Mean Length (cm) and number of samples	Mean Total mercury ($\mu g \cdot g^{-1}$) And number	Std. Dev. Total Hg	Mean selenium ($\mu g \cdot g^{-1}$) and number of samples
Beluga	Hendrickson	2010	Liver	25.5 (19)	413.0 (20)	16.3 (20)	14.9	7.49 (20)
Beluga	Hendrickson	2010	Kidney	25.5 (19)	413.0 (20)	4.16 (20)	2.86	2.37 (20)
Beluga	Hendrickson	2010	Muscle	25.5 (19)	413.0 (20)	1.04 (20)	0.45	0.30 (20)
Beluga	Hendrickson	2010	Muktuk	25.5 (19)	413.0 (20)	0.44 (20)	0.20	2.28 (20)
Beluga	Pangnirtung	2010	Liver		348.8 (3)	16.6 (3)	14.3	5.50 (3)
Beluga	Pangnirtung	2010	Kidney		386.1 (2)	5.78 (2)	0.42	2.52 (2)
Beluga	Pangnirtung	2010	Muscle		348.8 (3)	0.97 (3)	0.59	0.33 (3)
Beluga	Pangnirtung	2010	Muktuk		348.8 (3)	0.174 (3)	0.13	2.11 (3)
Beluga	Arviat	2010	Liver		373.3 (15)	15.9 (15)	14.4	6.18 (15)
Beluga	Arviat	2010	Kidney		373.3 (15)	4.94 (15)	2.53	3.83 (15)
Beluga	Arviat	2010	Muscle		373.3 (15)	1.15 (15)	0.55	0.37 (15)
Beluga	Arviat	2010	Muktuk		373.8 (14)	1.41 (14)	0.21	
Beluga	Sanikiluaq	2010	Liver		363.9 (10)	20.0 (11)	11.0	11.2 (11)
Beluga	Sanikiluaq	2010	Kidney		363.9 (10)	4.13 (11)	1.23	4.29 (11)
Beluga	Sanikiluaq	2010	Muscle		363.9 (10)	1.14 (11)	0.24	0.40 (11)
Beluga	Sanikiluaq	2010	Muktuk		363.9 (10)	0.51 (11)	0.13	

Table 2. Correlation matrix between unadjusted mercury concentrations ($\mu g \cdot g^{-1}$ wet weight) in four organs of twenty beluga whales from Hendrickson Island in 2010.

		Liver	Kidney	Muscle	Muktuk
Liver	r		0.677	0.775	0.748
	p		0.001046	0.000060	0.000149
	n		20	20	20
Kidney	r			0.836	0.791
	p			0.000004	0.000033
	n			20	20
Muscle	r				0.940
	p				0.000000
	n				20

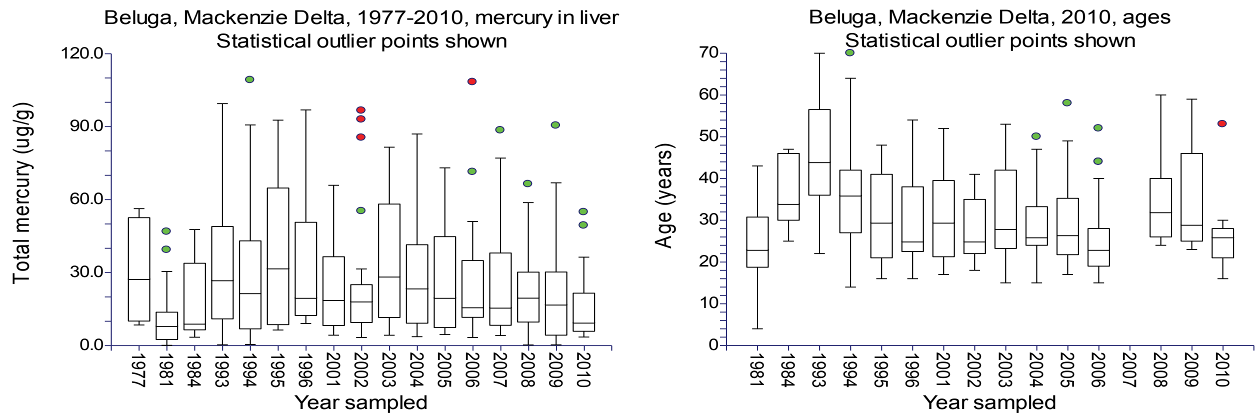
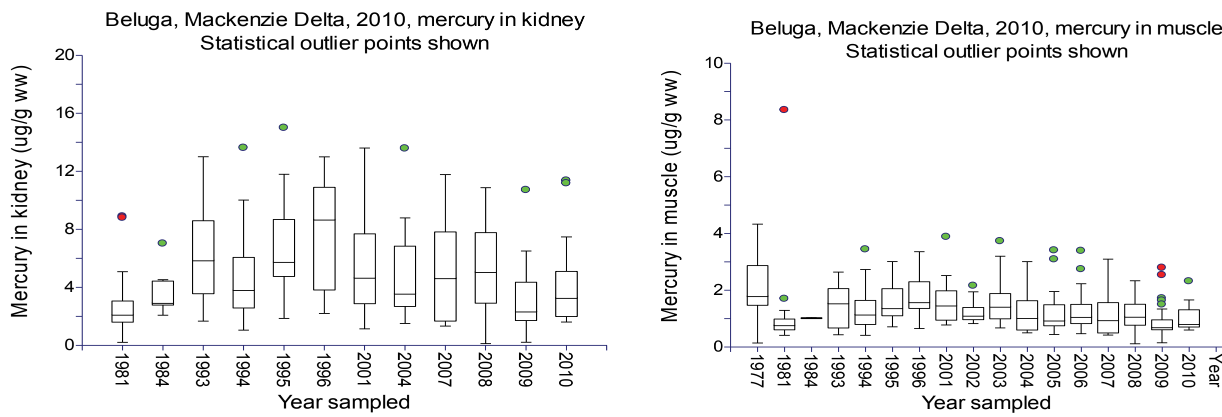


Figure 1. Box plots of median mercury levels (µg·g^{-1} wet weight) in liver of beluga whales from the Mackenzie Delta from 1977 to 2010 (left panel). The horizontal line in each box represents the median value while the box itself represents the range from the 25th to the 75th percentile or the interquartile 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. Right panel, median ages of whales from the same samples; no ages were obtained from the samples in 1977 or 2007. Green dots represent mild statistical outside values and red dots severe ouside values.



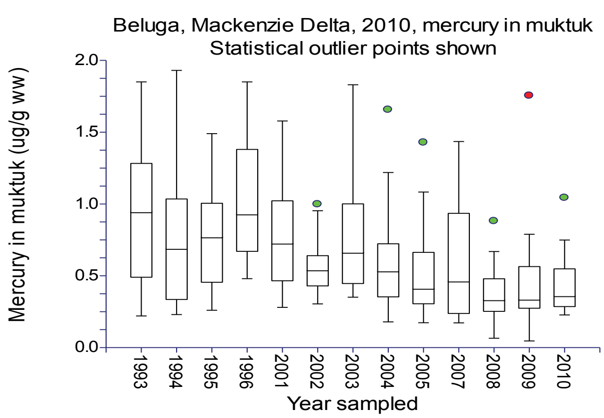


Figure 2. Median levels of mercury in kidney (left), muscle (centre) and muktuk (right) of beluga whales from Hendrickson Island, 2010. Note that the vertical scale on each panel differs and that they all differ from the vertical scale shown for mercury in liver (Figure 1). Box properties as in Figure 1.

maximum 54.9 $\mu g \cdot g^{-1}$; the standard deviation of the mean was 14.9 $\mu g \cdot g^{-1}$ was almost as large as the mean. The high variability of mercury in these samples makes it statistically difficult to detect trends over time. Of the four organs analyzed, liver normally has the highest levels and that pattern was retained in 2010 with the average liver concentration of 16.3 $\mu g \cdot g^{-1}$, followed by kidney 4.16 $\mu g \cdot g^{-1}$, muscle 1.04 $\mu g \cdot g^{-1}$ and muktuk 0.44 $\mu g \cdot g^{-1}$ (Table 1). Mercury levels among the four organs were strongly, positively correlated with each other (Table 2). Ages were obtained for the 19 males in 2010 and these ranged was from 16 to 53 years with an average age of 25.5 years. Mercury in liver was correlated with age ($r=0.674$, $p=0.0016$) as it was in kidney ($r=0.732$, $p=0.0004$), muscle ($r=0.781$, $p=0.00008$) and muktuk ($r=0.769$, $p=0.0001$). The strongest organ-to-organ correlation in this sample was between muscle and muktuk ($r=0.94$).

Data on whale lengths were collected and the individual lengths varied from 356 to 513 cm with a mean length of 413 cm. Length was less effective as an indicator of mercury in liver than age; the correlation between length and mercury in liver was only 0.37 ($p=0.12$, not significant). However length did correlate with mercury in kidney ($r=0.69$, $p=0.0008$), muscle ($r=0.65$, $p=0.002$) and muktuk ($r=0.59$, $p=0.006$) and so, in the absence of age, length can help to understand levels of mercury in several organs.

Mean statistics can be influenced by statistically extreme points such as unusually high or low values and the data typically contain some of these values. For the past several years data from different years have been illustrated using box plots showing the median and percentile ranges instead of means because medians are influenced less by extreme values. Figure 1 shows the median levels of mercury liver over the period from 1977 to 2010 (left panel) and median ages (right panel). No ages were obtained from samples in 1977 or 2007.

The median level of mercury in liver in 2010 (9.6 $\mu g \cdot g^{-1}$) was the lowest found since the 1980s. All the median values after about 1993 were quite

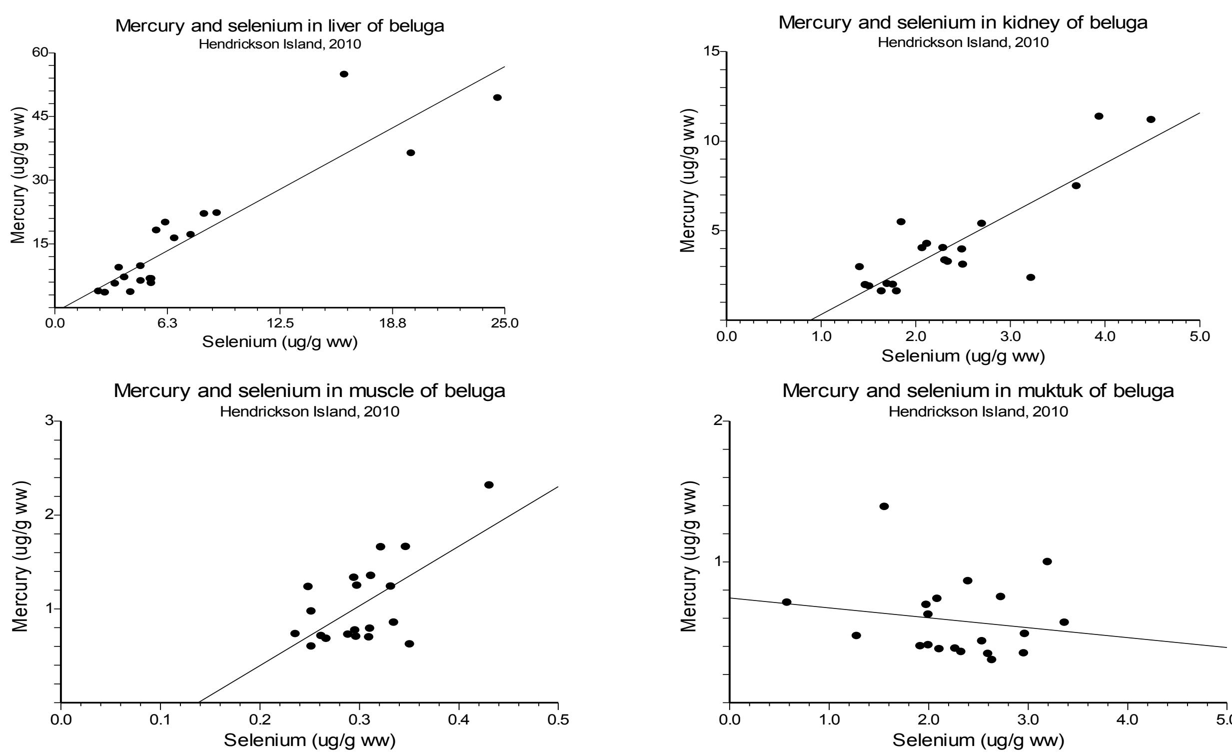


Figure 3. Relationships between concentrations of mercury and selenium ($\mu g \cdot g^{-1}$ wet weight) in liver (upper left), kidney (upper right), muscle (lower left) and muktuk (lower right) of beluga whales from Hendrickson Island, 2010. Note differences in scales of both axes.

similar and fell in the range of about 10 to 20 $\mu g \cdot g^{-1}$ with no consistent trend to higher or lower values. Figure 2 shows similar plots for kidney, muscle and muktuk for all the samples and again there is no unambiguous single trend although the pattern of the medians suggests that, if anything, values may have declined somewhat since the mid 1990s. More rigorous statistical analysis may reveal trend information not readily discernable by these illustrations.

Mercury and selenium levels in liver were strongly correlated as in previous collections. Figure 3 illustrates the relationships between these elements for the four organs analyzed for mercury and selenium (weight basis, not molar basis). Liver showed a strong relationship (R-squared =0.84, p<0.000001, Figure 3, upper left); kidney a somewhat weaker relationship (R-squared=0.72, p=0.000002, Figure 3, upper right) and muscle weaker yet (R-squared=0.40, p=0.003, Figure 3, lower left). These results are similar to those reported in 2010. Unlike the other organs, muktuk showed no obvious statistical relationship between mercury and selenium (R-squared 0.03, p=0.47, Figure 3, lower right). If the concentrations of mercury and selenium are expressed not as micrograms per gram but instead as micromoles per gram, then the atomic ratios of these elements are evident. For example, the mean concentrations of both mercury and selenium for the four organs analyzed are listed in Table 1. The weight concentration is converted to the corresponding molar concentration by dividing by the atomic weight, 200.59 for mercury and 78.96 for selenium. Thus 16.3 $\mu g \cdot g^{-1}$ mercury in liver is (16.3/200.59=0.081 $\mu M\ g^{-1}$) and 7.39 $\mu g \cdot g^{-1}$ selenium is (7.49/78.96=0.095 $\mu M\ g^{-1}$). Hence the molar ratio of mercury to selenium is 0.081/0.095=0.855 indicating a small molar excess of selenium over mercury. The corresponding molar ratios for kidney and muscle were 0.692 and 1.36 respectively. The Hg/Se ratio in muktuk, however, was only 0.076 indicating approximately an order of magnitude greater molar excess of selenium over mercury in muktuk than in the other organs. Examining the concentrations of Hg and Se in Table 1, it appears that the low ratio of Hg/Se is due to low levels of mercury in muktuk rather than to high levels of selenium. We are unaware of any reports of HgSe in muktuk but the large excess of Se over Hg suggests that its formation there would be likely. Usually mercury follows protein with protein-rich organs having more mercury than protein-poor tissues and it would be of scientific interest to determine the protein and more specifically the sulfhydryl group content of muktuk.

Mercury and selenium in beluga from Arviat, 2010

Fifteen beluga were sampled from Arviat in 2010, 8 males, 4 females and 3 of unknown gender. Ages have not been determined yet for these whales but their average length was 373 mm, somewhat shorter than the mean length of whales from Hendrickson Island. The mean level of mercury in liver was 15.9 $\mu g \cdot g^{-1}$ as compared with 4.94 $\mu g \cdot g^{-1}$ in kidney, 1.15 $\mu g \cdot g^{-1}$ in muscle and 1.41 $\mu g \cdot g^{-1}$

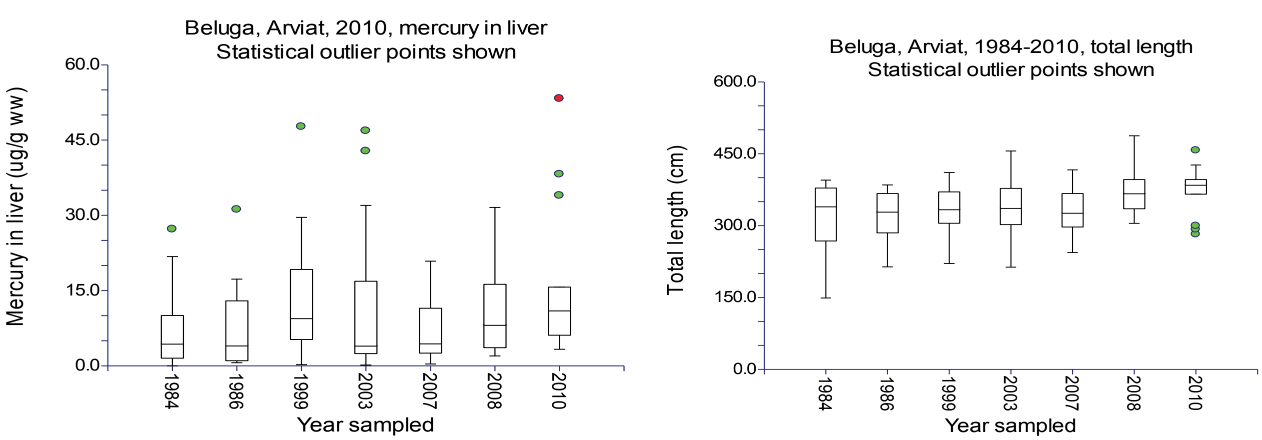
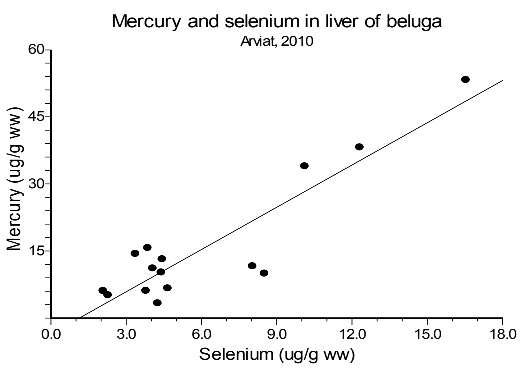


Figure 4. Box plots of median mercury levels ($\mu g \cdot g^{-1}$ wet weight) in liver of beluga whales from Arviat for seven samples from 1984 to 2010 (left panel) and similar plots of body length for the same occasions (right panel). Box properties as in Figure 1.

Table 3. Ages and levels of mercury in liver of male and female beluga from Arviat, 1984–2010

Year	Number females	Age females (years)	Liver Hg Females ($\mu g \cdot g^{-1}$ww)	Number males	Age males (years)	Liver Hg males ($\mu g \cdot g^{-1}$ww)
1984	18	23.3	6.76	5	24 (n=3)	6.12
1986	10	21.8	7.52	5	25.4	7.60
1999	18	21.4	12.8	15	22.8	12.4
2003	15	19.9	17.7 (n=13)	21	19.0	5.75 (n=19)
2007	3	26.7	14.9	9	18.1	4.67
2008	6	24.7	11.6	6	21.2	8.91
2010	4		8.40	8		17.3



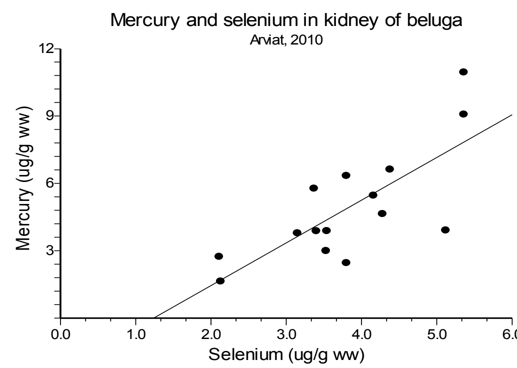
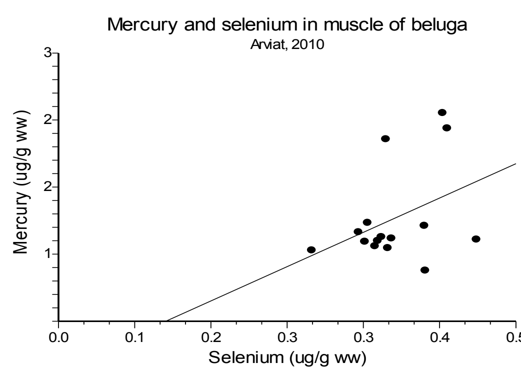


Figure 5. Relationship between concentrations of mercury and selenium ($\mu g \cdot g^{-1}$ wet weight) in liver (left), kidney (centre), and muscle (left) of beluga whales from Arviat, 2010. Note differences in scales of both axes. There was no statistical relationship between the two elements in muscle.



in muktuk (Table 1). While the mean level in liver was the highest we have recorded from that community, it was largely due to the influence of three unusually high values (34, 38 and 53 $\mu g \cdot g^{-1}$). The median levels in liver in 2010 can be visualized in the context of 6 previous collections made from the same location since 1984 (Figure 4). The median value in 2010 was 11.1 $\mu g \cdot g^{-1}$, also the highest median we have recorded yet from Arviat.

Gaden and Stern (2010) found that mercury levels in female beluga from Arviat decreased between the early 1980s and 2008. The uncorrected medians and interquartile ranges in liver from all 15 beluga combined in 2010 did not detect this trend. Considering the 4 females separate from the 8 males separately, the mean found for females (8.4 $\mu g \cdot g^{-1}$) was about half that for males (17.3 $\mu g \cdot g^{-1}$).

Ages of the whales from Arviat are not available yet. Lengths of the whales were taken and median lengths are shown in Figure 4 (right panel); the median lengths were slightly greater in 2010 than in 2009 or on previous occasions; the whales taken in 2010 may have been slightly older than those in 2009. However, correlation calculations identified no significant relationship between length and levels of either mercury or selenium in liver, kidney or muscle. We have no analyses of selenium in muktuk. The relationships between mercury and selenium in the three organs are plotted in Figure 5. There were significant relationships between Se and Hg in liver and kidney but not in muscle.

Mercury and selenium in beluga from Sanikiluaq, 2010

Data on eleven whales (9 males, 1 female, 1 unknown) were added to the accumulated information from Sanikiluaq in 2010. Mercury in liver ranged from 7 to 39 $\mu g \cdot g^{-1}$ with a mean

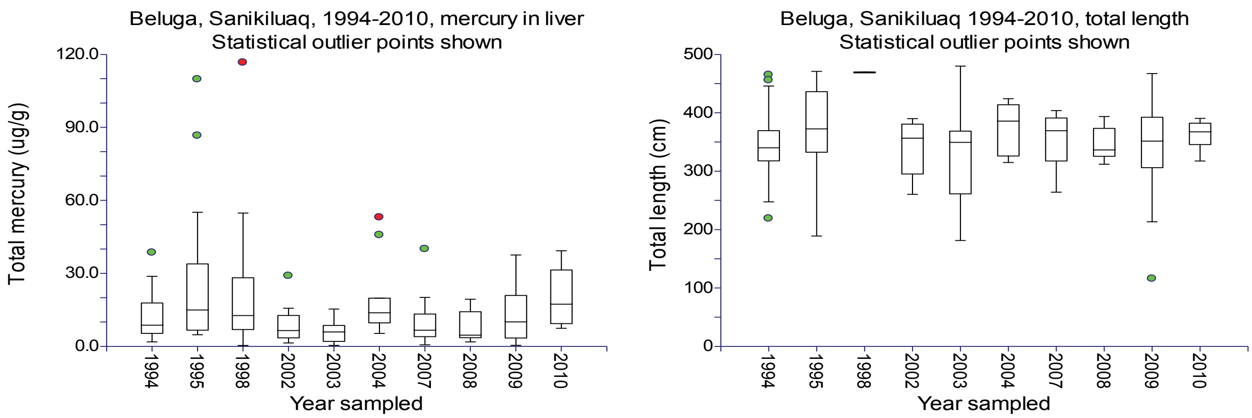
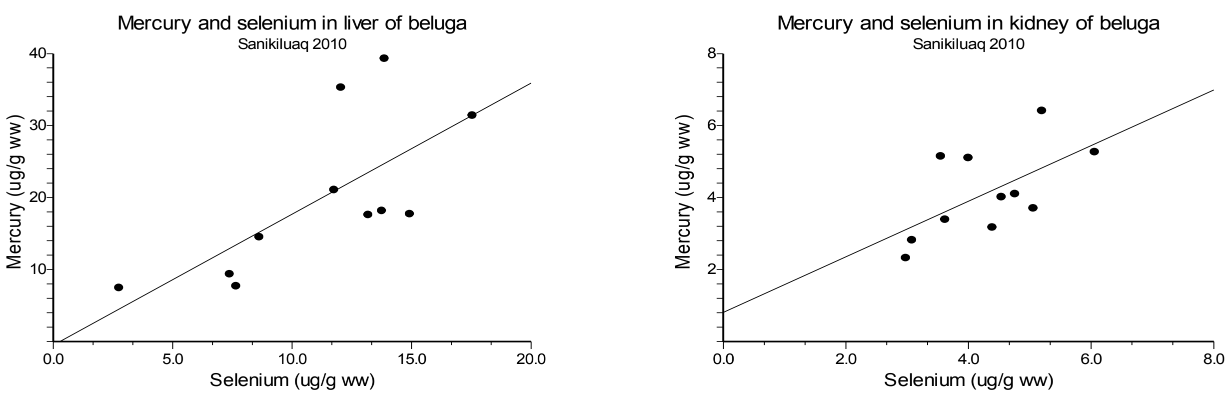


Figure 6. Box plots of median mercury levels (μg·g^{-1} wet weight) in liver of beluga whales from Sanikiluaq for ten samples from 1994 to 2010 (left panel) and similar plots of total length for the same occasions (right panel). Details of boxes as in Figure 1.



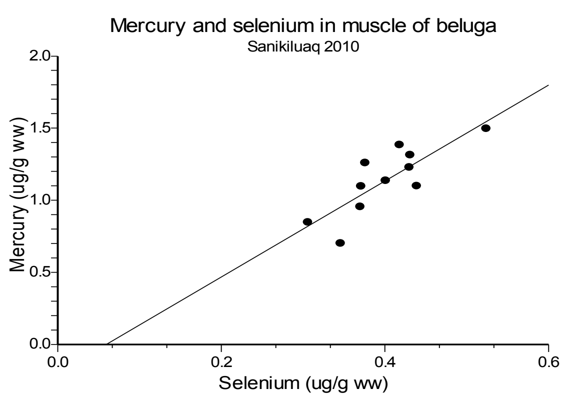


Figure 7. Relationship between concentrations of mercury and selenium (μg·g^{-1} wet weight) in liver (left), kidney (centre), and muscle (left) of beluga whales from Sanikiluaq, 2010. Note differences in scales of both axes. There was no statistical relationship between the two elements in muscle.

of 20 $\mu g \cdot g^{-1}$ (Table 1). Lengths were obtained for 10 of the 11 whales and these ranged from 317.5 to 390.5 cm. The levels of mercury in the four organs analyzed followed the usual pattern of highest values in liver followed by kidney, muscle and muktuk (Table 1). Selenium in liver ranged from 3 to 18 $\mu g \cdot g^{-1}$ (mean of 11.2 $\mu g \cdot g^{-1}$). The median levels of mercury in liver are compared with 9 previous collections from Sanikiluaq since 1994 in Figure 6 (left).

The relationships between mercury and selenium are shown in Figure 7 for the three organs analyzed for both elements. The relationship between mercury and selenium was statistically meaningful for liver (r-squared=0.49) and muscle (r-squared =0.66) but not for kidney (r-squared=0.36).

Mercury and selenium in beluga from Pangnirtung, 2010

We obtained only three samples from Pangnirtung in 2010, one of which was considerably smaller (274 cm) than the others (366 and 406 cm). The small individual, presumably a young one, had mercury in liver at only 0.57 $\mu g \cdot g^{-1}$ as compared with 27.8 and 21.5 $\mu g \cdot g^{-1}$ in the other two. We have a total of 17 collections from Pangnirtung taken over the interval from 1982 to 2010 but several of those collections comprised small numbers of samples. For example all five collections since 2006 consisted of five or fewer animals. We have ages for most of the samples in eleven of these collections but not for 2010. The pattern of median values for mercury in liver over the period since 1982 is shown in Figure 8 (left) along with the pattern of median lengths (Figure 8, right).

With only three animals in 2010, correlations between mercury and selenium were not calculated for any of the organs.

The data to date do not usually suggest a single trend to higher or lower values over the time periods available for the various sites. The longest term for monitoring has been in the Mackenzie Delta and the preliminary analyses presented here suggest that levels in beluga there appear to have increased from the 1970s until the mid-1990s and then decreased somewhat since then (Figure 1). At Arviat, the plots (Figure 4) suggest a small increase in mercury levels (pooled genders) although this may be an artifact of sampling from somewhat larger whales; more rigorous statistical analyses have suggested the opposite trend in females. The data from Sanikiluaq suggest that levels may have increased in the last few years relative to lower levels in the early 2000s (Figure 6). Median mercury in beluga liver from Pangnirtung is higher than it was in the 1980s but appears to have changed little since the mid-1990s(Figure 8) although sample numbers have been small for the past several years.

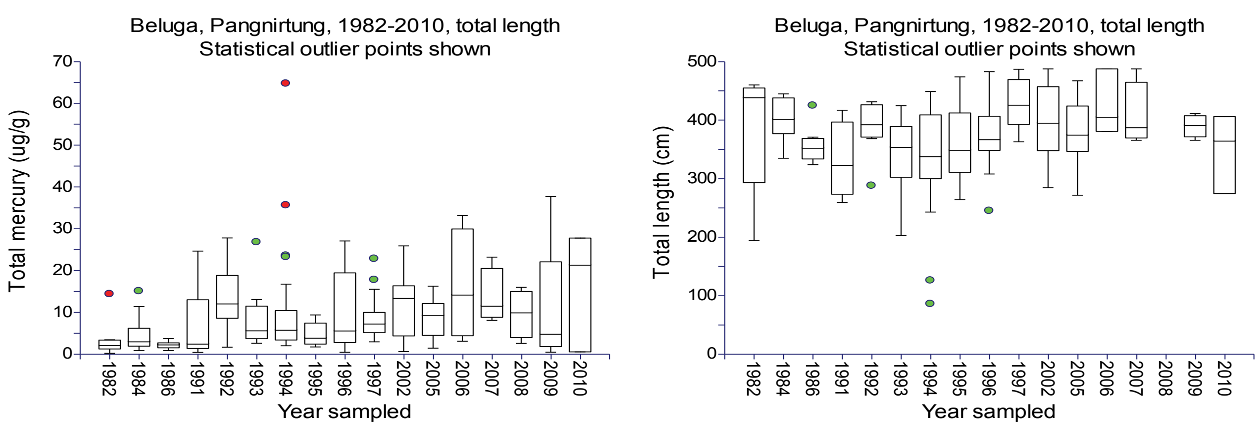


Figure 8. Box plots of median mercury levels ($\mu g \cdot g^{-1}$ wet weight) in liver of beluga whales from Pangnirtung for 17 samples from 1983 to 2010 (left panel) and similar plots of body length for the same occasions (right panel). Box properties as in Figure 1.

Expected Project Completion Date

Mercury at the levels in the beluga reported here remains a concern with regard to human dietary intakes. The levels also pose legitimate questions regarding the sources of the mercury, the toxicological effects on the animals themselves, the relationship between mercury and selenium, and temporal and spatial patterns of mercury contamination. Probably some form of this research will have to be continued for as long as beluga and other marine mammals in the Arctic are hunted for human consumption.

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Temporal Trend Studies of Trace Metals and Halogenated Organic Contaminants (HOCs), including New and Emerging Persistent Compounds, in Mackenzie River Burbot, Fort Good Hope, NWT

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Abstract

Tissues from burbot collected at Fort Good Hope (Rampart Rapids) in December 2010 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) and OC (1988, 1994, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009) together covering time spans of 25 and 22 years, respectively. No significant correlation between length and mercury concentration was observed with muscle or liver for either sex. Mean Hg concentrations in muscle and liver over the entire data sets were 0.346 ± 0.140 (n=438) and 0.086 ± 0.075 (n=447) $\mu g\ g^{-1}$, 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.

Résumé

Nous avons analysé des tissus de lotte prélevés au Fort Good Hope (rapides Rampart) en décembre 2010 pour en déterminer les taux de contaminants organohalogénés (organochlorés, pentachlorophénols, agents ignifuges bromés, fractions de carbone organique) et de métaux lourds (Hg, Se et As). Nous avons combiné les données recueillies à cette date aux données existantes concernant les métaux (1985, 1988, 1993, 1995, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009) et les organochlorés (1988, 1994, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009), ce qui, dans l'ensemble, couvre des périodes de 25 et de 22 années respectivement. Aucune corrélation significative n'a été observée entre la longueur des muscles ou du foie et la concentration de mercure qui s'y trouve pour chacun des sexes. La moyenne des concentrations de Hg dans les muscles et le foie selon la totalité des ensembles de données étaient de 0,346 ± 0,140 (n=438) $\mu g\ g^{-1}$ et de 0,086 ± 0,075 (n=447) $\mu g\ g^{-1}$ respectivement. Les concentrations de mercure dans les muscles se situent sous la concentration indicative recommandée de 0,50 $\mu g\ g^{-1}$ pour la vente com-

Conversely, PFDA concentrations show a consistent increase overtime. PFNA and PFUA levels peaked in 2003.

merciale. Les concentrations congénères majeures d'EDP ont augmenté de manière significative au cours de la période de 19 années qui s'étend de 1988 à 2008, mais elles se maintiennent actuellement à un ordre de grandeur moindre que celles du BPC. Depuis 1986, nous avons observé une diminution constante des concentrations d'APFO et de PFOS.

Key Messages

- Mean Hg concentrations in muscle and liver over the entire data sets were 0.346 ± 0.140 (n=438) and 0.086 ± 0.075 (n=447) $\mu g\ g^{-1}$, respectively.
- Since the mid-1990s, a 1.6 and 2.0-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 $\mu g\ g^{-1}$ for commercial sale.
- Significant declines, 10- and 4-fold, occurred for both α- and γ-HCH over 20 year time period between 1988 and 2010. ΣPCBs and ΣDDT have increased significantly since the mid-1990s.
- PBDE concentration seemed to have peaked in the mid-2000s and are now on the decline.
- Current ΣPBDE levels are approximately one order of magnitude less than those of PCBs.
- Since 1986, a consistent decline was observed in both PFOA and PFOS concentrations. Conversely, PFDA concentrations show a consistent increase overtime. PFNA and PFUA levels peaked in 2003.

Messages clés

- La moyenne des concentrations de Hg dans les muscles et le foie de la totalité des ensembles de données était de 0,346 ± 0,140 (n=438) $\mu g\ g^{-1}$ et de 0,086 ± 0,075 (n=447) $\mu g\ g^{-1}$, respectivement.
- Depuis le milieu des années 1990, une augmentation des concentrations de mercure, de l'ordre de 1,6 et de 2, a été relevée respectivement dans les muscles et le foie des lottes dans la région Fort Good Hope.
- Les concentrations de mercure dans les muscles et le foie se situent sous la concentration indicative recommandée de 0,50 $\mu g\ g^{-1}$ pour la vente commerciale.
- Des diminutions significatives d'un ordre de 10 et de 4 ont eu lieu pour l'α-HCH et le γ-HCH au cours d'une période de 20 années entre 1988 et 2010. Celles de ΣBPC et de ΣDDT ont augmenté de façon considérable depuis le milieu des années 1990.
- Les concentrations d'EDP semblent avoir atteint un point culminant au milieu des années 2000 et sont présentement en baisse.
- Les concentrations actuelles de ΣPBDE sont d'un ordre de grandeur moindre que celles du BPC.
- Depuis 1986, nous avons observé une diminution constante des concentrations d'APFO et de PFOS. En revanche, les concentrations d'APFD présentent une augmentation constante au fil des ans. Les concentrations d'APFN et d'APFU ont atteint leur point maximal 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 2010–2011

In December 2010, 39 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 25 years and 16 time points (1985, 1988, 1993, 1995, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010). Mean Hg concentrations in muscle and liver over the entire data sets were 0.346 ± 0.140 (n=438) and 0.086 ± 0.075 (n=447) $\mu g\ g^{-1}$, respectively. Muscle mercury levels in muscle are below the recommended guideline level of 0.50 $\mu g\ g^{-1}$ 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 a 1.6 and 2.0-fold increase in mercury concentrations in Fort Good burbot muscle and liver, respectively, since the mid-1990s. For selenium and arsenic no trends were observed in either the muscle or liver (Tables 1 and 2). The highest measured As concentration, 17.16 $\mu g\ g^{-1}$, occurred in a muscle sample from a female burbot collected in 1999.

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

Table 1. Mean (standard deviation) concentrations of mercury, selenium and arsenic in Fort Good Hope burbot muscle (µg g^{-1}).

Collection	Sex	n	Length	Hg	Se	As
Apr–85[1]	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)
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)

[1]Wagemann 1985; [2]n=20

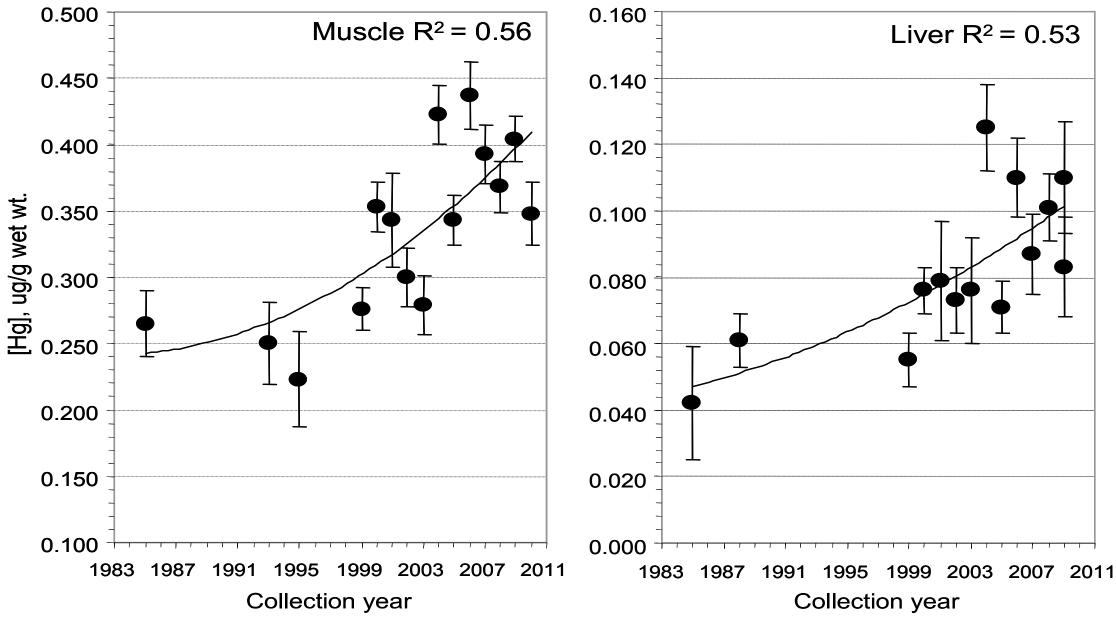

Figure 1. Mean Hg concentrations in muscle (left) and liver (right) from Fort Good Hope burbot (males + females).

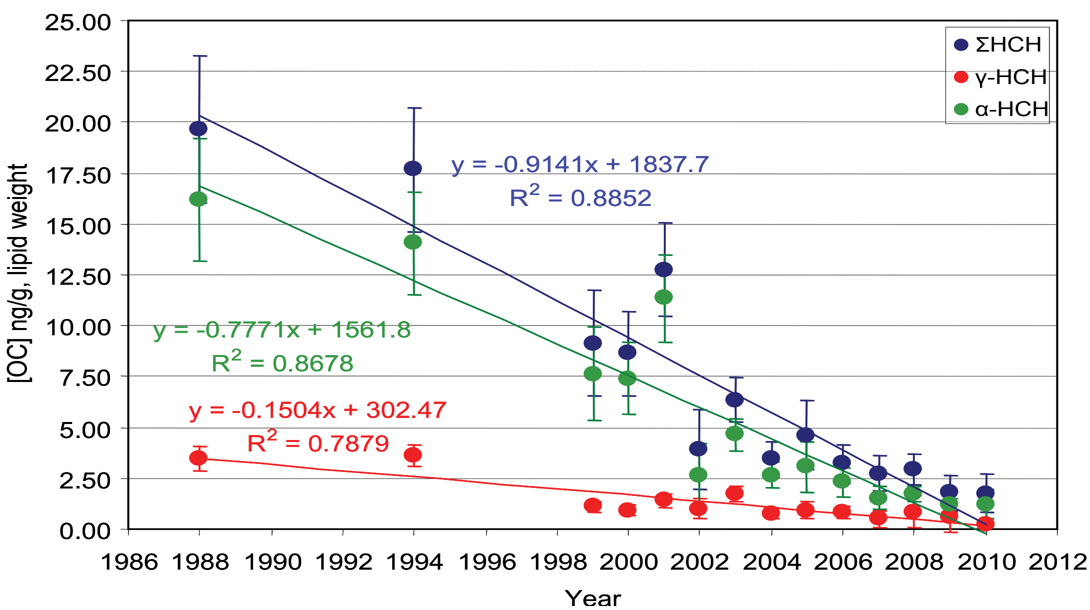

Figure 2. Lipid normalized ΣHCH, α–, γ-HCH concentrations in FGH burbot liver (1988–2010).

Table 2. Mean (standard deviation) concentrations of mercury, selenium and arsenic in Fort Good Hope burbot liver (μg 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)
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)

[1]Wagemann 1985; [2,3]n=19

22 year time period (Figure 2). β-HCH concentrations were below the detection limit in most samples. ΣPCBs and ΣDDT have increased significantly since the mid-1990s (see Carrie et al. 2010).

Major PBDE congener and homologue concentrations in selected burbot liver samples are listed in Table 5 (1988 to 2010). PBDE 47 is the most predominant PBDE congener residue in the burbot liver followed by PBDE 99, 100, 153 and 154. In general, PBDE concentrations seemed to have peaked in the mid-2000s and are now on the decline. Results for perfluoroalkyl compounds are shown in Table 6.

Expected Project Completion Data

Temporal trend studies are long-term propositions and thus annual sampling is projected into the foreseeable future.

Table 3. OCs in Burbot liver from Fort Good Hope (mean and standard deviation, ng g^{-1}, ww)

Year	sex	n	% Lipid	ΣCBz	ΣHCH	ΣCHL	ΣDDT	ΣPCB	ΣCHB	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	9	24.73 (14.27)	4.05 (3.72)	0.87 (0.45)	25.35 (21.84)	35.65 (26.15)	57.62 (32.22)	201.65 (167.60)	3.90 (2.66)	24.89 (20.06)
2005	M + F	10	24.50 (12.12)	4.71 (2.14)	1.09 (0.61)	22.16 (12.40)	19.46 (9.28)	29.23 (8.49)	110.33 (67.35)	4.42 (2.01)	42.50 (23.38)
2006	M + F	10	32.74 (15.87)	3.77 (1.99)	1.00 (0.46)	21.42 (19.01)	35.53 (15.68)	61.84 (44.44)	158.00 (149.07)	3.59 (2.00)	5.25 (4.86)
2007	M + F	9	31.89 (10.25)	7.53 (3.20)	0.90 (0.44)	24.67 (11.80)	42.13 (15.73)	38.19 (17.57)	119.16 (72.60)	6.96 (3.03)	5.79 (2.78)
2008	M + F	9	39.09 (9.74)	8.83 (2.41)	1.19 (0.44)	15.26 (10.06)	38.59 (17.71)	101.86 (55.71)	289.16 (210.32)	6.52 (1.74)	3.38 (2.58)
2009	M + F	10	30.68 (14.59)	5.19 (2.63)	0.54 (0.33)	39.32 (15.85)	32.32 (22.51)	85.31 (39.57)	271.53 (187.86)	4.12 (2.36)	5.33 (3.15)
2010	M + F	10	33.2 (13.8)	2.31 (0.89)	0.69 (0.28)	10.67 (9.28)	16.06 (13.03)	37.22 (26.41)	115.87 (112.18)	2.01 (0.82)	1.68 (1.38)

Table 4. Lipid normalized OCs concentrations in Burbot liver from Fort Good Hope (mean and standard deviation, ng g^{-1})

Year	sex	n*	ΣCBz	ΣHCH	α-HCH	γ-HCH	ΣCHL	ΣDDT	ΣPCB	ΣCHB	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	9	16.75 (9.42)	3.39 (0.91)	2.62 (0.66)	0.76 (0.26)	133.85 (124.50)	168.22 (103.73)	257.46 (159.14)	883.24 (823.31)	25.38 (21.39)
2005	M + F	8	18.81 (8.02)	4.63 (1.69)	3.08 (1.24)	0.94 (0.39)	83.67 (41.03)	69.12 (36.06)	103.47 (46.49)	408.43 (208.31)	42.50 (20.38)
2006	M + F	8	16.62 (4.37)	3.20 (0.95)	2.30 (0.74)	0.85 (0.29)	62.22 (54.07)	112.70 (80.80)	151.22 (105.33)	445.42 (410.90)	15.04 (13.90)
2007	M + F	9	23.56 (6.03)	2.73 (0.87)	1.53 (0.59)	0.52 (0.41)	78.62 (30.26)	143.95 (68.04)	129.20 (59.81)	363.09 (168.67)	18.40 (6.81)
2008	M + F	8	17.13 (4.37)	3.03 (0.75)	1.69 (0.38)	0.96 (0.78)	41.20 (7.52)	102.71 (52.23)	283.38 (200.27)	803.57 (648.00)	9.54 (8.29)
2009	M + F	9	16.93 (6.49)	1.78 (0.87)	1.17 (0.33)	0.61 (0.73)	107.70 (61.18)	115.56 (73.82)	293.91 (166.30)	1032.16 (745.13)	22.22 (13.64)
2010	M + F	10	5.79 (3.02)	1.75 (0.94)	1.24 (0.74)	0.22 (0.09)	26.53 (23.94)	43.87 (43.62)	101.13 (93.38)	289.96 (284.94)	4.23 (3.67)

*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 (1913.5)	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)	1054.0 (1381.1)	774.1 (932.6)	513.3 (804.8)	296.4 (509.3)	282.0 (483.4)

*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

PDDoDA=mdl=0.05; PFUA (mdl=0.05); *Higher value due to one sample with a measured concentration of 304.24 ng g^{-1}. If this value is excluded then the mean value for PFDA and total FOCs for the 2001 samples are 7.15 (7.47) and 15.38 ng g^{-1}, respectively.

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Trace Metals and Organohalogen Contaminants in Fish from Selected Yukon Lakes: a Temporal and Spacial Study

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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 16 years, 13 and 11 time points, respectively. Mean Hg levels over the entire data sets for the Laberge and Kusawa samples were 0.47 ± 0.22 (n=123) and 0.38 ± 0.25 (n=114) μg g^{-1}, respectively. In both lakes, levels are just below the recommended guideline level of 0.50 μg g^{-1} for commercial sale. No significant trends have been observed in the Laberge lake trout Hg levels over the last 16 years. In Kusuwa Lake, after a significant drop in the trout muscle mercury concentrations in 2001, levels increased consistently until 2007. Significantly lower Hg concentrations were measured in the fish collected in both 2008 and 2009 but, seemed to increase again in 2010. As was observed with the mercury, after a rapid decline, the lipid adjusted OC concentrations seem to

Résumé

Des contaminants organohalogénés (pesticides organochlorés, biphényles polychlorés, produits ignifuges bromés et composés organiques fluorés) et des métaux lourds (Hg, Se et As) ont été dosés dans des échantillons de muscle de touladis capturés dans deux lacs du Yukon, soit les lacs Kusawa et Laberge. La série chronologique des teneurs en métaux lourds du muscle de ces touladis s'étend sur 16 ans et est constituée de 13 dates d'échantillonnage pour le lac Laberge et de 11 pour le lac Kusawa. Pour l'ensemble des données, la concentration moyenne de Hg est de 0,47 ± 0,22 (n=123) μ g g^{-1} pour le lac Laberge et de 0,38 ± 0,25 (n=104) μ g g^{-1} pour le lac Kusawa. Ainsi, les concentrations sont tout juste inférieures à la limite de 0,50 μ g g^{-1} établie pour la vente commerciale de poisson. Au cours des 16 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 importante des concentrations de mercure dans le muscle de touladis en 2001, qui a été suivie d'une augmentation constante de

start to increase again around 2003/04. Significant variability in the Laberge samples is observed and as a result no temporal trends are evident.

ces concentrations jusqu'en 2007. Des concentrations de Hg significativement plus faibles ont été mesurées dans le poisson prélevé en 2008 et en 2009, mais semblent remonter de nouveau en 2010. Comme on l'a observé pour le mercure, après une baisse rapide, les concentrations d'organochlorés corrigées en fonction de la teneur en lipide ont recommencé à augmenter vers 2003 ou 2004.

L'importante variation observée dans les échantillons prélevés dans le lac Laberge fait en sorte qu'aucune tendance chronologique ne ressort clairement.

Key Messages

- Currently heavy metal (mercury, selenium and arsenic) time trend data from Laberge and Kusawa Lake trout cover 16 years, 13 and 11 time points, respectively.
- The mean Hg levels in the Laberge and Kusawa trout muscle samples over the entire data sets were 0.47 ± 0.21 (n=133) and 0.38 ± 0.25 (n=114) μg g^{-1}, respectively. In both lakes, levels are just below the recommended guideline level of 0.50 μg g^{-1} for commercial sale.
- No significant trends have been observed in the Laberge lake trout Hg levels over the last 16 years.
- In Kusuwa Lake, after a significant drop in the trout muscle mercury concentrations in 2001, levels increased consistently until 2007. Significantly lower Hg concentrations were measured in the fish collected in both 2008 and 2009 but, seemed to increase again in 2010.
- 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 concentrations de métaux lourds (mercure, sélénium et arsenic) dans le muscle de touladis des lacs Laberge et Kusawa s'étend sur 16 ans, et est constituée de 13 dates d'échantillonnage pour le lac Laberge et de 11 pour le lac Kusawa.
- Pour l'ensemble des données, la concentration moyenne de Hg dans le muscle de touladi est de 0,47 ± 0,22 (n=123) m g g -1 pour le lac Laberge et de 0,38 ± 0,25 (n=104) m g g^{-1} pour le lac Kusawa. Ainsi, les concentrations sont tout juste inférieures à la limite de 0,50 m g g^{-1} établie pour la vente commerciale de poisson.
- Au cours des 16 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 importante des concentrations de mercure dans le muscle de touladis en 2001, qui a été suivie d'une augmentation constante de ces concentrations jusqu'en 2007. Des concentrations de Hg significativement plus faibles ont été mesurées dans le poisson prélevé en 2008 et en 2009, mais semblent remonter de nouveau en 2010.
- Comme on l'a observé pour le mercure, après une baisse rapide, les concentrations d'organochlorés corrigées en fonction de la teneur en lipide ont recommencé à augmenter vers 2003 ou 2004. La variation importante observée dans les échantillons prélevés dans le lac Laberge fait en sorte qu'aucune tendance chronologique ne ressort clairement.

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 2010–2011

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 2010, 10 lake trout were collected each from 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 17 years, 14 and 12 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 0.47 ± 0.21 (n=133) and 0.38 ± 0.25 (n=114) ug g^{-1}, respectively. In both lakes, levels are just below the recommended guideline level of 0.50 $\mu g\ g^{-1}$ 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=133) and Kusawa ([Hg]=m*length + b, m=0.0018, b=-0.5046, r2=0.52, $p<0.001$, n=114) 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 17 years. In Kusuwa Lake, after a significant drop in the trout muscle mercury concentrations in 2001, levels increased consistently until 2007. Significantly lower Hg concentrations were measured in the fish collected in both 2008 and 2009 but, seemed to increase again in 2010.

Table 1. Mean (standard deviation) concentrations of mercury, selenium and arsenic in lake trout muscle from Laberge and Kusawa Lakes. All levels are in µg/g.

	Year	n	Length	Hg	Se	As
Laberge	1993	13	483 (110)	0.44 (0.11)	0.45 (0.08)	0.15 (0.04)
	1996	18	472 (93)	0.32 (0.10)	0.32 (0.12)	0.12 (0.06)
	1998	7	700 (125)	0.61 (0.24)	0.42 (0.07)	0.18 (0.12)
	2000	6	590 (108)	0.43 (0.21)	0.66 (0.14)	0.13 (0.04)
	2001	22	639 (92)	0.54 (0.23)	0.57 (0.13)	0.10 (0.04)
	2002	5	570 (120)	0.38 (0.15)	0.61 (0.12)	0.11 (0.05)
	2003	8	593 (98)	0.56 (0.25)	0.47 (0.10)	0.10 (0.03)
	2004	5	614 (68)	0.54 (0.23)	0.38 (0.09)	0.09 (0.04)
	2005	10	606 (97)	0.50 (0.19)	0.47 (0.09)	0.06 (0.03)
	2006	1	800	0.68	0.45	0.08
	2007	9	674 (109)	0.70 (0.27)	0.42 (0.05)	0.08 (0.03)
	2008	10	580 (78)	0.37 (0.19)	0.43 (0.07)	0.06 (0.02)
	2009	10	538 (58)	0.41 (0.18)	0.41 (0.03)	0.06 (0.02)
	2010	10	547 (49)	0.49 (0.19)	0.45 (0.07)	0.08 (0.03)
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)

Organohalogens: Tables 2 and 3 list the mean wet weight HOC concentration in trout from Lake Laberge and Kusawa Lake, respectively, over the 16 year time period from 1983 to 2010. 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.

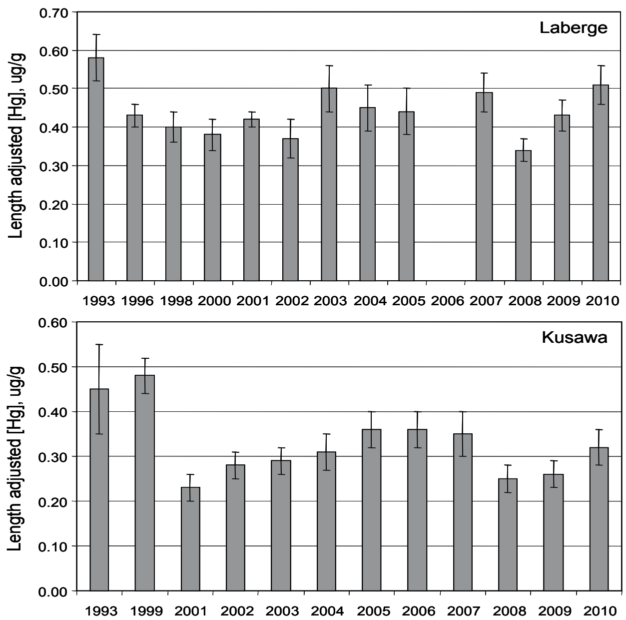

Figure 1. Length adjusted Hg concentrations in trout muscle from Lake Laberge (1993–2010) and Kusawa (1993–2010). Only Kusawa trout less than 700 mm in length were used in the ANCOVA.

Table 2. Mean (S.D.) HOC levels (ng/g wet wt.) in lake trout muscle from Lake Laberge

Laberge	N	Age	% lipid	ΣPCB	ΣDDT	ΣCHL	ΣHCH	ΣCHB	ΣCBz
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)

Table 3. Mean (S.D.) OC levels (ng/g wet wt.) in lake trout muscle from Kusawa Lake

Kusawa	N	Age	% lipid	ΣPCB	ΣDDT	ΣCHL	ΣHCH	ΣCHB	ΣCBz
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)

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)
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	6475 (2398)*	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)
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; *The value is being checked.

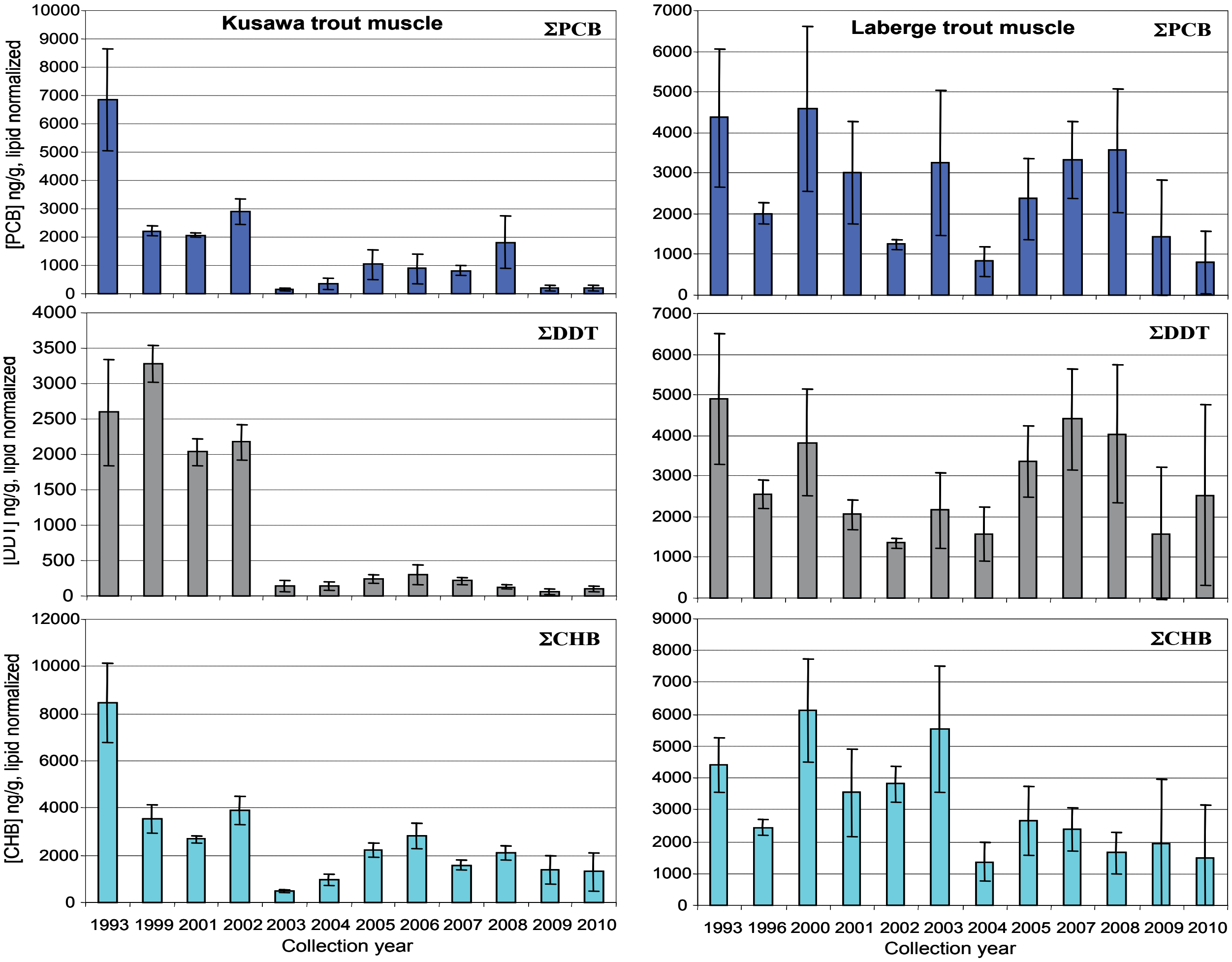

Figure 2. Lipid adjusted OC group concentrations in trout muscle from Kusawa and Laberge (1992–2010).

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.

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.

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

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Abstract

The objectives of this on going study are to maintain current data on contaminant levels in marine mammals and to continue to assess the temporal trends of halogenated organic compounds (HOCs). This will allow us to determine whether the levels of these compounds in the marine mammals, and hence exposure to Arctic people who traditionally consume them, are changing with time. These results will also help to test the effectiveness of international controls and, in conjunction with projects such as CFL (IPY & NSERC) and ArcticNet, to understand the effects that climate variation may have on these contaminant levels.

Key Messages

- No trends were observed for major OC groups in the western Arctic beluga. In particular, HCHs levels are not showing the declines observed atmospherically and in the Arctic Ocean since the ban in the usage of the technical mixture by China in 1983 and followed by India in 1990.

Résumé

Les objectifs de ses recherches longitudinales sont de maintenir des données à jour sur les niveaux de contaminants chez les mammifères marins et de continuer d'évaluer les tendances temporelles des composés organiques halogénés. Ceci nous permettra de déterminer si les niveaux de ses composants chez les mammifères marins, et plus particulièrement, l'exposition de la population de l'Arctique qui traditionnellement les consomme change avec le temps. Ces résultats nous aideront aussi à établir l'efficacité des contrôles internationaux en lien avec des projets tel que : CFL (API & NSERC) et ArticNet, nous permettant ainsi de comprendre les effets des changements climatiques sur ses niveaux de contaminants.

Messages clés

- Aucune tendances furent observées pour les groupes de composés organiques majeurs chez les bélugas d'Arctique de l'Ouest. En particulier, les concentrations de HCH ne sont pas à la baisse, tel qu'observé dans l'atmosphère et dans l'Océan Arctique depuis l'interdiction de son utilisation par la Chine en 1983 et l'Inde en 1990.

- Since 2006, on average, only four beluga were collected and analyzed annually from Pangnirtung. Such a small sample size makes any interpretation of the results highly improbable. Conversely, through funding from Nunavut Wildlife Management Board (until 2009) and the Department of Fish and Ocean, we have managed to accumulate an excellent series of samples from Sanikiluaq (1994, 1995, 1998, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010). As such, we propose, once again, that NCP consider switching our eastern Arctic temporal beluga monitoring location to Sanikiluaq. This will, however, entail additional retrospective analysis and costs to NCP.

- En moyenne depuis 2006, seulement quatres bélugas furent amassés et analysés annuellement à Pargnirtung. Une si petite échantillon rend l'interprètation des résultats très improbable. Avec l'aide de fonds du Conseil de gestion des réserves fauniques du Nunavut (jusqu'en 2009) et du Ministère PO, nous avons réussi à accumuler une excellente banque d'échantillons de Sanikiluaq (1994, 1995, 1998, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010). D'ailleurs, nous proposons que le Programme de lutte contre les contaminants dans le Nord (PLCN) considère le réaménagement de notre station d'analyse temporel des bélugas Arctique de l'Est. Par conséquent, ceci engendera des analyses rétrospectives et des coût supplémentaires pour le PLCN.

Objectives

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

Introduction

Marine animals accumulate (relatively) high concentrations of halogenated organic compounds (HOCs). The objectives of this project, therefore, are to maintain current data on contaminant levels in marine mammals and to continue to assess the temporal trends of halogenated organic compounds (HOCs). This will allow us to determine whether contaminant levels in the marine mammals, and hence exposure to Arctic people who traditionally consume them, are changing with time. These results will also help to test the effectiveness of international controls and, in conjunction with projects such as the IPY CFL (Circumpolar Flaw Lead) System Study and ArcticNet Phase 1 and II to understand the effects that climate variation may have on the contaminant levels in these animals and the health of the stocks.

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

Activities in 2010–2011

Samples collected and analysed to date are in Table 1–4. Since 2006, on average, only four beluga were collected and analyzed annually from Pangnirtung. Such a small sample size makes any interpretation of the results highly improbable. Conversely, through funding from NWMB and DFO, we have managed to accumulate an excellent series of samples from Sanikiluaq (1994, 1995, 1998, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010). As such, we propose, once again, that

NCP consider switching our eastern Arctic temporal beluga monitoring location to Sanikiluaq. This will, however, entail additional retrospective analysis and costs to NCP.

Results

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

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

Aging of the 2007–2010 Hendrickson Island beluga have now been completed. During the collection of the 2008 animals, there was a mix up with the labeling of the jaws (i.e. could not verify which jaws belonged to which animal tissues) but, genetic analysis has been employed to rectify the problem, Results are expected in the near future after which we will conduct use ANCOVA to correct the mean mercury concentrations for age. Once completed Stern and Loseto plan on publish an up-dated version of the paper by Lockhart et al. (2005).

Performance Indicators

- Northerners engaged in your project; All samples included in this study were collected as part of community monitoring programs.
- Leveraged funding (2010–11); FJMC \$20K, ArcticNet \$230K, CFL \$75K
- Meetings/workshops you held in the North;
    1) April 12, 2010. Interview with CBC North to discuss whale sampling program and results in Nunavut (this was organized through DFO and ArcticNet); http://www.cbc.ca/canada/north/story/2010/04/12/hudson-bay-belugas.html?ref=rss; A Radio news story ran: Interviews with G. Stern and S. Ferguson.
    2) February 2011. A Summary report was prepared and submitted to the Tuktoyaktuk HTC outlining the July 2010 Hendrickson Island beluga sampling field season.
    3) April 12–15, 2011. ArcticNet IRIS meeting in Inuvik
- Citable publications; (2008–2011)

1) 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.
2) 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.
3) Kuzyk, Z.A.; Macdonald, R.W.; Johannessen, S.C.; Stern, G.A. 2010. Biogeochemical controls on PCB deposition in Hudson Bay. Sci. Technol. 44, 3280–3285.

4) Loseto, L. L.; Stern, G. A.; Deibel, D.; Connelly, T. L.; Prokopowicz, A.; Fortier, L.; Ferguson, S. H. 2008a. Linking mercury exposure to habitat and feeding behaviour in Beaufort Sea beluga whales. J. Marine Systems, Special Issue: Sea ice and life in a river-influenced arctic shelf ecosystem, 74, 1012.

5) Loseto, L. L.; Stern, G. A.; Ferguson, S.H. 2008 Size and biomagnification: How habitat selection explains beluga mercury levels. Environ. Sci. Technol. 11, 3982–3988.

6) Loseto, L.L.; Stern, G.A.; Deibel, D.; Connelly, T.; Gemmill, B.; Prokopowicz, A.; Fortier, L.; Ferguson, S.H. 2009. Summer diet of beluga whales inferred by fatty acid analysis of the eastern Beaufort Sea food web. J. Experimental Marine Biology and Ecology, 374, 12–18.

7) Pucko, M.; Stern, G.A.; Macdonald, R.W.; Barber, D.G. 2010. 2α- and γ hexachlorocyclohexane (HCH) measurements in the brine fraction of sea ice in the Canadian High Arctic using a sump-hole technique. Environ. Sci. Technol. 44, 9258–9264.

8) Pucko, M.; Stern, G.A.; Barber, D.G.; Macdonald, R.W.; Rosenberg, B. 2010. International Polar Year (IPY) Circumpolar Flaw Lead (CFL) System Study: the importance of brine processes for α- and γ-hexachlorocyclohexane (HCH) accumulation/rejection in the sea ice. Atmosphere-Ocean, 48 (4) 2010, 0–00 doi:10.3137/OC318.2010.

9) Pucko, M.; Stern, G.A.; Macdonald, R.W.; Rosenberg. B.; Barber, D.G. 2011a. The influence of the atmosphere-snow-ice-ocean interactions on the levels of hexachlorocyclohexanes (HCHs) in the Arctic cryosphere. J. Geophysical Research – Oceans. 116, C02035, doi:10.1029/2010JC006614.

10) Pucko, M.; Stern, G.A.; Macdonald, R.W.; Barber, D.G.; Rosenberg. B.; Walkusz, W. When will α-HCH disappear from the Arctic Ocean? Submitted to Journal of Marine Systems, March, 2011b.

11) Chaulk, A.; Stern, G.A.; Armstrong, D.; Barber, D.G.; Wang, F. 2011. Mercury distribution and transport across the ocean-sea ice-atmosphere interface in the western Arctic Ocean. Environ. Sci. Technol., 45, 1866–1872.

Expected Project Completion Data

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

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

Loc	Year	Sex	n	Age	%lipid	ΣCBz	ΣHCH	ΣCHL	ΣDDT	ΣPCB	ΣCHB	Dieldrin	Oxychlor
HL	1989	M	12	29.0 (15.0)	90.5 (3.7)	421.5 (185.9)	269.3 (111.3)	1857.6 (667.8)	2930.8 (1125.8)	3800.0 (1587.7)	4548.0 (1462.6)	297.5 (112.1)	487.7 (143.6)
HI	1994	M	10	33.4 (10.8)	93.3 (2.8)	669.6 (168.7)	215.8 (55.5)	1601.4 (495.5)	4283.8 (2591.7)	3949.1 (1819.5)	11207.4 (6735.6)	324.2 (118.4)	477.0 (109.9)
HI	1995	M	15	32.1 (10.4)	81.3 (3.3)	783.2 (380.4)	211.9 (40.6)	2076.2 (1025.8)	3907.7 (1753.7)	4176.6 (1473.3)	6701.0 (3207.3)	287.9 (141.7)	519.1 (348.2)
HI	1996	M	10	27.5 (6.8)	92.4 (4.6)	666.3 (117.5)	243.0 (23.3)	1803.1 (274.0)	4415.3 (2030.9)	4246.8 (1146.9)	10519.3 (4708.5)	397.7 (133.4)	498.3 (45.0)
HI	2001	M	18	32.3 (9.7)	82.2 (3.5)	518.7 (169.4)	205.5 (44.0)	1932.4 (808.5)	3445.1 (1633.7)	3986.7 (1737.5)	6266.4 (3634.6)	296.9 (103.9)	499.0 (225.6)
HI	2002	M	9	30.4 (8.1)	90.9 (2.2)	421.1 (109.1)	234.3 (34.8)	1408.9 (351.3)	2480.3 (1361.5)	2745.7 (1033.7)	7024.5 (3324.2)	376.0 (113.4)	439.9 (126.1)
HI	2003	M	9	27.2 (9.3)	91.3 (3.9)	518.3 (113.2)	243.1 (50.1)	1556.5 (361.5)	2736.0 (2134.3)	3084.4 (1462.9)	6188.5 (2600.1)	338.4 (100.7)	519.7 (119.3)
HI	2004	M	10	25.3 (6.0)	85.1 (6.8)	888.0 (189.0)	329.2 (50.8)	2932.8 (535.7)	3747.0 (1928.3)	4894.1 (948.8)	7554.1 (2360.1)	500.7 (99.4)	744.8 (192.5)
HI	2005	M	10	26.8 (9.6)	92.4 (3.4)	623.5 (196.3)	269.3 (68.2)	2568.5 (1715.6)	4545.8 (3595.3)	3633.1 (1906.5)	5680.1 (3776.0)	447.0 (186.8)	991.7 (684.7)
HI	2006	M	14	23.6 (7.2)	90.8 (6.2)	567.6 (197.7)	229.8 (33.6)	1498.8 (416.7)	2017.0 (851.8)	3100.2 (1081.7)	3673.6 (1614.5)	289.0 (80.4)	518.23 (162.2)
HI	2007	M	10	25.0 (19.2)	86.0 (9.9)	650.1 (251.8)	254.7 (31.9)	2236.1 (853.1)	3805.4 (2124.4)	3744.1 (1391.8)	7226.1 (3276.8)	359.3 (114.0)	698.4 (281.2)
HI	2008	M	10	25.5 (12.2)	80.1 (5.9)	392.4 (90.5)	121.5 (23.5)	1412.5 (582.7)	1348.7 (698.8)	3006.6 (1247.6)	4585.5 (2707.9)	209.2 (68.6)	290.5 (99.5)
HI	2009	M	10	nd	94.0 (3.7)	434.8 (131.1)	191.2 (88.6)	1336.7 (380.6)	4309.7 (2317.5)	3697.7 1475.1)	7268.0 (4382.7)	347.7 (99.6)	432.0 (133.4)
HI	2010	M	10	23.8 (3.5)	92.1 (3.5)	497.7 (93.8)	222.4 (48.0)	1074.5 (260.1)	2619.5 (866.3)	2397.5 (438.4)	6081.2 (2470.8)	384.0 (97.2)	522.3 (104.3)

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

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

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

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

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

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

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

Resolving the Arctic Ocean Monomethylmercury Conundrum

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Abstract

Monomethyl mercury (MMHg), a toxic form of mercury (Hg) that bioaccumulates through foodwebs, is present in some Arctic marine mammals and fish at concentrations above the Canadian commercial marketing limit. However, the source of MMHg to Arctic marine foodwebs has remained extremely elusive. Our previous research has shown that there are very high concentrations of "methylated Hg" species in Arctic marine waters, but it appears that most of it is in the non-bioaccumulative dimethyl Hg (DMHg) form. MMHg concentrations are extremely low in bulk seawater samples and insufficient to explain MMHg concentrations in pelagic marine organisms inhabiting the water column. This leaves us with a conundrum: where is the MMHg in pelagic marine organisms coming from? We have conducted unique experiments using Hg

Résumé

Le mercure monométhylique (MMHg), une forme toxique de mercure (Hg) bioaccumulable dans la chaîne alimentaire, est présent dans certains mammifères marins et poissons de l'Arctique dans des concentrations excédant la limite permise pour la commerciale de ces espèces au Canada. La source du MMHg se retrouvant dans la chaîne alimentaire de la population marine de l'Arctique nous échappe encore. Nos recherches précédentes ont démontré qu'il existe des concentrations extrêmement élevées de « Hg méthylé » dans les espèces des eaux marines arctiques, mais dans la plupart des cas, il s'agit de diméthylmercure (DMHg) non biocumulateur. Les concentrations de MMHg relevées dans les échantillons globaux d'eau de mer sont extrêmement basses et insuffisantes pour expliquer la présence de concentrations de MMHg dans les organismes marins pélagiques habitant la colonne d'eau, ce qui suscite

stable isotope tracers that show MMHg is definitely being produced in Arctic marine waters. But because bulk water samples have low concentrations of MMHg, we now hypothesize that inorganic Hg(II) is methylated to MMHg on the surface of particles by bacteria, where it remains bound and concentrated at much higher concentrations than observed in bulk water samples. Pelagic organisms feeding on these MMHg-rich particles/bacteria then become the primary source of MMHg to marine organisms at the top of the foodweb. We tested this critical hypothesis at five sites while aboard the CCGS Amundsen as it sailed through the Northwest Passage and into the Beaufort Sea in August of 2010. All water samples have been analysed for concentrations of total Hg (THg; all forms of Hg in a sample), MMHg and DMHg. Particulate samples have also been analysed for MMHg. We are currently processing and interpreting the data, and will soon begin drafting a manuscript detailing our findings for publication in a peer-reviewed scientific journal.

des interrogations : d'où provient le MMHg présent dans les organismes marins pélagiques? Nous avons effectué des expériences uniques en leur genre fondées au moyen de traceurs isotopiques stables du mercure qui montrent que le MMHg est assurément produit dans les eaux marines arctiques. Cependant, parce que les échantillons globaux d'eau contiennent de faibles concentrations de MMHg, nous formulons maintenant l'hypothèse que le Hg(II) inorganique est méthylé par des bactéries à la surface des particules et transformé en MMHg, où il reste lié et concentré en quantités largement supérieures à celles que l'on observe dans les échantillons globaux d'eau. Les organismes pélagiques qui se nourrissent de ces particules et bactéries riches en MMHg deviennent ensuite la source principale de MMHg pour les organismes marins au sommet de la chaîne alimentaire. Nous avons mis cette hypothèse critique à l'épreuve dans cinq endroits pendant notre séjour à bord du CCGS Amundsen qui a traversé le passage du Nord-Ouest et navigué jusqu'à la mer de Beaufort au mois d'août 2010. Tous les échantillons d'eau ont été analysés afin de mesurer les concentrations totales de Hg (THg; toutes les formes de Hg se trouvant dans l'échantillon), MMHg et DMHg. Des échantillons particuliers ont aussi été analysés pour mesurer la présence de MMHg. À l'heure actuelle, nous traitons et interprétons les données, et rédigerons bientôt un document présentant nos conclusions aux fins de publication dans une revue scientifique évaluée par des pairs.

Key Messages

- MMHg, the toxic and bioaccumulative form of Hg, is produced in Arctic seawaters.
- Concentrations of MMHg dissolved in seawater, however, are too low to result in significant bioaccumulation.
- We hypothesize that inorganic Hg(II) is methylated to MMHg on the surface of particles by bacteria, where it remains bound and concentrated at much higher concentrations than observed in bulk water samples.
- Pelagic organisms consuming these MMHg-rich particles/bacteria then become the primary source of MMHg to upper marine trophic levels.

Messages clés

- MMHg, la forme toxique d'Hg biocumulative, est produite dans les eaux marines arctiques.
- Les concentrations de MMHg dissoutes dans l'eau de mer sont toutefois trop faibles pour entraîner une bioaccumulation significative.
- Nous avons émis l'hypothèse que l'Hg (II) inorganique est méthylé par les bactéries à la surface des particules et se transforme en MMHg, où il reste lié et concentré en quantités largement supérieures à celles que l'on observe dans les échantillons globaux d'eau.
- Les organismes pélagiques consomment ces particules ou bactéries riches en MMHg, puis deviennent la source principale de MMHg dans les niveaux trophiques marins supérieurs.

Objectives

The primary objective of our research is to resolve the conundrum as to the source of MMHg to Arctic marine foodwebs, especially those foodwebs that are pelagic (open ocean) in origin. We are addressing this objective by quantifying individual pools of MMHg in Arctic marine waters that are bioavailable for accumulation at the base of food webs.

Introduction

MMHg, a toxic form of Hg that bioaccumulates through foodwebs, is present in some Arctic marine mammals at concentrations above the Canadian fish commercial sale limit of 0.5 $\mu g\ g^{-1}$ wet weight (ww) (Arctic Monitoring and Assessment Programme 2002). In the North Open Water (NOW), for example, a large productive polynya in the Canadian Arctic, concentrations of MMHg in muscle of ringed seals are 0.56 ± 0.25 $\mu g\ g^{-1}$ ww (Campbell et al. 2005). At this average concentration, Northern people could eat approximately 90 g of seal meat per week before consuming the U.S. Environmental Protection Agency's maximum MMHg weekly limit of 50 μg. Although there is some evidence that concentrations of MMHg in Arctic marine mammals have increased since industrialization (Outridge et al. 2005), sources of MMHg to Arctic marine foodwebs have remained extremely elusive.

We have recently published a number of papers examining potential sources of MMHg to Arctic marine waters. For example, in 2004 we sampled seawater and snowpacks in the Canadian high Arctic for methylated species of Hg (St.Louis et al. 2007). We discovered that, although seawater sampled under the sea ice had very low concentrations of THg (on average 0.14–0.24 ng L-1), 30–45% of the THg was in the methylated form, which we thought was primarily MMHg (on average 0.057–0.095 ng L-1). We also found 11.1 ± 4.1 pg L-1 of DMHg in seawater and calculated that there could be a significant flux of DMHg to the atmosphere from open water regions. This flux could then result in MMHg deposition into nearby snowpacks via photolysis of DMHg to MMHg in the atmosphere. In fact, we found high concentrations of MMHg in a few snowpacks near regions of open water. Overall, though, the median wet/dry loads of 0.03 mg MMHg ha-1 in high Arctic snowpacks were far below wet-only annual MMHg loadings in areas such as the remote Boreal ecoregion of Canada (0.5 ± 0.2 mg ha-1). Therefore, most Arctic snowpacks contribute relatively little to marine pools of MMHg at snowmelt.

From 2003 to 2007, we also continuously measured concentrations of MMHg in two Canadian sub-Arctic rivers (the Nelson and the Churchill) that drain into western Hudson Bay to determine if they could be sources of MMHg to marine waters (Kirk et al. 2008b). MMHg concentrations were low in the Nelson River (0.05 ± 0.03 ng L-1). The Churchill River, however, had relatively high concentrations of MMHg (0.18 ± 0.09 ng L-1) and hence may be an important source of MMHg to organisms feeding in the Churchill River estuary. Despite high Churchill River MMHg concentrations, average MMHg exports to Hudson Bay from the Churchill River (4 ± 4 kg year-1) were about half the Nelson River exports (9 ± 4 kg year-1), due to the larger flow of the Nelson River. Interestingly, combined MMHg exports to Hudson Bay from Nelson and Churchill River discharge were ~13 times greater than MMHg snowmelt inputs (1 ± 1 kg year-1). Although Hg inputs from rivers and snowmelt together potentially accounted for a large portion of the THg pool in Hudson Bay, the inputs accounted for a lesser portion of the MMHg pool, thus highlighting the importance of Hg(II) methylation in Hudson Bay waters as a source of MMHg to marine food webs.

We also examined the distribution of THg, gaseous elemental Hg(0) (GEM), DMHg and MMHg in marine waters of the Canadian Arctic Archipelago (CAA), Hudson Strait, and Hudson Bay (Kirk et al. 2008a). Concentrations of THg were low throughout the water column in all regions sampled (0.40 ± 0.47 ng L-1). Concentrations of MMHg were also generally low at the surface (23.8 ± 9.9 pg L-1); however at mid- and bottom depths, MMHg was present at concentrations that we thought were sufficient to initiate bioaccumulation of MMHg through Arctic marine pelagic foodwebs (maximum 178 pg L-1; 70.3 ± 37.3 pg L-1). In addition, at mid and bottom depths, the % of THg that was

MMHg was high (maximum 66%; 28 ±16%), suggesting that active methylation of inorganic Hg(II) occurs in sub-surface Arctic marine waters.

At the time, our results suggested that the concentrations of MMHg in sub-surface polar marine waters were high enough to initiate the biomagnification of MMHg documented in, for example, the NOW and Beaufort Sea marine pelagic food webs, where MMHg concentrations in lower food chain organisms (e.g., zooplankton) were 3-4 ng g^{-1} ww (Campbell et al. 2005; Stern and Macdonald 2005). Using our measured seawater MMHg concentrations, we calculated log bioaccumulation factors (BAFs), defined as the log of the ratio of the concentration of MMHg in zooplankton (ng g^{-1} ww) to the concentration of MMHg in water (ng mL-1), of between 4.6 and 4.8 for the zooplankton, identical to log BAFs quantified from zooplankton in freshwater systems in northwestern Ontario (4.4 to 4.8).

Interestingly, there was a significant correlation between concentrations of MMHg and DMHg at all sites and depths (slope=0.87), which initially suggested to us that "methylated Hg" species are in equilibrium with each other and/or were produced by similar processes throughout the water column. This may still be true. However, the actual concentrations of MMHg we and others have reported in the past may be incorrect.

Historically, we sampled for DMHg by purging seawater samples with ultra-high purity (UHP) nitrogen gas, and trapping volatile DMHg on carbotraps. We sampled for MMHg by collecting another water sample and preserving it with trace-grade sulfuric acid (H2SO4) equivalent to 0.5% of the sample volume, as was done in all other marine studies (e.g., Mason et al. 1998, Sunderland et al. 2009). Unfortunately, it was recently discovered using laboratory experiments that when a seawater sample is acidified for preservation purposes, the DMHg in the sample is readily converted to MMHg (Black et al. 2009). This gives the impression that there are high concentrations of MMHg in seawater, when in fact it is total "methylated Hg" species that we are actually quantifying (i.e., MMHg + DMHg). Luckily, we measured both DMHg and "methylated Hg" species at each of our Arctic marine sites in the past so that we can back calculate out the MMHg-only component as follows:

$$\text{MMHg} = (\text{Methylated Hg} - \text{DMHg}) \quad \ldots(1)$$

When these calculations are done, concentrations of MMHg in bulk water samples are actually very low and insufficient to explain the bioaccumulation of MMHg into the pelagic foodweb. On average, only 13% of what we previously called MMHg is actually MMHg (maximum 0.023 ng L-1; 0.009 ± 0.005 ng L-1). However, we do not know the efficiency at which DMHg is converted to MMHg when acidification occurs. For example, because DMHg is gaseous, there may be some loss of DMHg from samples prior to or during the acidification process, especially as MMHg samples were collected in Teflon bottles, which are not gas tight, whereas DMHg samples were collected in gas tight glass vessels. If some of the DMHg is lost, MMHg concentrations calculated from equation (1) would be underestimated. Research in a field setting was required to elucidate how much of the DMHg present in Arctic marine water is converted to MMHg upon acidification, and how "true MMHg" concentrations can be calculated from previously collected acidified "methylated Hg" samples.

Igor Lehnherr (Postdoctoral Fellow, University of Alberta) recently published a manuscript in the prestigious journal Nature Geoscience (Lehnherr et al. 2011) showing that inorganic Hg(II) is actively being methylated in bulk seawater samples (also see Monperrus et al. 2007). Dr. Lehnherr has quantified methylation and demethylation rate constants (kM and kD) using stable Hg isotope tracers in unique incubation experiments. For example, Dr. Lehnherr has measured the rate at which the Hg(II) tracer (198Hg(II)) is being methylated to form MM198Hg, and the rate at which the MMHg tracer (MM199Hg) is simultaneously being demethylated. The difference between these two rates provides a measure of net MMHg production in seawater. These highly technical experiments showed that at most of the polar ocean sites he sampled, MMHg is being produced in the water column of polar oceans.

This has now left us with a really big conundrum! Where are pelagic organisms getting their MMHg if MMHg concentrations are extremely low in bulk water samples, and DMHg is not bioaccumulated? Because Hg(II) methylation (i.e., MMHg production) is occurring in the water column of Arctic marine seawaters as shown by Dr. Lehnherr, we hypothesized that inorganic Hg(II) is methylated to MMHg on the surface of particles by bacteria, where it remains bound and concentrated at much higher concentrations than observed in bulk water samples. Pelagic organisms consuming these MMHg-rich particles/bacteria then become the primary source of MMHg to upper marine trophic levels.

Activities in 2010–2011

To test our hypothesis, there were two major components to our research program:

1) quantify the actual concentrations of MMHg in Arctic seawaters, and

2) quantify the concentration of MMHg on bacteria/particles.

The field portion of this research program was conducted aboard the CCGS Amundsen icebreaker at five sampling stations in the Northwest Passage of the Canadian Arctic Archipelago during August 2010. At each sampling station, we sampled water from 4 different depths (surface waters (0–5 m); depth of the chlorophyll maximum (30–60 m); mid-column or depth of oxygen minimum (150–400 m); and bottom waters (200–800 m).

1) Quantifying the actual concentrations of MMHg in Arctic seawaters:
At each sampling station and depth, we collected:

1. a bulk water sample that was acidified with trace-grade H2SO4 equivalent to 0.5% of the sample volume to determine the concentration of "methylated Hg" species in the sample as has always been done in the past.
2. a bulk water sample that was first be purged with UHP nitrogen gas onto carbotraps to remove DMHg from the water and quantify DMHg concentrations, and then acidified with trace-grade H2SO4 equivalent to 0.5% of the sample volume to actually quantify the true concentration of MMHg left behind once the DMHg as been removed.

This protocol allowed us to not only quantify the true concentration of MMHg in seawater, but also develop a relationship between "methylated Hg" and true MMHg concentrations to back calculate previously collected data in Arctic seawaters. This protocol also allowed us to develope a standard (and proper) protocol for all future MMHg sampling in marine waters.

2) Quantifying the concentration of MMHg on bacteria/particles:
It was extremely important to collect bacteria/particles and directly quantify MMHg concentrations on them. Therefore, we filtered a known volume of seawater (12 L) through pre-weighed, acid-rinsed Whatman cellulose nitrate filters with pore sizes of 0.2 μm in Teflon filter towers to collect both particles and bacteria. Following sampling, filters were freeze-dried, reweighed and analysed for MMHg concentrations. This methodology allowed us to calculate both concentrations of MMHg on bacteria/particles (ng g^{-1}), and concentrations of particle-bound MMHg in bulk water samples (ng L-1).

Analyses of samples:
All samples were collected using strict clean-hands, dirty-hands sampling protocols. Samples were either analysed in the University of Alberta Low-level Mercury (Hg) Analytical Unit (THg and MMHg) or the Trent University Worsfold Water Quality Centre (DMHg), both of which have successfully participated in international and inter-laboratory Hg analytical comparisons over the past 8 years. Analytical protocols used for this study were recently detailed in Lehnherr et al. (2011).

Capacity Building and Communications:
Prior to originally submitting our proposal to the NCP, we contacted via e-mail the NWT Regional Contaminants Committee (Lorna Skinner), Inuit Research Advisor for research in the Inuvialuit region (Shannon O'Hara), Niqiit Avatittinni Committee (Nunavut; Erika Solski) and the Inuit Research Advisor for Nunavut (Stephanie McDonald). We were encouraged to visit as many communities as possible while onboard the CCGS Amundsen in 2010, including Resolute Bay, Kugluktuk, Cambridge Bay, Tuktoyaktuk and Sachs Harbour. However, the journey through the Northwest Passage was so quick that we did not have a chance to visit these communities while also conducting our research. However, Dr. Lehnherr did conduct a lecture for the "Schools on Board" program while aboard the

CCGS Amundsen, describing contaminants in the Arctic, using Hg as a special case and teaming up with others who talked about organic contaminants. Dr. Lehnherr also gave students a tour of his onboard laboratory, and taught students how to pipette and filter samples for water chemistry analyses. There were 8–9 students involved with Schools on Board, 3–4 of who were from northern communities (e.g., Inuvik and Rankin Inlet). Dr. Lehnherr, Anabelle Baya and Fiona Wong also created a Powerpoint presentation that will be used as a "canned" talk for future Schools on Board. Dr. Lehnherr also presented a poster describing his research proposal at the 18th annual NCP Results Workshop in Whitehorse, Yukon (28–30 September 2011), and will also present his findings at the ArcticNet Annual Meeting in December 2011.

Results

All samples were successfully collected and analyzed. At this time, we are in the process of QA/QCing the data, as well as interpreting them within the context of our hypotheses.

Discussion and Conclusions

We will provide a discussion of our results as soon as we have them interpreted. Our goal is to have a manuscript drafted by the end of the summer for submission to a peer-reviewed scientific journal.

NCP Performance Indicators

- *Number of northerners engaged in your project:* 3–4 (Schools on Board).
- *Number of meetings/workshops you held in the North:* 1–2 (Schools on Board).
- *Number of students (both northern and southern) involved in your NCP work:* 3–4 (Schools on Board); 1 Postdoctoral Fellow (Dr. Lehnherr); 1 PhD Candidate (Anabelle Baya); 1 undergraduate NSERC summer student (Tracy Zhang).
- *Number of citable publications (e.g., in domestic/international journals, and conference presentations, book chapters, etc):* None yet.

Expected Project Completion Date

September 2011.

Acknowledgments

We wish to thank Valery Bazira Girishaka, Crystal Raab and Brian Dimock for their help in analyzing the samples. We also appreciate the logistical support of the ArcticNet program while aboard the CCGS Amundsen icebreaker.

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Temporal Trends of Halogenated Organic Chemicals in Beluga Whales (*Delphinapterus leucas*) from Hendrickson Island and Pangnirtung

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Abstract

This long-term study is examining the temporal trends of halogenated organic chemicals in beluga whales from two sites: Hendrickson Island (HI) and Pangnirtung. Our time-series dates back to the early 1980s and the resolution or frequency of our time-series is particularly strong for samples collected post-2000: in the HI animals, for example, our data-set includes collections from 1984, 1993 and every year from 2000 to 2010. Similarly, for Pangnirtung, our data-set includes animals sampled in 1982, 1986, 1992, 1995 and every year from 2000 to 2010 with the exception of 2003, 2004 and 2009. The chemicals of interest include the suite of fluorinated surfactants, brominated flame retardants, polychlorinated naphthalenes (PCNs) and short-chain chlorinated paraffins (SCCPs). Concentrations of Σ2HBCD (sum of α- and β-isomers) were much smaller than Σ6BDEs and were typically smaller than 5ng/g in animals from both locations. Liver-based concentrations of C8-C12 perflurocarboxylic acids (Σ5PFCAs) in animals from HI showed a decline over our study period at a rate of ca. 8 ng/g per

Résumé

Cette étude à long terme examine les tendances temporelles des produits chimiques organiques halogénés décelés chez les bélugas à deux emplacements : Hendrickson Island (HI) et Pangnirtung. Nos séries chronologiques remontent au début des années 1980. La fréquence de ces dernières est particulièrement élevée pour les échantillons prélevés après l'année 2000. À titre d'exemple, chez les spécimens de HI, notre ensemble de données comprend des collections de 1984, de 1993 et de chaque année pour la période allant de 2000 à 2010. En ce qui concerne Pangnirtung, notre ensemble de données comprend des prélèvements effectués en 1982, en 1986, en 1992, en 1995 et chaque année durant la période allant de 2000 à 2010, sauf en 2003, 2004 et 2009. Les produits chimiques d'intérêt comprennent l'ensemble des surfactants fluorés, des produits ignifuges bromés, des naphtalènes polychlorés (NPC) et des paraffines chlorées à courte chaîne (PCCC). Les concentrations de Σ2HBCD (somme des isomères α- et β)) étaient plus faibles que celles des Σ6BDE et généralement moindres que 5 ng/g chez les animaux des deux sites. Les

year. No clear discerning trend was observed for Σ5PFCAs in animals from Pangnirtung. For PFOS, there was linear increase (0.53 ± 0.10 ng/g, per year) in measured concentrations from 1984 to 2000 (r2=0.4319, p<0.01) in animals from HI. After that time, concentrations have remained relatively stable at ca. 10 ng/g (wet weight). The temporal trend profile in PFOS for animals from Pangnirtung was similar to what we observed for animals from HI. PCNs were measured in animals from HI sampled in 2000 and 2008. Mean ΣPCNs in animals from 2000 (254.3 ± 33.7 pg/g, wet weight) were similar to that for animals collected in 2008 (257.7 ± 26.8 pg/g, wet weight).

Key Messages

- Relative to BDEs, Σ2HBCD concentrations in animals from both locations were small [< 5 ng/g (lipid weight)]. There was a small increase in Σ2HBCD concentrations in animals from Pangnirtung over our study period (0.06 ng/g per annum); animals from HI showed a similar increase from 1993 to 2009 but we did observe a notable decrease in concentrations in 2010;
- Concentrations of Σ5PFCAs in beluga from HI showed a significant decrease in concentrations of a rate of ca. 8 ng/g per year. The temporal trends for Σ5PFCAs in animals from Pangnirtung was not clear;
- From the 1980s to 2000, liver based concentrations of PFOS increased linearly in animals from both study sites. After that time, PFOS concentrations have remained relatively stable at ca. 10 ng/g (wet weight) in animals from HI, but have declined in animals from Pangnirtung;
- There were no statistical differences (Student t-test, p>0.05) in the concentrations of ΣPCNs in animals from HI analyzed from 2000 and 2008.

concentrations d'acides perfluoro-carbozyliques C8-C12 (Σ5APFC) dans le tissu hépatique des animaux de HI indiquent qu'au cours de la période sur laquelle s'est échelonnée notre étude, il y a eu une baisse d'environ 8 ng/g par an. On n'a observé aucune tendance distincte quant aux Σ5APFC chez les animaux de Pangnirtung. En ce qui a trait aux perfluorooctanesulfonates (PFOS), on a relevé une augmentation linéaire (0,53 ± 0,10 ng/g, par an) dans les concentrations mesurées de 1984 à 2000 (r2=0,4319, p<0,01) chez les animaux de HI. Après cette période, les concentrations sont demeurées relativement stables à un niveau d'environ 10 ng/g (poids frais). Le profil de la tendance temporelle en ce qui a trait aux PFOS chez les animaux de Pangnirtung était semblable à celui des animaux de HI. Les NPC (naphtalènes polychlorés) ont été mesurés chez les animaux de HI échantillonnés en 2000 et en 2008. Le niveau moyen de NPC chez les animaux échantillonnés en 2000 (254,3 ± 33,7 pg/g, poids frais) était similaire à celui des animaux échantillonnés en 2008 (257,7 ± 26,8 pg/g, poids frais).

Messages clés

- En ce qui a trait aux BDE, les concentrations de Σ2HBCD chez les animaux des deux emplacements étaient faibles [< 5 ng/g (poids lipidique)]. Une légère augmentation du taux de concentration de Σ2HBCD a été relevée chez les animaux de Pangnirtung au cours de la période sur laquelle s'est échelonnée notre étude (0,06 ng/g par an); une augmentation similaire a été relevée chez les animaux de HI de 1993 à 2009, mais nous avons toutefois relevé une diminution importante de ces concentrations en 2010.
- En ce qui concerne les concentrations de Σ5APFC chez les bélugas de HI, on a observé une diminution importante d'environ 8 ng/g par an. Il a été impossible d'établir des tendances temporelles précises en ce qui a trait aux Σ5APFC chez les animaux de Pangnirtung.
- Des années 1980 aux années 2000, on a observé une augmentation linéaire des concentrations de PFOS dans le tissu hépatique des animaux des deux emplacements visés par l'étude. Après cette période, les concentrations de PFOS sont demeurées relativement stables à environ 10 ng/g (poids frais) chez les animaux de HI, mais elles ont baissé chez les animaux de Pangnirtung.

- On n’a relevé aucune différence statistique (test t de Student, p>0,05) dans les concentrations de ΣNPC au cours des analyses des animaux visés par l’étude menée à HI de 2000 à 2008.

Objectives

- To continue to build on our temporal trend data set for a suite of halogenated chemicals of emerging concern in beluga whales from Hendrickson Island (HI) and Pangnirtung.

Introduction

Our knowledge of the contemporary and/or historical environmental emissions of many anthropogenic chemicals is quite sparse. One means of constructing the emission profile of a chemical is to examine concentrations in a well defined environmental compartment. Because of their abundance, ecological significance and that they are top TL animals, beluga whales make an ideal bio-indicator species. The overriding assumption in using beluga whales as an indicator species to track emissions of chemicals is that changes in the inputs of any persistent chemical into the environment will be reflected by a similar concentration change in these animals. While it is thought that changes in climate could confound interpretations of temporal trend studies there is currently no method to control or correct for this variable.

This current study builds on our annual sampling campaign and chemical analyses of beluga whales for halogenated organic chemicals from two locations in the Canadian Arctic: Hendrickson Island and Pangnirtung.

Activities in 2008–2009

Samples investigated: The animals selected for study were stored in our archived repository at Fisheries & Oceans Canada. Beluga from Hendrickson Island (HI: 1984, 1993, 1995, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009 and 2010) and Pangnirtung (1982, 1986, 1992, 1995, 2002, 2005, 2006, 2007, 2008 and 2010) were the basis of our time-trend study. Table 1 shows the number of animals analyzed from each of the collection years; when available, ten male animals were selected for study.

Chemical analysis: Analytical methods adopted for our study have already been published in the peer-review literature. All analyses except that of PCNs which was done at Ontario Ministry of the Environment (OMOE) were performed in the toxic aquatic chemical laboratory at Fisheries & Oceans Canada, Winnipeg. Hydrophobic chemicals like BDEs, HBCD, SCCPs and PCNs were analyzed in the blubber of animals as described previously (Tomy et al., 2008;Tomy et al., 1997; Helm et al. 2002). BDEs were analyzed by gas chromatography with electron capture negative ion (ECNI) low resolution mass spectrometry. Quantification of BDE congeners were done using external standard solutions. Total BDE congeners are based on the sum of -47, -85, -99, -100, -153 and -154. Isomers of HBCD were analyzed by liquid chromatography tandem mass spectrometry in the negative electrospray ionization mode. Total HBCD is based on the sum of the α- and γ-diastereoisomers. SCCPs were analyzed by high resolution mass spectrometry. Total SCCP concentrations are based on the sum of C10-C13 chain lengths and were analyzed by GC-high resolution mass spectrometry (GC-HRMS). PCNs were also analyzed by GC-HRMS and quantified by isotope dilution. Fluorinated compounds were extracted and analyzed in the liver of the animals as described in Tomy et al. (Tomy et al., 2005;Tomy et al., 2009). Compounds investigated include perfluorooctanoate (C8: PFOA), perfluorononanoate (C9: PFNA), perfluorodecanoate (C10: PFDA), perfluoroundecanoate (C11: PFUA), perfluorododecanoate (C12: PFDoDA), perfluorooctane sulfonate (PFOS) and perfluorooctane sulfonamide (PFOSA). Total perfluorinated carboxylate concentrations are based on the sum of C8-C12.

Table 1. Geometric mean (GM), maximum (max) and minimum (min) concentrations (ng/g) of chemicals of emerging concern in beluga whales from Hendrickson Island[a].

Year	N		Σ_6BDEs	Σ_2HBCD	ΣSCCPs	Σ_5PFCAs	PFOS	PFOSA
1984[b]	10	GM				156.83	4.85	48.09
		min				98.35	2.23	8.47
		max				235.32	10.40	111.67
1993	10	GM	5.21	0.34	340.01	147.35	10.46	102.79
		min	3.61	0.086	114.88	71.71	4.37	65.72
		max	7.57	4.59	493.85	313.10	15.89	154.94
1995	10	GM	6.31	1.39	254.12	116.08	10.04	97.67
		min	3.76	0.88	44.02	35.01	5.0	44.19
		max	10.49	5.88	399.87	282.37	14.8	216.07
2000	10	GM	9.18	1.20	NC[c]	45.32	13.63	7.32
		min	4.27	0.095		22.92	8.58	3.87
		max	17.62	2.77		113.82	20.27	16.33
2001	11	GM	8.89	2.22	204.64	30.73	9.87	65.61
		min	1.54	0.75	30.38	6.02	5.22	31.90
		max	17.14	5.48	192.91	88.61	16.12	146.52
2002	10	GM	8.31	0.82	NC	37.17	8.08	22.26
		min	3.51	0.13		15.47	1.67	5.40
		max	18.50	1.72		78.63	24.26	51.74
2003	11	GM	11.63	2.15	NC	38.67	12.01	7.81
		min	7.02	1.28		21.68	5.71	4.56
		max	24.32	3.36		76.21	19.91	16.54
2004	10	GM	18.39	2.95	NC	21.57	11.21	6.96
		min	14.56	2.26		8.72	6.88	4.45
		max	25.94	3.68		50.32	24.12	12.05
2005	10	GM	4.77	1.70	248.98	67.16	11.91	127.01
		min	1.29	0.85	3.06	35.64	6.01	48.23
		max	15.69	3.32	430.26	122.69	23.04	228.40
2006	10	GM	8.63	1.17	3.96	9.72	7.98	22.51
		min	4.43	0.77	0.82	4.87	1.67	5.41
		max	17.10	2.98	13.90	16.03	24.26	51.74
2007	10	GM	8.91	1.37	NC	43.64	11.17	16.09
		min	1.86	0.62		29.77	4.25	7.76
		max	15.03	3.47		82.81	20.32	24.47
2008	10	GM	8.66	2.53	NC	9.88	6.71	8.59
		min	1.55	1.36		5.19	4.17	3.77
		max	22.76	3.97		21.31	11.67	14.03

Year	N		Σ_6BDEs	Σ_2HBCD	ΣSCCPs	Σ_5PFCAs	PFOS	PFOSA
2009	10	GM		1.82	NC	24.83	9.58	25.65
		min		0.62		14.89	6.26	16.14
		max		6.97		62.68	18.06	51.74
2010	10	GM		0.66	NC	34.84	10.16	15.03
		min		0.13		17.81	7.25	9.57
		max		1.45		67.65	13.71	29.72

[a] concentrations of Σ_6BDEs, Σ_2HBCD and ΣSCCPs were determined in the beluga blubber and are expressed on a lipid weight basis. Σ_5PFCAs, PFOS and PFOSA were measured in the liver and are expressed on a wet weight basis; [b]blubber samples were not available for this year; [c]NC=not complete.

Table 2. Geometric mean (GM), maximum (max) and minimum (min) concentrations (ng/g) of chemicals of emerging concern in beluga whales from Pangnirtung[a].

Year	N		Σ_6BDEs	Σ_2HBCD	ΣSCCPs	Σ_5PFCAs	PFOS	PFOSA
1982	8	GM	3.50	0.17	199.04	9.56	10.67	21.27
		min	2.79	0.08	108.28	6.06	7.25	13.83
		max	6.23	0.97	320.12	27.19	19.30	31.24
1986	7	GM	3.61	0.09	161.49	5.07	14.24	42.26
		min	3.00	0.03	83.33	1.46	9.28	33.06
		max	5.01	1.72	513.90	12.79	20.19	47.41
1992	8	GM	6.24	1.17	330.28	9.49	20.61	48.12
		min	4.72	0.54	101.64	4.03	14.83	29.70
		max	9.63	2.01	724.19	22.30	31.40	74.03
1995	10	GM	5.60	0.04	116.90	14.52	14.58	44.64
		min	3.08	0.03	98.58	7.02	5.39	24.46
		max	15.68	0.61	282.48	24.65	43.43	120.43
2000	4	GM	17.14	1.51	NC[b]	95.14	29.09	16.71
		min	14.73	0.93		52.04	12.26	9.94
		max	20.89	2.63	NC	163.13	56.24	22.59
2001	3	GM	15.96	1.06		73.38	25.45	19.93
		min	14.46	0.99		64.50	18.30	18.11
		max	16.82	1.15		80.90	33.57	21.81
2002	8	GM	6.14	0.05	116.71	23.18	22.61	61.16
		min	3.68	0.02	92.48	11.79	14.64	23.76
		max	22.93	0.15	201.87	54.97	35.71	160.57

Year	N		Σ_6BDEs	Σ_2HBCD	ΣSCCPs	Σ_5PFCAs	PFOS	PFOSA
2005	10	GM	9.98	1.26	16.48	17.22	16.34	26.62
		min	3.49	0.88	3.29	2.40	3.81	12.59
		max	17.47	1.77	82.49	46.57	51.68	82.89
2006	4	GM	14.53	0.97	2.95	16.23	21.98	29.02
		min	10.55	0.65	1.10	6.69	12.71	20.16
		max	17.09	1.35	8.72	49.37	44.52	34.24
2007	5	GM	9.20	0.93	NC	43.08	9.43	26.03
		min	4.86	0.42		38.07	7.92	18.21
		max	18.18	1.92		47.60	11.40	40.87
2008	4	GM	21.46	2.57	NC	103.82	17.06	6.91
		min	15.90	1.54		53.95	9.02	4.80
		max	31.55	4.64		171.05	35.16	18.14
2010	10	GM		0.92	NC	18.49	9.89	3.16
		min		0.53		5.93	3.35	0.65
		max		9.82		70.23	42.13	9.01

[a] concentrations of Σ_6BDEs, Σ_2HBCD and ΣSCCPs were determined in the beluga blubber and are expressed on a lipid weight basis. Σ_5PFCAs, PFOS and PFOSA were measured in the liver and are expressed on a wet weight basis; [b]NC=not complete.

Quality assurance: Certified reference materials for BDEs in beluga blubber from the National Institute of Standards and Technology (SRM 1945) were used for each batch of 20 samples. The agreement between our measured BDE concentrations and the accepted SRM-1945 values were excellent. For PCNs, blanks and native spikes samples were carried through the entire process. Small quantifiable amounts of some PCN congeners were detected in the blanks but these were less than 10x than was measured in the samples. The PCN method used at OMOE is accredited for sediment (CALA). No reference materials are yet available for HBCD, SCCPs or for the fluorinated compounds. Our laboratory also participates in the NCP Quality Assurance Program.

Statistical analyses: For calculating arithmetic and geometric means, non-detect concentrations were replaced with half the method detection limit. Statistical treatment of the data was done using SigmaStat. The Q-test was used to remove outliers in the data-set (Dean and Dixon, 1950).

Results

Liver based concentrations of Σ5PFCAs, PFOS, PFOSA and lipid based concentration of Σ6BDEs, Σ2HBCDs and ΣSCCPs in beluga whales from our two study sites are shown in Table 1 and 2. Concentrations of PCN homologues for animals from HI sampled in 2000 and 2008 are shown in Table 3.

Table 3. Geometric mean (GM), maximum (max) and minimum (min) concentrations (ng/g, wet weight) of PCNs in beluga whale blubber from Hendrickson Island[a].

Year	N		ΣPCNs
2000	10	GM	235.5
		min	118.2
		max	430.5
2008	10	GM	243.9
		min	127.6
		max	400.4

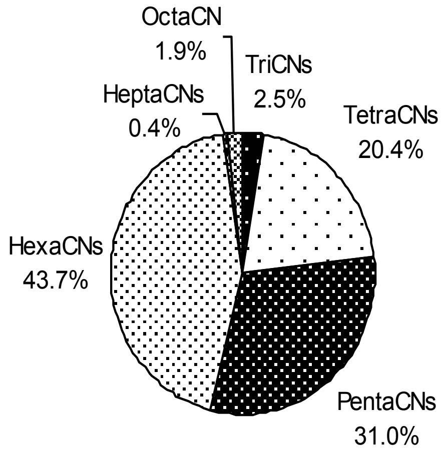

Figure 1. Relative distribution of PCN homologue groups in beluga whale blubber from Hendrickson Island. Concentrations in animals from 2000 (*n=10*) and 2008 (*n=10*) were treated together as there was no statistical differences in concentrations in animals from either year.

(a) Beluga from Hendrickson Island

Total BDE concentrations were greater than those of Σ2HBCD and were dominated by congener 47 which accounted for ca. 58% of the total BDE burden in the animals (profile analysis based on animals collected post-2000). For the HBCD, the α-isomer was consistently greater than that of γ-isomer. The temporal trend profile for Σ2HBCD shows a small but borderline increase ($p=0.05$) in concentrations over the period 1984 to 2009 our study period of 0.04 ng/g per year but then there is a noticeable significant decrease ($p<0.01$) in concentrations in 2010 (gm: 0.66 ± 0.13 ng/g, lw) relative to 2009 (gm: 1.82 ± 0.57 ng/g, lw).

Prior to 2000, Σ5PFCA wet weight liver concentrations were ca. 160 ng/g. Since that time, concentrations have decreased dramatically with a post-2000 range of 67.2 ng/g measured in animals from 2005 to 9.8 ng/g in animals from 2006. Overall, the observed annual rate of decline of Σ5PFCA over our study period was ca. 8 ng/g per year. For PFOS, there was linear increase (0.53 ± 0.10 ng/g, per year) in measured concentrations between 1984 to 2000 ($r2=0.4319$, $p<0.01$). After that time, concentrations have remained relatively stable at ca. 10 ng/g (wet weight). The trend in PFOSA concentrations mirrored that of PFOS for the pre-2000 period. After that time, no discernible trend in PFOSA concentrations were observed.

There were no statistical differences (Student t-test, $p>0.05$) in the concentrations of ΣPCNs (tri- to octachloronaphthalenes) in animals analyzed from 2000 and 2008. Total PCN concentrations whale blubber ranged from 118 to 430 pg/g (wet weight) and were in the same range as those reported in beluga blubber from Kimmirut, NT of 36-383 pg/g wet weight (Helm et al., 2002). As is typical of biotic samples that are higher in the food web, the dominant PCNs present are those that are most bioaccumulative. These include tetraCN-42, pentaCNs-52/60, and hexaCNs-66/67. Most other congeners were not detected in these samples. On average, the hexaCNs were the most dominant contributors to total PCNs (44% ± 16%) followed by the pentaCNs (31% ± 9%) and the tetraCNs (20% ± 12%) (see Figure 1).

Using relative potencies for the PCN congeners based on enzyme induction assays (H4IIE EROD or H4IIE-luciferase; Villeneuve et al., 2000; Blankenship et al., 2000), average dioxin toxic equivalents (TEQ) contributed by PCNs are estimated to be 290 fg/g blubber. This is also within the range of 28-430 fg TEQ/g reported previously (Helm et al., 2002).

(b) Beluga from Pangnirtung

Similar to what was observed in HI, Σ6BDE concentrations consistently exceeded those of Σ2HBCD with BDE-47 accounting for ca. 70% of the total BDE burden (profile analysis based on animals collected in 2000 and after). The temporal trend of Σ2HBCD shows a small but significant increase ($p<0.01$) in concentrations over our study period. Regression analyses suggest a small annual rate of increase of 0.06 ± 0.02 ng/g per year (±SE).

The relative proportions of individual PFCA homologues in liver of animals from Pangnirtung was similar to Hendrickson Island; the rank order of concentrations were PFUA>>PFDA>PFNA>PFOA≈PFDoDa. The temporal trend profile was not clear for animals collected from Pangnirtung: there were three time points (2000, 2001 and 2008) in which liver based concentrations of Σ5PFCA were elevated relative to other years. There was a fairly good agreement with the PFOS temporal trend in beluga at both study sites: from 1980s to 2000 from Pangnirtung, liver based concentrations of PFOS increased linearly at an annual rate of 0.88 ± 0.26 ng/g. This rate was ca. 2× greater than what we observed in animals from Hendrickson Island. After that time, concentrations declined significantly in a linear manner. A similar observation was made for PFOSA, which also showed a linear decrease from 2003.

Activities that are ongoing

There are still gaps in the SCCP dataset which we hope to fill over this calendar year. We have been reluctant to combine extracts for SCCP analysis as we are still screening samples for some newly reported FRs e.g., 2-ethylhexyl-2,3,4,5-tetrabromobenzoate and bis(2-ethylhexyl)-2,3,4,5-tetrabromophthalate, the latter of which was been shown to bioaccumulate in a Norwegian Arctic food web. We still have to interpret chromatograms of 2009/2010 animals from HI and 2010 animals from Pangnirtung for BDEs.

Acknowledgments

Continued support by NCP to help fund our analyses is greatly appreciated.

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Anticipating the Effect of Climate Change on Contaminant Exposure in the Arctic

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Abstract

Climate change is occurring most rapidly in the North and an urgent question is how this might affect the exposure of Northern people and wildlife to persistent organic contaminants. Building upon a review identifying the most urgent model development and parameterization needs for addressing the overarching scientific issues of contaminant exposure in a changing Arctic, we performed global model calculations aimed at understanding how the transport and delivery of organic contaminants may be different in the future. The following were incorporated into the future climate scenarios: i) increased air and surface temperatures ii) altered precipitation rates (but not frequency) iii) reduced sea-ice cover in the Arctic iv) altered snow cover in the northern hemisphere (related to temperature, precipitation and duration of spring melt period) and v) increased levels of particulate organic carbon in the water column of the Arctic Ocean due to increased primary productivity. For all investigated substances the calculated exposure-relevant freely dissolved concentration in Arctic Ocean surface water for the future climate scenarios was within a factor of 2.5 of the default, typically much less (i.e. ± 25%).

Résumé

Les changements climatiques se produisent plus rapidement dans le Nord. Voici la question que nous devons nous poser de toute urgence : quelles répercussions ces changements auront-ils sur l'exposition des habitants et des animaux sauvages du Nord aux contaminants organiques persistants? À partir d'une analyse dans laquelle on définit les besoins les plus urgents en matière d'élaboration et de paramétrisation d'un modèle pour l'étude de la question concernant l'exposition aux contaminants dans un Arctique en évolution, nous avons réalisé des calculs globaux afin de comprendre comment le transport et l'entrée des contaminants organiques seraient peut-être différents dans l'avenir. Nous en avons inclus les résultats dans des scénarios climatiques futurs : i) hausse des températures de l'air et de surface; ii) modification de l'intensité des précipitations (mais pas de la fréquence); iii) réduction de la couverture des glaces de mer dans l'Arctique; iv) modification de la couche de neige dans l'hémisphère nord (qui est liée à la température, aux précipitations et à la durée de la période de dégel au printemps); v) hausse des niveaux de carbone organique en particules dans la colonne d'eau de l'océan Arctique en raison de la production primaire accrue.

Pour toutes les substances analysées, et aux fins de l'établissement des scénarios climatiques futurs, la concentration dissoute libre liée à l'exposition aux contaminants dans l'eau de surface de l'océan Arctique se situait en-deçà d'un facteur de 2,5 de la valeur par défaut, et elle était même inférieure, en général (c.-à-d. ± 25 %).

Key Messages

- A holistic assessment approach considering abiotic factors, biological factors, and human behaviour is required to elucidate how global climate will influence ecological and human exposure in the Arctic.
- Whereas changes to long range transport and contaminant delivery to the Arctic ecosystem can be expected to occur under future climate scenarios, they may be of limited magnitude (i.e. a factor of two or less) for many organic compounds.
- These changes are often limited in size due to compensatory behaviour, whereby different alterations cause changes in opposite directions and therefore tend to cancel each other out (as opposed to being additive or synergistic).
- The 'forest filter effect' may be enhanced in the future, acting as a mitigating factor on ecological and human exposure in the Arctic.
- Changes in lifestyle, particularly the dietary transition away from consumption of marine mammals, have the potential to greatly overshadow any changes in exposure related to altered fate and transport, at least for chemicals that are biomagnified in marine food webs.

Messages clés

- Il faut adopter une stratégie d'évaluation globale qui tient compte des facteurs abiotiques, des facteurs biologiques et du comportement humain pour découvrir comment les changements climatiques mondiaux influeront sur l'exposition des écosystèmes et des êtres humains aux contaminants dans l'Arctique.
- Bien qu'il faille s'attendre, selon les scénarios climatiques futurs, à ce qu'il y ait des changements dans le transport sur longue distance et l'entrée des contaminants dans l'écosystème arctique, ceux-ci seront peut-être limités (c.-à-d. un facteur de deux ou moins) pour bon nombre de composés organiques.
- Ces changements sont souvent limités en taille en raison des comportements compensatoires adoptés, selon lesquels diverses modifications causent des changements dans des directions opposées et tendent par conséquent à s'annuler les unes les autres (au lieu de s'additionner ou de créer des synergies).
- L'effet de filtre qu'ont les forêts pourrait s'accroître dans l'avenir et agir comme un facteur qui atténuerait l'exposition aux contaminants des écosystèmes et des êtres humains vivant dans l'Arctique.
- L'évolution du mode de vie, en particulier l'abandon de la consommation de mammifères marins, pourrait éclipser tout changement dans l'exposition afférent à la modification du devenir et du transport des contaminants, du moins pour ce qui est des produits chimiques bioamplifiés dans les réseaux tropiques marins.

Objectives

Long-term:

- To identify and describe mechanisms by which a changing climate may affect the exposure of Arctic populations to organic contaminants and mercury, including changes in chemical use and emissions, in the delivery of contaminants to the Arctic ecosystem, in their processing within the Arctic physical environment and in the human food chain.
- To estimate the likely magnitude of changing contaminant exposure in the Arctic in response to different scenarios representing global climate change.
- To assess to what extent a changing climate may confound contaminant time trends obtained by analyzing residue levels in marine organisms from the Arctic.

Short-term:

- To assess how the global transport of persistent organic pollutants of different partitioning and degradation characteristics and their accumulation in the Arctic is expected to change as a results of a changing global climate
- To evaluate the performance of a dynamic, seasonally-resolved model quantifying the efficiency of air-to-marine food chain transfer in the Arctic for different contaminants and under different environmental conditions
- To quantify the potential changes in the exposure of Northerners to organic contaminants that could arise from the transition from a traditional to a southern diet, whereby this transition may be accelerated by Arctic climate change.

Introduction

Global climate change and the potential implications for human and ecological exposure to organic chemicals in both source and remote regions is of growing interest among scientists and regulators in the field of environmental toxicology and chemistry (Macdonald et al., 2003ab, 2005, Kraemer et al. 2005, Jenssen 2006, Schiedek et al. 2007, Noyes et al. 2009, Lamon et al., 2009). Indeed, some studies have already attempted to (re)interpret temporal trends in measured concentrations of several organic contaminants in biota and abiotic samples collected at sites in the Arctic and/or sub-Arctic in the context of global climate change that has already occurred (McKinney et al., 2009, Carrie et al., 2010, Rigét et al., 2010, Bustnes et al., 2010). Research has also been directed towards simulating the fate and transport of organic chemicals and how alterations to key environmental input parameters influence the behaviour of contaminants in the environment (McKone et al., 1996, MacLeod et al., 2005, Dalla Valle et al., 2007, Lamon et al., 2009). These studies are typically based on projections of global climate changes operating at local, regional and global scales as compiled by the Intergovernmental Panel on Climate Change (2007) or ACIA (2005).

With respect to global-scale fate and transport, the climate change scenarios investigated by Lamon et al. (Lamon et al., 2009) resulted in higher air concentrations of the simulated compounds (PCB 28 and 153) in source/temperate regions and the Arctic. Enhanced volatilization from primary sources was the most influential factor along with temperature-related changes in partitioning. Alterations in atmospheric circulation, ocean currents and precipitation had a minor influence on Arctic air concentrations of the modeled compounds. Global-scale simulations parameterized to represent high NAO index conditions also correspond to elevated air concentrations (MacLeod et al., 2005) in the Arctic but the model study was not intended to address the intermittent nature (i.e. time dependence) of this phenomenon. At the local/regional-scale in temperate latitudes (McKone et al., 1996, Dalla Valle et al., 2007), the climate change scenarios investigated lead to reduced exposure potential/risk compared to the baseline scenario. These results reflect enhanced dissipation and transport out of the model domain.

Previous model simulations have been conducted for only a limited number of compounds, covering a relatively narrow range of physical-chemical properties and susceptibility to degradation. Furthermore, global-scale model output reported in these studies is limited to air concentrations as opposed to output potentially more relevant for human and ecological exposure to organic compounds such as freely-dissolved concentrations (or fugacities) in aquatic environments. For these reasons, there is a strong rationale to expand the range of compounds included in model simulations and also focus on additional model outputs (e.g. freely-dissolved concentration in marine water column). The main objective of this study is to explore the potential implications of global climate change on the fate and transport of a wider range of representative organic chemicals in the context of human and ecological exposure in the northern hemisphere, with a particular focus on the Arctic ecosystem. The implications for human exposure to contaminants via the marine environment are highlighted because consumption of marine mammals is known to be a major historical and contemporary source of contaminants for the most highly exposed humans in the Arctic (Dewailly et al, 1993, Kuhnlein et al., 1996, 2004, Undeman et al., 2010).

Activities in 2010–2011

During the past year, we reviewed the potential impact of global climate change on contaminant fate, transport, bioaccumulation, exposure and risk. Various potential changes (e.g. physical, biological, behavioural) were prioritized in terms of their influence on human exposure to organic contaminants in the Arctic. Monitoring and modeling studies described in the literature, the magnitude of projected changes and simplified quantitative approaches served as the basis for assessing the potential importance of different processes. A rationale for conducting the review was to provide insights to guide future research efforts in terms of model development and parameterization required to better address the overarching scientific issues. The review was published in a peer-reviewed journal article (Armitage et al., 2011).

A second major activity was to explore in what direction and to what extent organic contaminant transport to, and deposition and accumulation in, Arctic marine ecosystems might change in a warmer future. A newly developed version of the zonally averaged global transport and distribution model Globo-POP, which now includes a mechanistic description of a seasonal snow cover, was parameterized for the present and a future state of the global climatic system, based broadly on regional and global projections for the period 2071–2090 presented in the Arctic Climate Impact Assessment (2005) and by the Intergovernmental Panel on Climate Change (2007). Assuming hypothetical continuous global emissions of a slate of organic contaminants with varying partitioning and degradation characteristics, we then compared the calculated contamination of the Arctic environment under the two climate scenarios. The processes responsible for the largest changes in Arctic contamination were identified.

Results and Discussion

It is unnecessary to reproduce here the findings of the review in detail. We only summarize the main findings (Armitage et al., 2011) here:

- Whereas increasing temperatures will directly influence global contaminant distribution, other climatic changes such as a reduction and seasonal elimination of a sea-ice cover and changes to the frequency and intensity of precipitation events in source regions and in the Arctic itself are expected to affect the accumulation of organic contaminants in the Arctic.
- Contaminant exposure could change significantly if major changes in the Arctic food chains were to occur, in particular changes that result in a lengthening of the food chain. However, it is difficult to judge how likely the occurrence of such changes is.
- The fate of contaminants that sorb strongly to organic matter in aquatic systems may be greatly affected by changes in the primary productivity and organic matter dynamics. Currently, predictions on how Arctic Ocean productivity will change vary widely ($<10\%$ to $>250\%$).
- Large changes in exposure may arise from changes in how much and where chemicals are being used and released in the environment. This is particularly true if chemicals, whose transport to Northern latitudes is limited, will be used in closer proximity to, or even within, the Arctic in the future. Higher temperatures could also enhance contaminant volatilization from primary and secondary sources outside the Arctic.

- Contaminants have been shown to become mobilized into the atmosphere during fires in the boreal forest, and an increased frequency of such fires could result in higher emissions. Those emissions are currently hard to quantify.
- Human behavior has the largest potential to change contaminant exposure, e.g., if changes in prey availability and/or consumer preference accelerate the ongoing substitution of traditional food items with imported foods from the South.

The results of the review informed the model-based comparison of long-range transport potential and contaminant delivery to the Arctic ecosystem under current and future global climate scenarios. In particular, it facilitated the decision on what factors to incorporate into the future climate scenarios. These factors were:

i. increased air and surface temperatures (relatively uniform temperature increases in mid- and low-latitudes in the northern hemisphere over the year in comparison to northern regions with substantially warmer winters and only slightly warmer summers)

ii. altered precipitation rates (Increases in precipitation in mid- to high latitudes in the Northern hemisphere and decreases at lower-latitudes)

iii. reduced sea-ice cover in the Arctic (relying on the more extreme scenario with negligible sea-ice cover by the end of summer, i.e. no multi-year ice)

iv. shorter periods of snow cover in the northern hemisphere (related to temperature, precipitation and duration of spring melt period) and

v. increased levels of particulate organic carbon in the water column of the Arctic Ocean due to increased primary productivity (two scenarios were considered a) negligible change in the concentration of POC in Arctic surface waters (assuming strong nutrient-limitation) and b) 250% increase in the concentration/volume fraction of POC in Arctic surface waters (assuming no nutrient limitation and enhancements due to disappearance of sea-ice in summer).

A set of industrial chemicals and pesticides were selected to be simulated. In the context of long-term global climate change, these compounds are best understood as analogs representative of different physical-chemical property combinations and hence potential behavior in the environment under current and future climate conditions. The partition coefficients of the selected compounds span 3–5 orders of magnitude whereas degradation half-lives vary by up to 4 orders of magnitude, capturing a wide range of potential behaviors in the global environment.

Since it is generally assumed that only the freely-dissolved fraction is bioavailable, the average fugacity in surface ocean water of the North Polar zone in the tenth year of simulation (fO) was used as a metric of long range transport potential and contaminant delivery. This metric is the most relevant for human and ecological exposure to organic contaminants via the marine environment as it can be related directly to the freely-dissolved concentration. fO was calculated for each chemical and three scenarios (i) Default, ii) the future climate with no change in POC in the Arctic ocean (GCC) and iii) the future climate with a 250% increase in POC in the Arctic ocean (GCC w/POC)) and then compared by normalization to the default scenario (i.e. Default output=1).

The average fugacities in surface ocean water in the North Polar zone in year 10 of the simulations for the two future climate scenarios relative to the default scenario are presented in Figure 1. Ocean water fugacities fO in the GCC scenario are generally within ±25% of those in the default scenario with the exception of β-HCH and chlorothalonil. The reasons why fOs are lower than in the default scenario vary depending on the chemical. For example, in the case of PCB 28, contaminant delivery to the atmosphere of the Arctic is elevated in the GCC scenario but deposition to the marine environment is less efficient, despite the reduction in sea-ice cover (and hence greater surface area for gaseous exchange). Wet and dry atmospheric deposition is less efficient in the GCC scenario (in relative terms) due to temperature-related reductions in the partitioning to rain, snow and aerosols. In other cases (e.g. BDE 47, 99, 209), atmospheric deposition to the marine environment is enhanced in relative terms in the GCC scenario (i.e. expanded surface

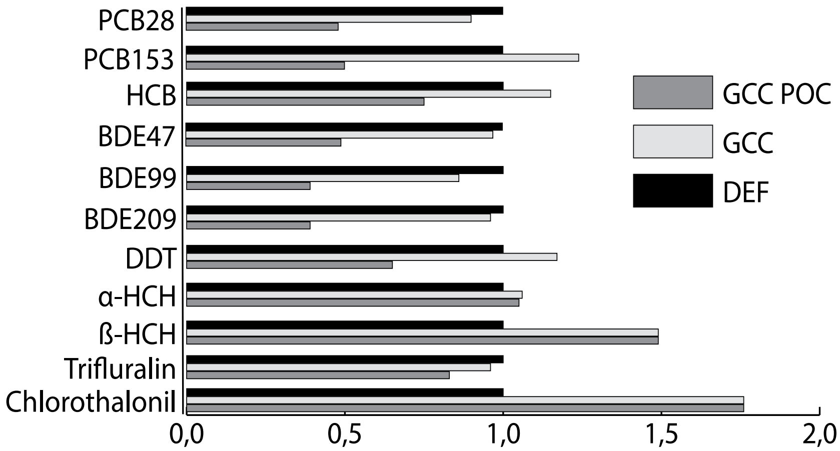

Figure 1. Average fugacity in surface ocean water in the North Polar zone in year 10 for the future climate scenarios relative to the default scenario.

area for gaseous air-ocean exchange + increased precipitation rates) but contaminant delivery to the Arctic atmosphere is markedly reduced, resulting in a net reduction in mass in the surface ocean compared to the default scenario. There are also cases (e.g. PCB 153) where contaminant delivery to the Arctic atmosphere is reduced in the GCC scenario but atmospheric deposition to the marine environment is enhanced in relative terms such that the net effect is to increase fO. For β-HCH and chlorothalonil, contaminant delivery to the Arctic atmosphere is substantially enhanced in the GCC scenario whereas the total atmospheric deposition fluxes are approximately equal in terms of relative efficiency.

The average fugacities in the water column are substantially reduced in the GCC w/POC scenario because of enhanced losses from the water column due to particulate sinking and/or because of the enhanced bulk sorptive capacity of the water column, which essentially corresponds to a reduced fraction of mass in the freely-dissolved phase (e.g.PCB 153, BDE 209). This reduction in fugacity corresponds to a reduction in ecological and human exposure as it is propagated in the food web. Interestingly, this mitigating effect is negligible for the more water-soluble analogs, two of which (β-HCH, chlorothalonil) exhibit the greatest enhancement in long range transport potential and contaminant delivery. These results imply that compounds other than those with typical POP characteristics (e.g. the 'dirty dozen') may be most sensitive to climate-related increases in long range transport potential and hence potential changes to ecological and human exposure in remote regions related to physical/environmental factors.

For some of the more hydrophobic chemicals, an enhancement in the forest filter effect is observed in the GCC scenarios, resulting in greater relative and absolute sequestration of emissions undergoing northward transport and hence lower mass fluxes to the North Polar zone. While the effect is relatively small, the hypothesis that altered litterfall related to global climate change could have some influence on long range transport potential is worth investigating further. Climate projections for the North Boreal zone all indicate warmer temperatures and higher annual precipitation rates in the future. Hence, litterfall and the associated mass flux of contaminants to forest soils can also be expected to be enhanced, particularly in autumn when litterfall rates peak in both coniferous and deciduous species (Fyles et al., 1986). Northward expansion of deciduous forests into the North Boreal zone may also have an important influence on enhancing the forest filter effect. While the estimated sorption capacity of deciduous canopies is similar to coniferous canopies, as are litterfall rates in the boreal forest (Berg and Meentemeyer 2001, Liu et al., 2004), both estimated gaseous deposition velocities and dry deposition velocities are higher to deciduous canopies in comparison to coniferous canopies. Fate and transport models could be parameterized to represent different "future forest" scenarios based on projected changes to actual evapotranspiration and fractional coverage of deciduous canopy to investigate potential enhancements to the forest filter effect more thoroughly.

It is important to clarify that the results characterizing contaminant fate presented here are best interpreted in the context of how organic contaminants may behave under contemporary conditions compared to future conditions during the main use/emission phase. In other words, these results are applicable to the uptake phase of the global environment as opposed to the depuration phase when primary sources are exhausted/eliminated and environmental reservoirs (e.g. boreal forest soils) become the driver of observed concentrations in the environment (e.g. via soil-to-air exchange).

Conclusions

The results of this modeling study indicate that changes to long range transport and contaminant delivery to the Arctic ecosystem (as characterized by the average fugacity in surface ocean water) can be expected to occur under future climate scenarios but may be of limited magnitude (i.e. a factor of two or less) for many organic compounds. Another conclusion to be drawn from this model assessment is that changes in near-surface air concentrations in the Arctic (i.e. what are typically measured) are not necessarily good proxies for changes in ecological and human exposure in terms of absolute magnitude or directionality.

In terms of ecological and human exposure to contaminants, the most interesting finding is that increased primary productivity and the resulting higher organic particle loads in the water column of the Arctic marine environment represents a potential mitigating factor for more hydrophobic compounds. Further studies to estimate/constrain the magnitude of change likely to occur under future climate scenarios would be useful, particularly since changes may be highly variable spatially (e.g. some areas enhanced substantially more than others).

In the context of human exposure however, it is important to realize that changes in lifestyle, particularly the dietary transition away from consumption of marine mammals (Kuhnlein et al., 1996, 2004), has the potential to greatly overshadow any changes in exposure related to altered fate and transport, at least for chemicals that are biomagnified in marine food webs, even if only in air-breathing organisms (Armitage et al., 2011, Kelly et al., 2007). For example, maximum biomagnification factors for some marine mammals (ringed seals, walrus, bowhead whale) were recently compiled and are in the range 15–20 (Debruyn and Gobas, 2006). This factor represents the maximum reduction in exposure that could be expected if consumption of marine mammals is substituted completely with fish from the same ecosystem. Switching to local terrestrial mammals (e.g. caribou) or even imported food items may also result in a relatively large reduction (i.e. greater than a factor of two) in human exposure to contaminants (Armitage et al., 2011). However, because it is uncertain how trends in dietary choices in the Arctic will evolve in the future (either due to prey availability or consumer preference) it is difficult to anticipate the extent to which exposure to organic contaminants via the marine environment will be reduced over time due to such shifts. Other changes to the biological environment/marine food web could also results in changes in exposure to contaminants (Macdonald et al., 2005).

NCP Performance Indicators

The number of northerners engaged in your project: This project does not involve any Northerners.

The number of meetings/workshops you held in the North: This project does not foresee any meetings/workshops in the North or anywhere else.

The number of students (both northern and southern) involved in your NCP work: The CLEAR project supports one graduate student at the University of Toronto, who is working on this project.

The number of citable publications: 1.

Expected Project Completion Date

The project is planned to last four years, and thus is expected to be completed in 2013.

Acknowledgments

The bulk of the funding for this project is provided by the European Union through the CLEAR project.

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Ice Core Archives of Atmospheric Hg Deposition from Arctic Canada and Greenland

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Abstract

Multiple glacier sites in the High Arctic (Canadian Ice caps and North Greenland) were sampled for studies of total mercury (THg) and/or monomethyl mercury (MeHg), including an 80-meter, over 200-yr long firn core from northeast Greenland (NEEM site). Results from cores drilled from Mt. Oxford ice-field and Agassiz ice cap (Ellesmere Island) reveal a period of enhanced atmospheric THg deposition from the mid 1990s up until ~2005. Data from a core obtained on southern Baffin Island (Penny ice cap) suggest that this interval of enhanced THg deposition was felt all over the Canadian Arctic. Ongoing analyses from the NEEM core should soon help to determine if this is a local

Résumé

Des échantillons ont été prélevés à différents glaciers de l'Extrême-Arctique (calottes glaciaires canadiennes et Groenland septentrional) pour des études sur le mercure total (THg) et le mercure monométhylique (MeHg), y compris une carotte de névé de 80 mètres et représentant une période de plus de 200 ans prélevée dans le Groenland septentrional (site NEEM). Les résultats obtenus des carottes prélevées dans le champ de glace du Mt. Oxford et la calotte glaciaire Agassiz (île Ellesmere) révèlent une période de dépôts atmosphériques accrus de THg entre le milieu des années 1990 jusqu'aux environs de 2005. Les données obtenues d'une carotte prélevée dans la partie sud de l'île de Baffin (calotte glaciaire Penny) permettent de croire que cet épisode de dépôts accrus de THg s'est

pattern or broader, regional phenomenon. Net deposition rates of THg calculated from ice cores suggest that mercury fluxed on Canadian High Arctic ice caps are at levels in the order of 0.1 μg m^{-2} yr^{-1} or less, which is much lower than THg accumulation rates inferred from lake sediments, peat bogs and alpine (mid-latitude) ice cores.

fait sentir dans tout l'Arctique canadien. Des analyses continues de la carotte de NEEM devraient bientôt nous aider à établir s'il s'agit d'une tendance locale ou d'un phénomène plus vaste, de portée régionale. Les taux de dépôts nets de THg calculés à partir des carottes de glace donnent à penser que l'accumulation de mercure sur les calottes glaciaires de l'Extrême-Arctique canadien est de l'ordre de 0,1 μg m-2 par année 1 ou moins, ce qui est nettement moindre que les taux d'accumulation de THg inférés à partir des sédiments lacustres, des tourbières et des carottes de glace prélevées en zone alpine (latitude tempérée).

Key Messages

- Results for all ice cores analyzed to date suggest that he mean concentration of THg in Arctic glacier snow (excluding near-surface layers) is relatively constant in space, and averages ~0.6 ng L^{-1}.
- Between the 1940s and mid–1990s, ice cores show little temporal variations in THg accumulation, suggesting a relatively constant influx from the atmosphere.
- A period of enhanced THg deposition from the atmosphere was found between mid 1990s and about 2005 in northern Ellesmere ice cores. There are indications that this was also recorded on southern Baffin Island. However, it is not clear at present if this event was confined to the Canadian Arctic or was a broader, possibly hemispheric or global phenomenon. An 80-m core of ice/firn core from North Greenland has been retrieved and sample analyses are ongoing to be completed in late June. The North Greenland results will be compared to the existing data and will allow us to see if the higher THg is a semi-hemispheric pattern.
- Based on fluxes calculated from ice cores, net atmospheric deposition rates for total mercury in the Canadian Arctic could be much lower than previously inferred from other sampling media such as lake sediments and peat bogs.

Messages clés

- Les résultats de toutes les carottes de glace analysées à ce jour donnent à penser que la concentration moyenne de THg dans la neige des glaciers de l'Arctique (à l'exclusion des couches proches de la surface) est relativement constante dans l'espace, avec une moyenne de ~0.6 ng L-1.
- Entre les années 1940 et le milieu des années 1990, les carottes de glace révèlent de faibles variations temporelles dans l'accumulation de THg, ce qui laisse deviner un influx atmosphérique relativement constant.
- Une période de dépôts atmosphériques accrus de THg a été révélée entre le milieu des années 1990 jusqu'aux environs de 2005 dans des carottes de glace prélevées à l'île d'Ellesmere. Des indications permettent de croire que ce phénomène a aussi été consigné dans la partie sud de l'île de Baffin. Cependant, il n'apparaît pas clairement pour le moment que cet événement se soit limité à l'Arctique canadien ou ait plutôt constitué un phénomène plus vaste, hémisphérique sinon mondial. Une carotte de glace/névé de 80 mètres a été prélevée au Groenland septentrional et les analyses des échantillons devraient être achevées à la fin de juin. Ces résultats seront comparés aux données existantes et nous permettront de déterminer si le niveau accru de THg est une tendance semi-hémisphérique.
- Compte tenu des flux calculés à partir des carottes de glace, les taux de dépôt atmosphérique de mercure total dans l'Arctique canadien pourraient être nettement moindres que ceux inférés à partir des autres milieux échantillonnés, comme les sédiments lacustres et les tourbières.

Objectives

1. Reconstruct a long-term historical record, dated back to preindustrial times, of atmospheric Hg and MeHg deposition using snow and ice from High Arctic regions.
2. Elucidate processes of Hg and MeHg deposition in Arctic snow, and the factors that influence the exchange of contaminants between air and other media.
3. Investigate the effects of changing climatic conditions on atmospheric Hg and MeHg deposition.

Activities planned in 2010–11

1. Obtain a ~80-m long firn core from the NEEM site (77.45ºN; 51.06ºW; ~3000 m asl) in North Greenland. This would be accomplished by Dr. J. Zheng in the summer 2010, with logistical support from the IPY-NEEM project. Based on the preliminary depth-age scale established for the NEEM site, this core should provide, at least, a 200-yr long record (dates back to pre-industrial time) of atmospheric THg and MeHg deposition for northern Greenland.
2. Extend the previously-recovered ~12-yr record of THg and MeHg deposition from Penny ice cap, southern Baffin Island (67.26ºN; 65.97oW; ~1850 m asl), by obtaining a ~20-m long firn core from the same site in April 2010.
3. In addition, there was an opportunity to obtain a 20-m firn core from the Bylot Island icefield in Sermilik National Park (78.73ºN; 17.20ºW; ~1340 m asl). This would be done by Dr. C. Zdanowicz as part of a reconnaissance trip to Bylot Island in May 2010 to evaluate the feasibility of establishing a glacier monitoring site in Sermilik National Park. The core would be analyzed for THg and MeHg. Obtaining even a short Hg record from this site would be highly valuable as it would help to bridge a wide gap in our present regional sampling coverage of the eastern Arctic.
4. Process, sample and analyze the cores obtained in Greenland and Arctic Canada, and prepare the findings for publication and report to relevant organizations.

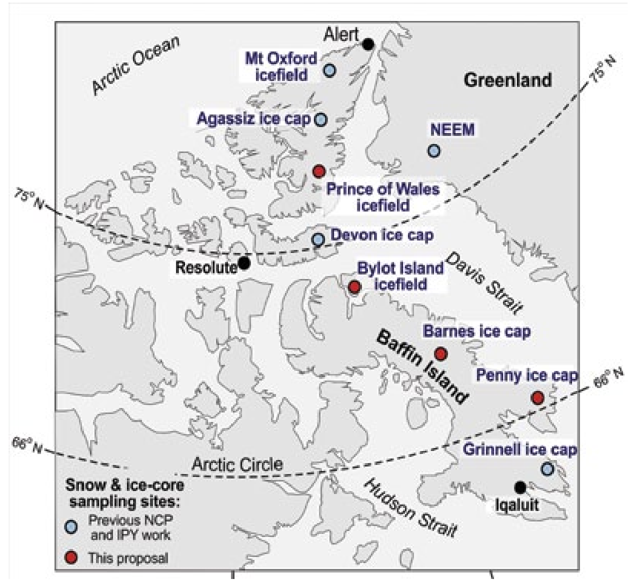

Figure 1. Snow and ice-core sampling sites in the Canadian Arctic and Greenland sampled for THg and/or MeHg under this and previous NCP-supported work. Samples from Grinnell ice cap, Barnes ice cap, Devon ice cap, and the Bylot Island and Prince of Wales icefields consist mostly in surface snow, while samples from NEEM, Mt Oxford, Agassiz and Penny ice caps are cores spanning between 29 and ~300 years of accumulation history.

Introduction

Over the past 15 years, much research effort has focused on springtime atmospheric mercury depletion events (AMDEs), during which elemental gaseous mercury (GEM; Hg^o) is converted to reactive gaseous mercury (RGM) that can then be scavenged and deposited into snow (see review in **Steffen *et al*. 2008**). It has been suggested that AMDEs may represent one of the main pathways by which atmospheric Hg can enter Arctic aquatic environments. However, there are considerable uncertainties about the net depositional flux of Hg associated with AMDEs because much (possibly most) of the Hg deposited in snow by this mechanism is subsequently re-emitted to the atmosphere by photo-reduction in the snowpack (**Lalonde *et al*. 2002**). A recent attempt at establishing a mass balance inventory of Hg for the Arctic Ocean concluded that AMDEs may contribute at most 22% of total Hg inputs to the Ocean, the balance being associated with riverine inputs, oceanic currents, and atmospheric deposition by non-AMDE pathways (**Outridge *et al.*, 2008**). However, the estimated total atmospheric Hg flux to the Arctic Ocean carries a very large uncertainty (nearly ± 100%), which is largely due to the lack of spatially- and temporally-continuous measurements of dry and wet Hg deposition in the Arctic region.

The longest time series of direct atmospheric Hg measurements (from Alert) barely spans two decades. Indirect estimates of Hg deposition trends from lake sediments and ombrotrophic bogs suggest 2 to >10-fold increases since pre-industrial times depending on the region considered (**Biester *et al.*, 2002, Shotyk *et al.*, 2003, Marvin *et al.*, 2004 and Outridge *et al.*, 2008**), but such proxy records can suffer from diagenetic effects that can lead to overestimated atmospheric input rates. Measurements of gaseous Hg trapped in central Greenland firn indicate that anthropogenic emissions of Hg caused a 2-fold rise in GEM concentrations before the 1970s (**Faïn *et al.*, 2008, 2009**). Meanwhile, a recent compilation of gaseous Hg measurements worldwide (**Sprovieri *et al.*, 2010**) shows that the large increase in Hg emissions in fast-developing countries (e.g, China) over the last decade are not currently reflected in the long-term measurements of total mercury in ambient air and precipitation from North Europe and North America. Collectively, these studies illustrate that there are still very large uncertainties regarding both contemporary and past accumulation rates of atmospheric Hg in the Arctic.

In order to reduce these uncertainties and improve current estimates of atmospheric Hg inputs to the Arctic and global environment, we utilize measurements of Hg in Arctic snow and ice cores to define past decadal trends and contemporary baseline deposition rates. Polar ice and snow cores are particularly well-suited for this task because (1) they are obtained from remote locations that are not affected by local contaminant sources; (2) particulate or soluble impurities measured in ice cores are delivered only from the atmosphere, unlike in lake sediments, for example; and (3) there is usually limited post-depositional modification of the depositional sequence in snow and ice. Furthermore, ice cores also preserve co-registered climatic indicators (layer thickness, melt percentage, oxygen isotopes, etc.) and contain atmospheric aerosols such as sea salts, which allow for the relationships between Hg and MeHg deposition, climate, and air chemistry, to be investigated from the same archive.

Ice and snow cores from Canadian Arctic ice caps have been widely used to study current and historical inputs of both natural and anthropogenic (industrial or other) contaminants (e.g., **Barrie *et al*. 1985; Niragu *et al*. 1990; Peters *et al*. 1995; Gregor *et al*. 1995; Koerner *et al*. 1999; Goto-Azuma *et al*. 1999; Zdanowicz *et al*. 2000; Krachler *et al*., 2004 and 2007, Shotyk *et al*., 2005; Zheng *et al*. 2003, 2006 and 2007**). In this study, we aimed to develop new ice-core records of total mercury (THg) deposition from several ice caps in the Canadian Arctic and Greenland. Two of the target sites, the Mt. Oxford icefield and Agassiz ice cap (Ellesmere Island) are about 150 km and 300 km, respectively, from the Alert air monitoring station, thereby providing an opportunity to compare trends in Hg deposition in snow with those measured in the air (GEM) at Alert.

Activities in 2010–2011

Sample collection and analyses: work accomplished

- An 80-meter long firn core has been recovered as planned from North Greenland (77.45° N and 51.06°W).
- On site Electrical Conductivity Measurements (ECM) on ice cores were carried out during drilling with a custom-made ECM system in order to locate the depths of larger volcanic eruptions (to set up the age-depth relationship). A set of samples for ion chemistry were also taken accordingly for confirmation of age-depth relationship. All samples were kept frozen and shipped frozen back to Ottawa.
- Based on ECM results, the bottom of the 80-m core could be dated back to mid of AD 1700. Therefore, this core will provide us information of total Hg background before the Industrial Revolution.

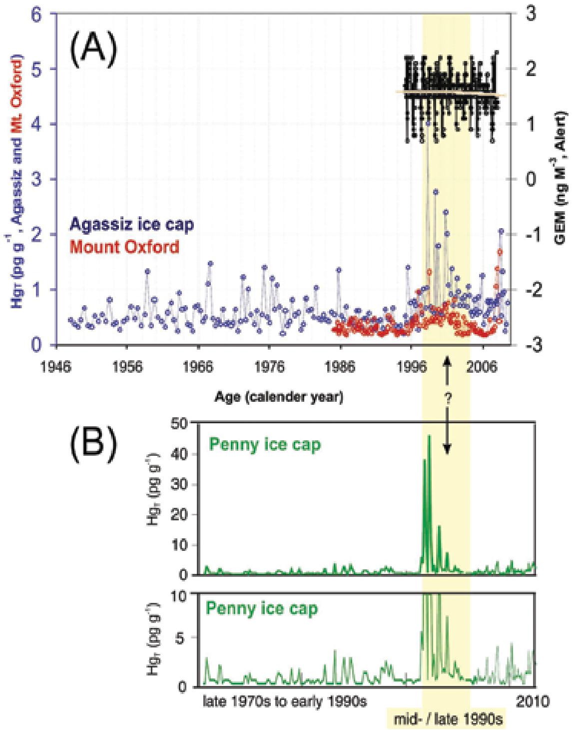

Figure 2. Ice core records of THg accumulation from northern Ellesmere Island (A) and southern Baffin Island (B). In panel (A), the ice-core THg data are compared with direct atmospheric GEM measurements from Alert, shown as a black line, with superimposed linear trend. (A. Steffen, pers. comm.). Note that the correlation between the Agassiz ice cap and Mt Oxford records (top) and the Penny ice cap record (bottom) is tentative at this stage.

- A 23-m long, 9-cm diameter core was successfully recovered from Penny ice cap in May 2010. Based on stratigraphic criteria, we estimate the new firn core to cover a period of accumulation of ~45 years, i.e. from ~1965 to 2010.
- In addition, surface snow samples (≤ 1 year of accumulation) were obtained from Aktineq Glacier on Bylot Island (May 2010), and from Barnes ice cap, central Baffin Island (April 2011). As well, archived snow and firn samples collected on the Prince of Wales icefield (central Ellesmere Island) have been processed for THg. These data will complete a north-to-south transect of sampling sites across the eastern Canadian Arctic (Fig. 1)
- All sample analyses for total Hg and organic Hg were or are being done in labs at the Geological Survey Canada or at the University of Ottawa's Biosciences laboratory. Preliminary results indicate that data from the two labs compare well.

Preliminary results and discussion

Temporal trends in THg deposition. Results of THg analyses of the Mt. Oxford, Agassiz ice cap and Penny ice cores are shown on Fig. 2. The time scale for the Agassiz and Mt. Oxford ice cores is based on annual layer counting of chemical and isotopic variations, and is thought to be accurate to within a few years. These two cores from northern Ellesmere Island show a broad peak in THg between the mid 1990s and 2005. The peak concentration of THg during this interval is almost twice that found between the 1950s and mid 1990s. The fact that the same feature is observed in two separate cores drilled hundreds of km apart and dated independently indicates that it reflects a real depositional episode, and is not an artefact of the analyses. Penny ice cap on southern Baffin Island experiences summer melt in its accumulation zone, which causes post-depositional mobilization of soluble chemical species in the firn. It can therefore not be dated by annual layer counting as the Ellesmere cores.

The time scale shown on panel (B) is approximate, and based on stratigraphic comparisons with a deeper core drilled in 1995 at this site. Interestingly, the Penny ice cap record also shows a period of enhanced THg deposition which appears to be broadly correlative with the later half of the 1990s. It is probable that the original chemical signature of this interval has been modified by melt and percolation during this decade, but there are grounds for thinking that this feature is not simply the result of elution. If it proves to the (modified) signature of the same episode of enhanced THg deposition seen in the Agassiz and Mt. Oxford cores, it would imply that this event affected a broad sector of the Canadian Arctic, from ~66 N to >75 N. However further verifications are needed to confirm this.

Prior to the 1990s and back to the 1940s, the ice cores suggest that atmospheric THg deposition was relatively uniform in the Canadian Arctic, as all three records show little or no temporal variations during these decades.

Comparison with direct atmospheric GEM monitoring at Alert.

On Fig. 2 (A) we compare the temporal trends of THg accumulation recorded in the Agassiz and Mt Oxford ice cores with the record of direct GEM measurements from Alert (A. Steffen, pers. comm.). Although the period of overlap over which such a comparison is feasible is quite short, it can be seen that the two types of records are quite different. The GEM record shows large seasonal variations but no pronounced interannual trend over the period of record, while the ice-core record clearly shows important interannual variations over the same period. This is not surprising, given that the direct atmospheric GEM record represents the atmospheric concentration of gaseous elementary Hg while the temporal variations in ice and snow is a representation of the net deposition of total Hg from the atmosphere, probably largely in particulate form. However the differences in the two records do suggest that GEM is in state of relative dynamic equilibrium in the atmosphere, while net accumulation in sow and ice (at least on glaciers) is not controlled by changes in the atmospheric GEM burden, but by other dynamic processes.

Deposition rate of THg on ice caps compared with lake sediments and peat bogs

Fig. 3 shows computed net THg accumulation rates on various Arctic glaciers, based on averaging of multiple years (except for the data by St-Louis et al., 2005, included for comparison). A weak north-to-south gradient in Hg flux was found, with F_{THg} increasing from < 0.1 μg m^{-2} yr^{-1} north of 80° (Agassiz, Mount Oxford) to ≥ 0.2 μg m^{-2} yr^{-1} on Penny Ice Cap (67°N). The mean F_{THg} for all sites was 0.11 ± 0.02 μg m^{-2} yr^{-1}. In absolute terms, the geographic differences are small and the uncertainties large, yet the highest value of FTHg (at the southernmost latitude) was twice the lowest flux (northernmost). The spatial (north-to-south) differences are believed to be largely related to particulate deposition (increasing toward the south) and/or higher wet deposition rate at lower latitudes.

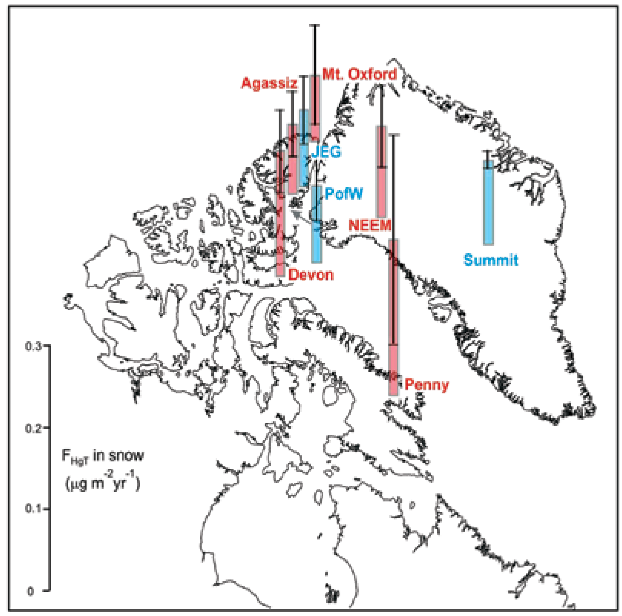

Figure 3. Mean annual deposition rates or fluxes (FT_{Hg}) for THg in snow and firn layers on Canadian Arctic glaciers and the Greenland Ice Sheet. Red bars are data obtained as part of this and previous NCP-supported work, and represent averages computed for at least eight years of accumulation in the past decade. Blue bars are based on data from St. Louis et al. (2005) for Ellesmere Island and Mann et al. (2005) for central Greenland. Error bars are ± 1 standard deviation.

Total Hg concentrations in surface and near-surface snow or firn layers are not stable, owing to dynamic exchanges with the atmosphere. Therefore in order to evaluate net THg accumulation rates in Arctic glaciers and ice caps, we used data retrieved from samples lower than 2 meters from the surface (Table 1). For comparison purpose, published total Hg fluxes retrieved from sediments and peat-bogs, are also listed in the table. Compared to those in sediments and peat bogs, atmospheric deposition of total Hg on ice caps in the Canadian High Arctic is much lower, suggesting that net transfer of total Hg from atmosphere to ground could be tens to hundreds of times less than what we previously thought; this is at least true on Canadian High Arctic ice caps and glaciers.

Table 1. Net accumulation rates (fluxes) of THg in Canadian Arctic ice glaciers and ice caps compared with figures derived from other media.

Category	Flux of total Hg kg/km^2/y	Reference
High Arctic glaciers/ice caps	0.073 to 0.086	This study
Canadian Arctic lakes	2.8±2.0	Muir et al. 2009
Canadian sub-Arctic lakes	7.5±5.9	Muir et al. 2009
South Greenland peat bogs	~20	Shotyk et al. 2003

Records reconstructed from sediments and peat bogs can properly evaluate temporal trends of total Hg variations and estimate the magnitude of increase for a certain time period. However, those records may no faithfully represent net atmospheric deposition because they include contributions from catchment runoff. In contrast, records of atmospheric deposition of total Hg from ice and snow of Canadian ice caps represent a net transfer from atmospheric deposition, therefore a real flux. Also, chemical processing of Hg within surface and near surface layers and the interactions between snow layers and atmosphere during and after AMDEs on glaciers are different from those on other media surfaces such as soil, vegetation, water etc. Further studies, however, are needed before directly applying results from glaciers to other locations.

Conclusions

Total Hg concentration peak exists between mid 1990s and 2005 in samples from the Agassiz Ice Cap and the Mt. Oxford Ice Field. Concentration of total Hg peak is ca 2x the amplitude of total Hg concentrations found between 1950 and mid-1990s. A net deposition rate of total Hg on Canadian High Arctic ice caps is found $< 0.1\ \mu g\ m^{-2}\ yr^{-1}$, much lower than those found in sediments, peat bogs and alpine ice cores. Greenland data will be available soon and further discussion will be released.

Results of MeHg analyses are still being compiled at this time; reporting of findings will therefore come at a later date in the year.

Expected Project Completion Date

Not later than August, 2011.

Acknowledgments

This study is financially supported by Canadian NCP, IPY and NRCan, GSC. All activities of this study were carried out under the management of the Environmental Geoscience and Climate Change Geoscience programs at Natural Resources Canada.

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Community Based Monitoring and Research

Temporal Trends of Mercury Levels in Food Fish Species in Lakes Used by Dehcho Community Members

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Abstract

The Dehcho First Nations is collaborating with Marlene Evans of Environment Canada to update mercury levels data in fish from lakes utilized by the Dene and Métis of the Dehcho communities. Data collected will also be useful in her studies of mercury levels, including her investigation of special variations in mercury concentrations and time trends.

The recent release of mercury data by Environment Canada and the resulting new health advisories from Health Canada have caused increased concerns in our communities. There are lakes and species of fish which are safe to harvest and contain acceptable levels of mercury. We want to be able to reassure people in cases where risks are low and warn people in cases where health advisories have been released. There may be a need to re-evaluate health risks due to the potential increase in mercury levels in fish due to climate change or other unknown causes.

Résumé

Les Premières Nations du Dehcho collaborent avec Marlene Evans d'Environnement Canada pour mettre à jour des données sur les taux de mercure des poissons qui proviennent des lacs utilisés par les Dénés et les Métis des collectivités des Premières Nations du Dehcho. Les données recueillies seront aussi utiles dans le cadre de l'étude d'Environnement Canada sur les taux de mercure, notamment dans l'enquête sur les variations exceptionnelles des concentrations de mercure et des tendances temporelles.

La récente publication des données sur le mercure par Environnement Canada et les nouveaux avis sanitaires de Santé Canada qui en découlent soulève de plus en plus d'inquiétude au sein de nos collectivités. Il y a des lacs où la pêche est sécuritaire et où les espèces de poissons contiennent des taux de mercure acceptables. Nous voulons être en mesure de rassurer les gens dans les cas où les risques sont bas et les avertir dans les cas où des avis sanitaires ont été émis. Il faudra peut-être réévaluer les risques

This project will continue next fiscal year and into the future until a complete update of "fishing lakes" have been assessed.

The work this year concentrated on collecting samples from fish from three lakes used by community members from Jean Marie River and Pehdzeh Ki. The study will continue in other communities which seem to be most affected; Sambaa Ke (Trout Lake) Liidlii Kue, Providence (FPRMB). Twenty samples from each major species of fish will be collected in the next few years from each of the "fishing lakes" used by the communities. Local youth will be involved in the project whenever possible, at either the classroom level or on the land.

pour la santé que présente la possible augmentation des taux de mercure dans le poisson, en raison des changements climatiques ou d'autres causes inconnues.

Le projet se poursuivra pendant le prochain exercice financier et même au-delà, jusqu'à ce que la mise à jour des évaluations de l'ensemble des lacs soit terminée.

Cette année, les travaux étaient axés sur le prélèvement d'échantillons sur les poissons provenant de trois lacs utilisés par les membres des collectivités de Jean Marie River et de Pehdzeh Ki. L'étude se poursuivra dans les autres collectivités qui semblent les plus touchées : Sambaa K'e (Trout Lake) Liidlii Kue (Fort Simpson), Ka'a'gee Tu (Kakisa) et Fort Providence (FPRMB). Au cours des prochaines années, pour chacun des lacs utilisés par les collectivités, on prélèvera 20 échantillons pour chacune des principales espèces de poissons. Les jeunes de la collectivité participeront au projet, lorsque possible, que ce soit en classe ou sur le terrain.

Key Messages

- The study to update mercury levels in fish has started with samples from three Dehcho lakes collected in 2010–2011.
- Training of local people in field research techniques will bolster the Dehcho First Nations initiative to have trained monitors in each of the Dehcho communities.
- Involvement of the community leadership and administration in this study will increase the capacity for collaborative management of aquatic resources in the Dehcho.

Messages clés

- L'étude qui vise à mettre à jour les données sur le taux de mercure du poisson est commencée; en 2010–2011, des échantillons ont été prélevés dans trois lacs de la région du Dehcho.
- La formation donnée à la population locale en techniques de recherche sur le terrain contribuera à soutenir l'initiative des Premières Nations du Dehcho, soit de doter chacune des collectivités du Dehcho de moniteurs formés.
- La participation des dirigeants et de l'administration des collectivités à cette étude facilitera la gestion conjointe des ressources aquatiques de la région du Dehcho.

Objectives

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

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

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

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

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

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

Introduction

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

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

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

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

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

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

Activities in 2010–2011

- In August, 2010, Dehcho First Nations employee, Mike Low attended a meeting in Sambaa Ke (Trout Lake) with Lorna Skinner of INAC to discuss the recent increase in mercury levels and the Health Canada advisory.
- In December 2010, George Low, the Dehcho AAROM Coordinator and Mike Low, the AAROM Technical Advisor, discussed the winter fishing project with the Chief and Band manager of the JMR First Nation. The First Nation was contracted to provide two community monitor/harvesters to work with our technicians during December and January at the two lake sites.
- Likewise we met with the Pehdzeh Ki First Nation in Wrigley to arrange for their fishing project.

- The community monitors guided us to McGill and Deep lakes in the JMR area and to Fish Lake in the Wrigley area and set the nets under the ice in the best locations traditionally fished.
- We were able to receive some late funding to begin the sample collection and mercury analysis process during the winter of 2010–2011.
- In the Jean Marie River area, an AAROM technician and two community workers gillnetted 67 fish for flesh samples and required data from McGill Lake. Likewise 13 samples were collected from Deep Lake.
- In the Wrigley area, an AAROM technician and two community workers gillnetted 57 fish for flesh samples and required data from Fish Lake.
- All flesh samples were shipped to Marlene Evans of EC for analysis.
- Due to a lack of funds, the time factor and logistics we were limited to the above two communities and three lakes in the 2010–2011 fiscal year.

Results

- McGill Lake;
  - 20 walleye samples shipped to Evans for analysis
  - 19 Pike samples shipped
  - 12 LN sucker samples shipped
  - 3 whitefish samples shipped
- Deep Lake;
  - 5 walleye samples shipped
  - 4 pike samples shipped
  - 3 burbot samples shipped
  - 1 whitefish sample shipped

  Note: the fishing was very poor. We fished several nets of various mesh sizes for several days with poor results.
- Fish Lake;
  - 20 Pike samples shipped to Evans
  - 5 walleye shipped
  - 7 burbot shipped
  - 18 whitefish shipped
  - Only 7 of 16 trout shipped (because the monitors ate them or gave them away before we picked them up a week later!)
- Total Samples – 3 lakes – 124 fish

Analysis results

Not available at this time. The collection phase continued into March. Marlene Evans will be providing analysis results when the data is ready and interpreted.

Discussion and Conclusions

The project has not progressed to the point where a discussion of results is possible.

NCP Performance Indicators

- A long-time northerner working as the AAROM Coordinator for the Dehcho First Nations coordinated the study.
- An Aboriginal biologist/technician organized and supervised the field work.
- Four individual Dene monitor/harvesters were hired by the First Nations to provide traditional knowledge guidance and field work for the two projects
- Four meetings were held regarding the project
- No students were involved during this phase due to timing and logistics.
- No publications at this time.

Expected Project Completion Date

March, 2013.

I apologize for the late report. We kept getting assurances that more trout were coming from Wrigley but it just hasn't happened.

Acknowledgements

- We would like to thank Lorna Skinner and Simon Smith of the Northern Contaminants Program for providing the guidance and late funding assistance which made the early start of this study possible.

- We would like to thank the Dehcho First Nations as well as the leadership and staff of the Jean Marie River First Nation and the Pehdehzeh Ki First Nation for their support and administration of the study.
- We enjoyed working in the field with Angus Sanguez and Earnest Hardisty of Jean Marie River and David Horassi, Jessie Clillie and Charlie Tale of Wrigley.
- Mike Low and Shawn Buckley supervised the field projects and kept the books straight.

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Tukisimakatigennik ('Understanding Together'): Inuit Knowledge and Scientific Inquiry into Contaminant Trends in Nunatsiavut

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Abstract

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

Résumé

Ce projet multidisciplinaire étudie les liens entre les connaissances scientifiques et le savoir inuit afin d'analyser les tendances dans la présence de contaminants chez les phoques annelés le long de la côte du Nunatsiavut. Dans un modèle de recherche à méthodes mixtes, des chasseurs et des dépositaires du savoir inuit sont interrogés au sujet des changements observés dans l'écologie des phoques annelés au fil du temps. Ce savoir est mis en relation avec les constatations scientifiques relatives aux tendances des contaminants chez les phoques annelés de la région. En 2010–2011, des guides d'entrevue préliminaires et des documents d'accompagnement (cartes et guide pratique multilingue) ont été élaborés pour orienter les discussions

topics both during hunting trips in the field and through interviews in the community of Nain. The interview guide was then refined and interview tools are being finalized. Initial analysis of IK documented through interviews is now being conducted.

avec les dépositaires du savoir inuit sur l'écologie des phoques annelés, leurs déplacements, leur régime alimentaire et leur état corporel. Des entrevues initiales ont été menées et le savoir inuit sur ces questions a été recueilli au cours d'expéditions de chasse et d'entrevues menées dans la collectivité de Nain. Le guide d'entrevue a été affiné et les outils d'entrevue ont été mis au point. Une première analyse du savoir inuit recueilli lors des entrevues est en cours.

Key Messages

- A mixed methods approach to linking Inuit Knowledge and science to understand trends in ringed seal contaminant levels is being used in Nain, Nunatsiavut
- Project interview guides and supporting materials (maps, prey species guide) were developed and adapted this year
- Initial interviews during hunting trips and in the community were conducted

Messages clés

- Un modèle de recherche à méthodes mixtes visant à mettre en relation le savoir inuit et les connaissances scientifiques afin de dégager les tendances dans les niveaux de contaminants chez les phoques annelés est appliqué à Nain, au Nunatsiavut
- Des guides d'entrevue et des documents d'accompagnement (cartes, guide sur les espèces proies) ont été mis au point et adaptés cette année.
- Des entrevues initiales ont été menées au cours d'expéditions de chasse et au sein de la collectivité.

Objectives

Specifically, the objectives of this project were to:

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

Introduction

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

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

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

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

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

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

Activities in 2010–2011

Overview
This project was awarded pilot project funding this past year (2010–11) under the NCP. During this year the following was accomplished:

- Teleconferences and face to face meetings of team members (CF, TS, MD and TB) took place to discuss project goals, process, feasibility, pilot year development;
- Team membership was increased and strengthened to include two local researchers (increased from one), NCP lead monitoring researcher (D Muir) and Trent based, trained RA (R Laing);
- Ringed seal IK interview protocol development took place (information and consent form development, and interview guides were developed, adapted and tested with participants in the field during video interviews in northern Nunatsiavut and in community (Nain) during participant mapping interviews);
- Semi-directive interview training took place with two community researchers;

- Pilot interviews (observations of changes as well as participant mapping/ethnographic) were conducted in northern Nunatsiavut with seal hunters (n=14);
- The development of an NVivo coding database was completed with the qualitative data gathered to date (provides structure for qualitative analysis);
- The development of an Inuktitut-Labrador local name-English prey spp guide was undertaken (currently under finalization);
- A review of the potential for the application of Fuzzy Cognitive Mapping for linking of IK and science on this topic versus mixed methods data triangulation and sequential analysis was performed and discussed among team members;
- Qualitative (IK gathered through interviews) and quantitative (scientific contaminant trend and ecology) data were reviewed for initial connection with phenomenological, temporal and geographic scale similarity to assess feasibility of proposed "linking" and "complementary" analysis through triangulation process.

Results

It is critically important that IK be gathered and documented in as accurate and precise a manner as possible. To this end, it was necessary to prepare resource materials for IK interviews and mapping exercises that allows harvesters and other knowledge holders to document their knowledge of ringed seal diet and ecology accurately and using appropriate terminology. To support this goal, an English – Labrador – Inuktitut illustrated ringed seal prey species guide is being finalized. It is similar to that developed by McLeod, Furgal et al. (2008) for a beluga whale ecology IK study in Nunavik (McLeod et al., 2006). This guide will be used in the full version of this project in 2011–12 and subsequently be provided to interview participants as gifts. Further, local and regional maps were created and printed for the IK interviews and data collection.

In cooperation with C Furgal's IPY sub-project on marine fats (E Dewailly PI) and in cooperation with T Brown's research on ringed seal health in Nunatsiavut the pilot interview guide was tested after training of local research assistants and the University based RA took place. Pilot interviews were conducted with hunters in a field setting (during ringed seal hunts and sampling trips). It has been argued that the most rich and detailed IK information is exchanged in settings of practice (ie. on the land, or out on a hunt). Additional digital photos and video of potential relevance for the interviews (common phenomenon being observed by hunters re: ringed seal diet or health) were also gathered at this time. Semi-directive, individual ethnocartographic (also referred to as participant mapping) interviews were also held with local Nunatsiavimmiut harvesters and other experts from Nain, Nunatsiavut. Interviews were conducted in the location and in the language of the participants choosing. The interviews focused on ringed seal diet, behaviour and general ecology with a focus on spatial, temporal variation and change over time in the Nunatsiavut region. Hunters identified any observed changes in ringed seal, their coat, fat, stomach contents and if there was anything else that had changed in the seals over their life while hunting. They also talked about any concerns in regards to ringed seals, which included topics ranging from and inclusive of climate change to contaminants. The pilot sample size of interviewees was identified to gather sufficient information with which to test the analytical and triangulation protocol and to fine tune the guide for participant comprehension and clarity. All interview audio recordings were translated (if required) and transcribed verbatim and reviewed and verified for reliability in transcription by a second researcher and the participant. All documented map information is being scanned and digitized using QGIS.

Discussion and Conclusions

Although the NCP has not identified any Nunatsiavut communities under the long-term trends monitoring program, contaminants data has been collected for species in Nunatsiavut over the past 15 years. In addition, the Nunatsiavut Government feels strongly that information with respect to contaminant levels in ringed seal from Nunatsiavut is a priority now and going forward. As such, we are co-leading this holistic program to better understand ringed seal behaviour and ecology in our region. Working closely with our hunters and local experts to better document their observations and knowledge about ringed seal and the supporting ecosystem will complete this holistic approach and create a better framework for understanding changes to the ecology of this important species.

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

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

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

c. Ringed seal satellite telemetry study

d. Ringed seal health (genomics) study

e. Contaminants module of kANGIDLUASUk Student Program Inc.

Capacity Building:
For this program, Mary Denniston has played a leading role on the local level, working closely with newly hired and experienced local researcher Frances Murphy and harvesters from the community of Nain. They work closely with the University and government based members of the project team. Involvement and leadership by the regional research staff has contributed to capacity building for local and regional research staff. Individuals involved will continue to gain valuable experience in this new and innovative project bringing together science and IK. This project is also expected to be valuable in supporting a growing agenda at the Nunatsiavut Research Centre towards cooperative science and IK and innovative IK research.

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

One graduate student level RA (R Laing) is also gaining experience and training through this project. They, along with the Nunatsiavut researchers, will continue to receive training in interviewing, participant mapping exercises (ethnocartography), and qualitative analysis.

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

Communications:
In addition to the creation of a Nunatsiavut field guide on ringed seal prey and ecology, local communications are being coordinated by the Northern Contaminants Researcher for Nunatsiavut. Updates on the progress and results of this project are being included in semi-annual contaminants newsletters, written by the Northern Contaminants Researcher. The Nunatsiavut Government maintains continuous contact and discussions with the hunters to ensure they are comfortable and have significant input to the directions of the research program. Initial radio interviews were conducted with the community and University based RA on the project during which this project was discussed. A final report on the progress of the one year program is being provided to the community and then upon completion of the final project in late 2012/early 2013 a IK/science report will be released and presented in the community. A contribution to the Nunatsiavut regional NCP presentation was included on this project as well

and updates were presented on the Nunatsiavut Research Day conducted in conjunction with the most recent ArcticNet Annual Scientific Meeting in December 2011.

NCP Performance Indicators

Indicator	Number in 2010–11
# of northerners engaged in the project:	18
# of meetings/workshops held in the North	4
# of students (northern and southern) involved:	10
# of citable publications produced:	2

Expected Project Completion Date

March, 2012.

Acknowledgements

We thank the harvesters and knowledge holders from the community of Nain who have participated in this work—their contribution has been incredibly valuable. This work would not have been possible without support from INAC-NCP.

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Communication, Capacity and Outreach

kANGIDLUASUk: A Cornerstone for Connecting Inuit Youth with Science Through Experiential Education and Outreach

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Abstract

The kANGIDLUASUk student program is pushing the frontiers of science in the Canadian Arctic, providing dynamic work and learning experiences for Nunatsiavut and Nunavik youth at the Torngat Mountains Base Camp and Research Station in the Labrador Inuit homeland of Nunatsiavut. Since its establishment four years ago, students have had the opportunity to assist a variety of scientists working out of the Base Camp with hands-on scientific fieldwork in marine, freshwater, terrestrial and glacial research programs. Located at the southern boundary of Torngat Mountains National Park, a unique and central aspect of the Base Camp is that it is managed and run by Inuit. This has allowed students to experience scientific research in their own cultural context, exploring

Résumé

Le programme étudiant kANGIDLUASUk repousse les frontières de la science dans l'Arctique canadien en permettant aux jeunes du Nunatsiavut et du Nunavik d'acquérir une expérience de travail et d'apprentissage dynamique au camp de base et à la station de recherche des monts Torngat au Nunatsiavut, la terre natale des Inuits du Labrador. Depuis la création du programme, il y a quatre ans, les étudiants ont eu l'occasion d'aider une variété de chercheurs en réalisant des travaux scientifiques sur le terrain dans le cadre de programmes de recherche marine, terrestre, glaciaire et sur l'eau douce. Situé à la frontière sud du Parc national du Canada des Monts-Torngat, le camp de base se distingue car il est géré et exploité par les Inuits. Cette particularité offre aux étudiants l'occasion de participer à des

questions and concerns about the natural environment through the dual lens of science and Inuit culture, values, and knowledge.

With the support of the Northern Contaminants Program, we have taken advantage of the unique aspects of the Base Camp to create a cross-curricular contaminants field unit for the Student Program that explores the key messages of the Northern Contaminants Program (NCP) through a variety of experiences and activities that allow students to gain knowledge related to contaminants and develop a variety of skills consistent with the vision and goals of the kANGIDLUASUk Student Program. The field unit involves presentations and hands-on fieldwork alongside researchers, multidisciplinary programming with Parks Canada, as well as exploratory activities and output projects that examine contaminant types, transport, global action and trends, marine food web dynamics, Inuit health and nutrition, and Traditional Ecological Knowledge. The module also provides opportunities and experiences for participants to develop and practice a variety of leadership, employability, traditional, and scientific investigation skills. It is our hope that the integration of this field unit within the kANGIDLUASUk Student Program will lead to an enhanced ability and excitement for Inuit youth to become engaged in contaminants related research and research undertaken by the NCP in general.

recherches scientifiques dans un contexte culturel qui leur est propre, ce qui leur permet d'explorer diverses questions et préoccupations au sujet de l'environnement tant sous l'angle scientifique qu'à travers la culture, les valeurs et les connaissances inuites.

Avec le soutien du Programme de lutte contre les contaminants dans le Nord (PLCN), nous avons tiré profit du caractère unique du camp de base pour créer, au sein du programme étudiant, une unité interdisciplinaire consacrée à la lutte contre les contaminants. Cette unité explore les différentes facettes du PLCN à travers diverses expériences et activités qui permettent aux étudiants d'acquérir des connaissances liées aux contaminants et de développer des habiletés rejoignant la vision et les cibles du programme étudiant kANGIDLUASUk. L'unité sur le terrain offre des présentations et une expérience active avec les chercheurs, des programmes pluridisciplinaires avec Parcs Canada ainsi que des activités exploratoires et des projets axés sur les résultats portant sur les types de contaminants, les déplacements, les actions et les tendances globales, la dynamique de la chaîne alimentaire marine, la santé et l'alimentation des Inuits et les connaissances écologiques traditionnelles. Le module offre aussi aux participants des occasions de développer et de mettre en pratique des compétences en leadership, leur employabilité et diverses habiletés traditionnelles et d'exploration scientifique. Nous espérons que l'intégration de cette unité au programme étudiant kANGIDLUASUk mènera à l'amélioration des compétences et à un engouement des jeunes Inuits pour les recherches liées à la lutte contre les contaminants et celles réalisées par le PLCN en général.

Key Messages

- Immersion in experiential learning opportunities in settings that are familiar and comfortable for Inuit youth results in more transformative experiences for them.
- The infusion of a contaminants module throughout the various kANGIDLUASUk Student Program experiences at the Torngat Mountains Base Camp and Research Station with cross-curricular programming creates a more dynamic and engaging experience.

Messages clés

- L'immersion au sein d'un milieu d'apprentissage et d'expérimentation dans un contexte familier et confortable offre une expérience inspirante aux jeunes Inuits.
- L'ajout du module de lutte contre les contaminants aux diverses composantes du programme étudiant kANGIDLUASUk au camp de base et à la station de recherche des monts Torngat crée une expérience des plus enrichissante et dynamique.

Objectives

- Deliver the key messages of the Northern Contaminants Program (NCP) through a variety of activities that allow students to gain knowledge related to contaminants and practical skills and experiences consistent with the vision and goals of the kANGIDLUASUk Student Program.
- Provide experiential work and learning opportunities for Inuit youth that influence their career or life paths through a multi-faceted and cross-cultural internship integrating Inuit culture, arctic science and northern adventure.
- Deliver a one-of-a-kind four week 2010 summer student program for 10 Inuit students from Nunatsiavut and Nunavik in conjunction with the programs (environmental and cultural) operating out of the Torngat Mountains Base Camp and Research Station.
- Continue developing a modular experiential program with Inuit and non-Inuit instructors that combines research-based learning, leadership training, and cultural awareness.
- Support students while providing opportunities for them to participate in several contaminants focused research programs, increasing their capacity to understand and engage in environmental and contaminants related research.
- Further develop and pilot modules of a contaminants based field unit that will be delivered annually to student interns participating in the program.

Introduction

For four years now, Parks Canada and the Nunatsiavut Government have piloted the operation of a base camp at the southern boundary of the Torngat Mountains National Park at kANGIDLUASUk. The camp—now named the Torngat Mountains Base Camp and Research Station—is managed and run by local Inuit and transforms the shores of kANGIDLUASUk into a unique gathering place. It is a place where researchers, tourists, government members, Parks Canada staff, families, and local Inuit share, teach, and learn together. The Base Camp has established a bedrock for scientists and Inuit to come together with the best that each have to offer to develop a "new way of knowing" as they explore their questions and concerns about the natural environment. Researchers have expressed strong support for the Base Camp, stating that "kANGIDLUASUk is a gift … it is an incredible opportunity to live in an Inuit camp and to work with Inuit – young and old—from Nunavik and Nunatsiavut."

Accompanying the development of the Base Camp was a philosophy that scientific research taking place in the Torngat Mountains should include meaningful experiential opportunities and capacity building for Inuit youth from both Nunatsiavut and Nunavik. As such, experiential education and outreach internships for Inuit youth were piloted. As a result, Inuit youth have had the opportunity to integrate into all of the unique and diverse aspects of the Base Camp for four consecutive weeks each field season, creating opportunities for them to experience the land, work with visiting scientists, and learn and share with local elders, Inuit contractors, government members, Parks Canada staff, local artisans, and international tourists. Since 2007, this outreach initiative – now named the kANGIDLUASUk Student Program—has expanded from 3 to 10 students and hired a full-time program coordinator (spring '09) to add depth to the program in the areas of group facilitation, cohesion, and leadership development as well as program planning, promotion, and module expansion.

In 2010, part of the refinement that took place within the kANGIDLUASUk student program was the development of a contaminants field unit. Components of the contaminants field unit were piloted where students learned about contaminants in the arctic. This involved presentations, activities, excursions and experiential fieldwork and labs alongside researchers and local Inuit leaders. With Northern Contaminants Program support for the overall kANGIDLUASUk student program, we were able to further develop the contaminants field unit for the program to engage Inuit youth in the scientific process and understanding of contaminants in the Arctic while building a variety of skill sets for future employability and life-long learning.

Activities in 2010–2011

The 2010 kANGIDLUASUk student program was based out of the Torngat Mountains Base Camp and Research Station in Nunatsiavut during July – August 2010. Ten Inuit students from Nunatsiavut (6) and Nunavik (4) communities participated in the four-week experiential work and learning internship. Participants were from Nain, Makkovik and Goose Bay in Labrador and Kangiqsualujjuaq within Nunavik. Activities included a blend of science, culture and adventure. The overall program was designed to contextualize each individual activity and foster a sense of connection and relevance to the scientific programs taking place.

A typical day involved:

- Working with researchers onboard Inuit longliners to study marine food web and contaminant dynamics.
- Travelling to historic Inuit sites and shared family homelands to encourage a sense of connection to place.
- Learning about the process of scientific research, from the identification of an issue, to forming a hypothesis, conducting data collection, safety, analysis and interpretation, and communication of the results.
- Harvesting country foods with local Inuit and elders for meals that residents of the base camp enjoy daily.
- Sampling, processing and storing tissues from these country foods for contaminants analyses while learning about short and long-range sources and origins of contaminants.
- Learning to prepare country food for eating and drying.
- Working with researchers studying the impacts of a changing climate on marine and terrestrial ecosystems.
- Assisting with archaeological field work and the documentation of Inuit oral history.

Other learning opportunities included…

- Hiking the Torngat Mountains and learning about the land and customs from local Inuit.
- Reflecting on experiences through music, art, photography, writing, discussions and storytelling.
- Presentations, workshops and field modules on arctic science and research, climate change, health and safety, leadership development, local Inuit history and folklore, Inuit arts and crafts, government and land management.

This year, a focus of the program was the development and design of a contaminants field unit and pilot delivery of unit modules. Through a combination of presentations, cross-curricular activities and experiential fieldwork in partnership with related research projects, Inuit harvesters, elders, and other Base Camp programming where appropriate, the module created opportunities for Nunatsiavut and Nunavik Inuit youth to increase their understanding of:

- contaminants, contaminant pathways, processes, issues, and effects that contaminants may have on wildlife and peoples in the north.
- the Northern Contaminants Program.
- the development and implementation of global agreements to reduce and/or eliminate the production, use, and release of contaminating substances into the environment.
- nutritional information and health benefits of consuming country foods.
- connections or linkages between Inuit Knowledge, values, observations, and perceptions and the scientific understanding of contaminants, contaminant issues and trends.

The program and field unit activities also provided opportunities and experiences that allowed program participants to develop and practice a variety of leadership, employability, traditional, and scientific investigation skills (Results, Figure 2).

Capacity Building and Training

Capacity building and training form the core purpose of the kANGIDLUASUk Student Program. The kANGIDLUASUk Student Program is designed with a focus on the provision of a variety of opportunities and support for interns to build critical employability skills, traditional skills, scientific investigation skills, and leadership skills, as well as the trust, confidence and resilience to use these skills (Results, Figures 1–3). As a result, program participants have acquired subsequent employment in various environmental jobs, and have been selected or invited to be involved in other unique learning opportunities (ie. conferences, Students on Ice expeditions). We believe the program has been successful because it engages students in a holistic research program through their own cultural lens. Because of this, students become excited about science and become engaged in the research process. It is our hope that the increased emphasis on the contaminants related module and work as a result of this proposal will lead to an enhanced ability and excitement for the students to become engaged in contaminants related research and research undertaken by the NCP in general.

Traditional Knowledge

Traditional Knowledge is an integral part of the student program at the Torngat Mountains Base Camp and Research Station and is a large part of the reason why the introduction of arctic research, including contaminants based work is well received. The Base Camp is managed and run by local Inuit. This has enabled youth to explore hands-on work and learning experiences in the context of Inuit culture, values and knowledge.

All research initiatives that operate from the Base Camp are logistically supported by Inuit. While assisting with field work, interns have opportunities to explore methods and concepts through the dual lens of science and Inuit culture, drawing on the expertise of both the researchers in their field of study as well as the skills and ecological knowledge of accompanying guides, wildlife monitors, research assistants, TMNP Inuit staff, and the captains and crew of local longliners.

With guidance from Base Camp and longliner staff, Torngat Mountains National Park (TMNP) Cooperative Management Board members, TMNP Inuit staff, visiting Nunatsiavut and Nunavik elders, as well as community members and families, interns also have the opportunity to learn, share, and teach a variety of traditional skills, crafts, and activities throughout the program. This has included carving, ulu making, traditional food preparation, traditional navigation, seal skin cleaning, and harvesting of char, seal, and caribou for Base Camp meals.

Throughout the program, interns travel to significant natural, historic and cultural sites in the region and within Torngat Mountains National Park with research programs, local Inuit guides and elders, as well as Parks Canada staff and archaeologists. Embedded within all outings—be it multi-day hiking trips, afternoon boil-ups, research endeavours, or excursions by speed boat or longliner—are opportunities to hear stories from many Nunatsiavut and Nunavik Inuit who lived and/or traveled in the area. Sharing these experiences with other Nunatsiavut and Nunavik leaders and elders provides a special connection between the generations.

The integrated program format also creates opportunities for cultural exchange, offering youth from both Nunatsiavut and Nunavik the opportunity to interact for an extended and intense period to share the diverse qualities they bring to the Base Camp experience, to discuss their futures from a broader perspective, and build connections to a network of young Inuit leaders across the eastern Arctic.

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Results

The kANGIDLUASUk Student Program invests a lot of time and energy in the quality of experience for each individual youth participant. A unique and dynamic 650 hour program, incorporating a multidisciplinary contaminants module has been created that touches both the minds and hearts of our students. The figures below, which are captured during exit feedback and evaluations with each youth participant, only begin to illustrate the extent of true impact of the experience. With respect to overall knowledge gained about contaminants, students indicated that their knowledge level before and after the program significantly increased (Figure 1). As mentioned previously, a core objective of the kANGIDLUASUk Student Program is to build capacity. Results of the program indicate that students feel they have gained valuable employment skills and have become more employable as a result of their participation in the program (Figures 2 and 3). Figure 4 is an outline summary of the contaminant field unit components developed to date.

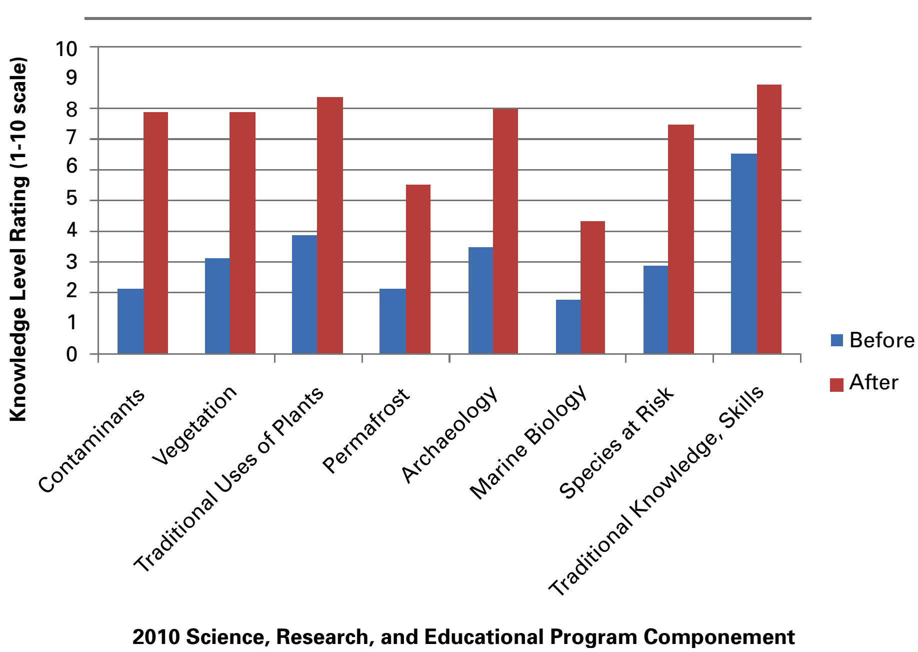

Figure 1: Mean self-rated student knowledge levels before and after participating in the 2010 kANGIDLUASUk Student Program.

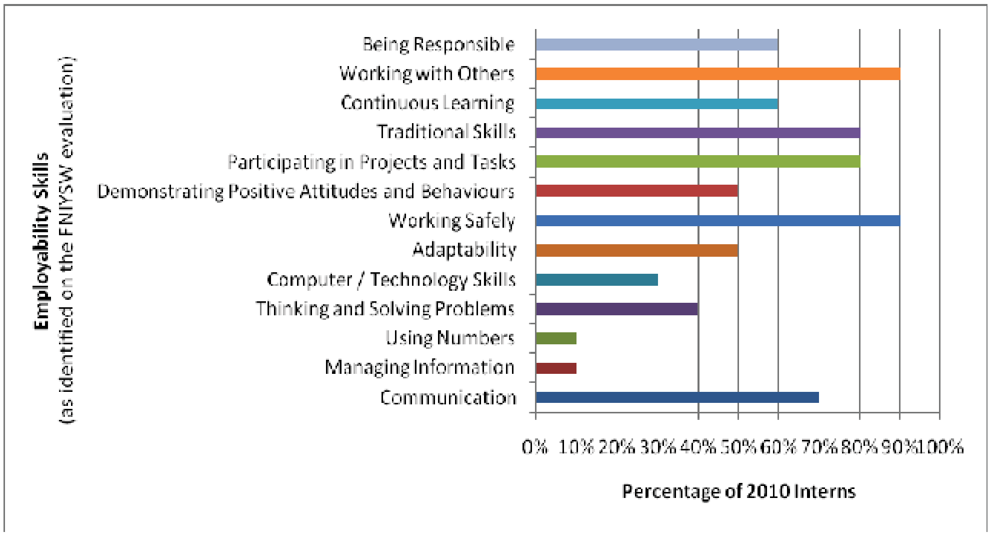

Figure 2: The percentage of 2010 interns who identified having developed and improved a variety of critical employability skills throughout their summer program experience. Employability skills as defined by the First Nations and Inuit Youth Summer Work Experience (FNIYSW) Evaluation.

Figure 3: The percentage of 2010 interns rating the benefits of their experience in regards to future employability and education (FNIYSW Evaluation).

	Rating		
Question	Absolutely	Somewhat	Not at all
Do you feel more employable as a result of your work experience?	80%	20%	0%
Are you more aware of the benefits of completing your education?	80%	20%	0%
Are you more aware of different types of jobs that are available?	80%	20%	0%

Figure 4: A summary of activities and knowledge and skill objectives for the kANGIDLUASUk Student Program contaminants field unit.

Module	Knowledge Objective	Skill and Behaviour Objectives	Activity
I. Country Foods	Why country foods are important; allow students to reflect on their own views and relationships with country foods.	Gather, record, organize, and summarize information, communication, numeric calculations, interpret data/information to identify patterns and relationships, working with others, respecting various perspectives, adaptability, time management, patience.	Shore lunch/boil-up; conducting interviews with each other and others at the Base Camp.
II. Contaminants Overview and Introduction to Northern Contaminants Program	Determine the students' baseline knowledge (pre-assessment); basic facts about contaminants; goals of Northern Contaminants Program; vocabulary associated with contaminants.	Communication, critical and logical thinking, respecting various perspectives.	Watch videos; Golden Bell True/False Game; develop glossary of contaminant-related terms
III. Types of Contaminants	Identify types of contaminants (POPS, metals, radionuclides, hydrocarbons, emerging contaminants) and their main characteristics and sources.	Critical thinking, interpreting data/ information, reading and summarizing information, communication, computer/ technology skills, adaptability, working with others.	Case studies
IV. Contaminants in Ecosystems	Food webs; bioaccumulation; biomagnifications; where different contaminants accumulate in an animal; differences between terrestrial and marine food webs and biomagnifications.	Communication; collection, dissection, and anatomy of marine species, working safely, adaptability, working with others, observation and recording, respecting various perspectives, traditional harvesting and navigation.	Roll playing biomagnification tag game; collection and dissection of marine species in conjunction with Marine Field Unit.
V. Where did it come from? Long Range and Local Contaminants	Identify types and sources of contamination.	Computer/technology skills, navigation, organize and summarize information, communication, categorizing and classifying information, working with others, adaptability, working safely, critical and logical thinking, solving problems, time management.	GPS cache hunt in conjunction with IPY/ ParkSPACE module, classifying examples of contaminants in the Arctic by their type and if they are long or short-range sources.
VI. Contaminant Trends, Global Action and Environmental Stewardship	Levels of some contaminants in the Arctic are decreasing and others are increasing; successes of the Stockholm Convention; need for global solutions; creation of new chemicals; Think Globally, Act Locally	Communication, think critically, respecting various perspectives.	Video;small group investigations. environmental stewardship activity around the Base Camp.
VII. Health and Country Food	There are many factors that affect health and well-being; the role of nutrients in health; nutritional benefits of country foods; country food and store bought food comparisons; traditional food preparation and cooking.	Communication, interpret and summarize data/information, working with others, respecting various perspectives, adaptability, patience, traditional food preparation/cooking.	TBD. Small group research and presentations using music, art, drama, or storytelling, prepare a group supper with traditional foods, "cheers" /toasting debrief during supper.

Discussion and Conclusions

It is clear that the immersion of Inuit youth in experiential learning opportunities in settings that are familiar and comfortable for them results in positive and transformative learning experiences and multifaceted skill development. 2011 program feedback and evaluations will be further developed to assess and report on program impact in these areas.

At this time, the field unit (Figure 4) is designed to be flexible, and can be conducted over consecutive days or spread out throughout the four-week Student Program to integrate opportunistic experiences that would complement the unit. The field unit is divided into seven modules that are intended to be completed in order, with each module building on the previous one. Knowing that weather is variable at the Base Camp, there is a combination of activities that can be delivered indoors (group program tent) and outdoors, with some flexibility within each module. Ideally, the facilitator will be able to draw on the resources at the Base Camp and integrate the contaminants field unit activities with other programming. If there are any experts on a particular area that is explored in the Contaminants Field Unit at the Base Camp, they can be brought in to teach or expand on a certain topic. Conversely, a particular facilitator could be brought to the Base Camp to deliver the field unit or its components over a series of consecutive days. Ongoing and final feedback from the 2011 field unit delivery will inform further module development in regards to delivery, content, and activities to ensure engaging, effective, accurate, and relevant experiences for participants.

NCP Performance Indicators

- *Number of northerners engaged in the project:* 44 (includes students, elders, base camp staff, TMNP staff, student program staff and Board of Directors)
- *Number of meetings/workshops held in the North:* >20 (the program is based out of Nunatsiavut, so all program meetings take place in the North)
- *Number of students involved:* 11 (10 students and a leader in training)
- *Number of citable publications:* 10 (reports, book entries, magazine, oral presentations)

Expected Project Completion Date

The contaminants module is continually being revised, updated and improved. The 2011 version of the contaminants module, which builds on work and activities completed over the past year will be completed in July to be implemented in the 2011 summer program. Feedback forms from 2011 evaluations will be used to adjust and refine module delivery, content, and activities. Expected module completion for print (with finalized design and graphics) is December 2011.

Acknowledgments

The kANGIDLUASUk Student Program gratefully acknowledges the generosity of our 2010 supporters:

Contributors

- Tasuijatsoak Trust
- Saputiit Youth Association of Nunavik
- Fednav Ltd.
- Parks Canada – Torngat Mountains National Park
- Indian and Northern Affairs Canada
  - Northern Contaminants Program
  - First Nations and Inuit Youth Employment Strategy
- Nasivvik Centre for Health and Changing Environments
- Environment Canada
  - Aboriginal Funds for Species at Risk

Organizations

- Nunatsiavut Government
- Environmental Sciences Group
- Torngat Mountains National Park Cooperative Management Board
- Labrador Inuit Development Corporation.
- ArcticNet
- International Polar Year

- Inuit Tapiriit Kanatami
- Schools on Board
- Air Inuit
- Trailhead Ottawa
- Nassituq – Saglek Radar Station

Thank you to the following individuals for their involvement, expertise, time and/or support with the 2010 field program and organizational development and operations:

Sam Lyall, Jason Dicker,Patrick Webb, Jenni-Rose Campbell, Paul Andersen, Brenda Jararuse, Lizzie Unatweenuk, Saladie Snowball, Charlie Annanack, Williami Annanack, Katie Hollet, Abbigail Webb, Donna Dicker, Harry Haye, Bennett Barbour, Eli Merkuratsuk, John Andersen, Kenny Dicker Jr., Jobie Unatweenuk, John Merkuratsuk, Robert Harris, Ron Webb, Gus Dicker, Bert Voisey, Lillian Blake, Charlotte Nochasak, Ben Andersen, George Gear, Ephraim Merkuratsuk, Andrew Andersen, Henry Lyall, Ches Webb, Joe Webb, Jerrett Webb, Bradley Webb, Joey Angnatok, Leo Angnatok, Samuel Ittulak, John Ross Angnatok, Ryan Merkuratsuk, Joe Atsatata, William Fox, Larry Brandridge, Willie Etok, Tommy Unatweenuk, George Berthe, Jessie Wyatt, John Jararuse, Jim Igloliorte, Derrick Pottle, Gary Baikie, Jacko Merkuratsuk, Angus Simpson, Judy Rowell, Rosie Lyall, Mary Annanack, Jenneth Curtis, Darroch Whittaker, Shawn Gerrow, Chantal Ouimet, Jeff Anderson, Alain Boudreau, Dave Cote, Patrick Wade, Lucette Barber,Tim Keane, Mary Denniston, Sharon Pevie, Heather Angnatok, Sandra Dicker, Theresa Hollett, Tom Sheldon, William Barbour, Veryan Haysom, Wilson Jararuse, Molly Emudluk, Minnie Unatweenuk, Sarah Unatweenuk, Samantha Emudluk, Elisapee Annanack, Dennis Wyatt, Minnie Mae Annanack, Annie Johannes, Annie Lidd, Julius Merkuratsuk, Susie Morgan, Sammy Unatweenuk, Gus Semigak, Tanya Brown, Sam Bentley, Mallory Carpenter, Trevor Bell, Jodie King, Carol Luttmer, Sophie Pantin, Laura Siegwart-Collier, Dan Myers, Luise Hermanutz, Alain Cuerrier, Julia Wheeler, Peter Koncz, John Jacobs, Wendy Sladen, Caroline Duchesne, Geoff Goodyear, Sarah Pasha Annanack, Jonathan Epoo, Josh Pamak, Peter Jefford, Isabella Pain, Buddy and Jenny Merkuratsuk, Ken Reimer, Chris Furgal.

Dehcho First Nations Participation on the NWT Regional Contaminants Committee (NWT RCC)

Project Leaders:
Ms. Carrie Breneman (Acting Resource Management Coordinator), Ms. Keyna Norwegian (Resource Management Coordinator) and Ms. Ria Letcher (Executive Director) of Dehcho First Nations

Project Team Members:
Dehcho First Nations (based in Fort Simpson, NT) provides representation for all of the member communities in the Dehcho Region which includes: Liidlii Kue First Nation, Fort Simpson; Deh Gah Gotie Dene Council, Fort Providence; Katlodeeche First Nation, Hay River Reserve; JMR First Nation, Jean Marie; Ka'a'gee Tu First Nation, Kakisa Lake; Pehdzeh Ki First Nation, Wrigley; Nahanni Butte Dene Band, Nahanni Butte; Sambaa K'e First Nation, Trout Lake; West Point First Nation, Hay River; Fort Simpson Metis Local, Fort Simpson and Fort Providence Metis Local, Fort Providence.

Abstract

As part of Dehcho First Nations' (DFN) membership on the Northwest Territories Regional Contaminants Committee (NWT RCC), DFN has been educating and communicating to its members the message of the Northern Contaminants Program. DFN has and will continue to communicate with its members about contaminants, research and other priorities and to gather information and feedback. The awareness and education of contaminants will inform traditional land users on the research results and activities. DFN's past and continued participation the NWT RCC has and will continue to enable concerns in the Dehcho Region to be brought to the NWT RCC and appropriately addressed.

In 2010 and 2011, DFN has participated in the NWT RCC by attending meetings, conference calls and communicating via email. DFN also served as a liaison between the NWT RCC and the local communities in the Dehcho Region and transferred information from the NWT RCC

Résumé

En sa qualité de membre du Comité régional des contaminants des Territoires du Nord Ouest (CRC-TNO), l'organisme des Premières Nations du Dehcho (PND) a fait connaître à ses membres le message du Programme de lutte contre les contaminants dans le Nord. L'organisme a communiqué avec ses membres et continuera de le faire pour les renseigner sur les contaminants, la recherche et d'autres priorités ainsi que pour obtenir des informations et de la rétroaction. La sensibilisation et la formation en matière de contaminants permettront aux utilisateurs des terres traditionnelles de connaître les activités de recherche et leurs résultats. La participation continue des PND au CRC-TNO permet de porter les préoccupations de la région du Dehcho à l'attention du CRC-TNO et de les régler de façon appropriée.

En 2010 et en 2011, la participation des PND au CRC-TNO a consisté à assister à des réunions, à participer à des conférences téléphoniques et à

to the local community and brought concerns from the local communities to the NWT RCC. Participation in the NWT RCC, allowed DFN to provide provided comments and input regarding socio-cultural considerations to project researchers.

communiquer par courriel. L'organisme des PND a aussi agi à titre de coordonnateur entre le CRC-TNO et les collectivités locales de la région du Dehcho.

Il a transmis des renseignements du CRC TNO aux collectivités locales et il a porté les préoccupations des collectivités à l'attention du CRC-TNO. Grâce à sa participation au CRC-TNO, l'organisme des PND a transmis aux chercheurs du projet des observations et commentaires sur des facteurs socioculturels.

Key Messages

DFN through continual participation in the NWT RCC:

- Provides a forum for the two-way transfer of contaminants information that is relevant to the Dehcho Region between residents, researchers, the Northern Contaminants;
- Enables socio-cultural input and considerations to be identified for research projects occurring in the North; and
- Enables local communities and residents in the Dehcho Region to provide concerns regarding contaminants and for these concerns to be appropriately addressed.

Messages clés

L'organisme des PND, par sa participation continue au CRC-TNO :

- offre aux résidents, aux chercheurs et aux responsables du programme de lutte contre les contaminants une tribune où peuvent être échangés des renseignements sur les contaminants qui touchent directement la région du Dehcho;
- permet de connaître les facteurs socioculturels liés au projet de recherche dans le Nord;
- permet aux collectivités locales et aux résidents de la région du Dehcho de parler de leurs préoccupations à l'égard des contaminants, ce qui permet de régler ces questions de façon appropriée.

Objectives

Dehcho First Nations (DFN) will facilitate the process of collaborative study, assessment and communication of information to residents of their region regarding the presence and possible effects of contaminants in the air, land, water and wildlife, from long range transport sources as well as local contaminants sources as appropriate.

Specific objectives include:

- To education and communicate with its members information regarding the Northern Contaminants Program;
- To gather information from communities in the Dehcho Region regarding contaminants, NCP research and other priorities;
- To attend the social/cultural review meetings and attend the annual NCP Results Workshop; and
- To work with researchers to initiate and organize research projects in the Dehcho Region and to identify and address community concerns within the Dehcho Region with the NWT Regional Contaminants Committee.

Introduction

The NWT Regional Contaminants Committee (NWT RCC) was established in 1997 with a primary focus on the Northern Contaminants Program. The NWT RCC was formally known as the NWT Environmental Contaminants Committee (NWT ECC). Members are identified by their participating aboriginal organizations and government agencies to represent community concerns relating to contaminants and the NCP program. The committee's role is to develop strategies and priorities each year and provide technical advice, traditional knowledge and perspectives to researchers and the NCP Management team.

Since it has become a member of the NWT RCC, DFN has been educating and communicating to its members the message of the Northern Contaminants Program. DFN has and will continue to communicate with its members about contaminants, research and other priorities and to gather information and feedback. The awareness and education of contaminants will inform traditional land users on the research results and activities. DFN's past and continued participation the NWT RCC has and will continue to enable concerns in the Dehcho Region to be appropriately addressed.

Activities in 2010–2011

In 2010–2011, DFN has participated and communicated with the NWT RCC and was involved with the RCC via conference calls, emails and meetings. DFN attended the Social/Cultural Review meetings and attended the annual NCP Results Workshop in September 2010 in Whitehorse, YK.

DFN has continued to work with researchers to initiate and organize research projects in the Dehcho region. In 2010–2011, DFN reviewed numerous research proposals to evaluate several socio-cultural criteria including: communication back to the local community; relevance of the project to Northerners, incorporation of traditional knowledge and local capacity building.

DFN has also continued to work towards educating and communicating to its members the messages of the Northern Contaminants Program. Most recently, DFN worked as a liaison to Trout Lake and brought forward concerns from local community members to NWT RCC regarding the recent public health advisory for the consumption of lake trout in Trout Lake.

As a result, of DFN's participation in the NWT RCC, a public meeting will be held in Trout Lake to educate local community members on the public health advisory and to enable community concerns to be brought forth to the NWT RCC.

AAROM is very instrumental in the Dehcho and is the lead person that has worked with Pehdzeh Ki, Sambaa K'e, and Jean Marie regarding mercury levels in fish in surrounding lakes within their respective traditional area.

DFN has also been sponsoring an Annual Youth Ecology Camp which has included activities and information related to traditional knowledge and ecology. Last years annual camp was held at Ekali Lake and information on water ecology was presented.

Results

DFN has made all communities in the Dehcho region aware of NCP services and funding opportunities to research contaminants in the Dehcho and bring awareness to community members. Dehcho have Fall, Winter and Spring Leadership meetings and an annual Assembly as Resource Management Coordinator it is my job to bring awareness of NCP to the members that attend and encourage communities to be involved in this type of programs. Reports will continue to be delivered to communities and presentation will be made available time permitting at leadership meetings.

Discussion and Conclusion

DFN will continue to participate in NWT RCC and will continue to communicate with their members. DFN will continue to raise community concerns in the NWT RCC and will enable these concerns to be addressed.

Expected Project Completion Date

Not applicable.

Arctic contaminants: Exploring Effective and Appropriate Communication between Inuvialuit Communities and Researchers

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Community members of Sachs Harbour, Northwest Territories

Abstract

Using contaminants research conducted through the International Polar Year's Circumpolar Flaw Lead System Study, Environmental Monitoring Projects from the Northern Contaminants Program, and Phase II of ArcticNet, this project explores the communication of research results with the Inuvialuit community of Sachs Harbour, NT. Project objectives are to consider participants' knowledge and perceptions of contaminants research and how research is communicated to communities; examine current communication methods used; and discuss, from a community perspective, how contaminants research can be communicated to communities in accessible, understandable, and relevant ways. Conducted using a participatory approach, this community-focused, collaborative study uses participatory video, semi-directive interviews and

Résumé

À partir des recherches menées sur les contaminants lors de l'Étude sur le chenal de séparation circumpolaire réalisée dans le cadre de l'Année polaire internationale, les projets de surveillance de l'environnement du Programme de lutte contre les contaminants dans le Nord et la phase II d'ArcticNet, le présent projet examine la communication des résultats de recherche à la collectivité inuvialuite de Sachs Harbour, dans les Territoires du Nord-Ouest. Les objectifs du projet sont d'examiner les connaissances et les perceptions des participants à l'égard de la recherche sur les contaminants et la façon dont les résultats sont communiqués aux collectivités, d'étudier les méthodes de communication qui sont actuellement utilisées et de discuter, selon une optique communautaire, de la manière dont les résultats des recherches sur les contaminants

discussion groups, which offers participants the opportunity to engage in and lead the two-way dialogue, determining how their knowledge is represented.

Over the course of four visits in the community, eleven initial interviews, eleven surveys and numerous informal meetings have occurred to date to establish the information and understanding participants retained through any and all previous research communication efforts, such as presentations, reports, and contact with researchers. 'Contaminants' and 'contamination' are viewed as very broad terms, including sources and causes that are both local and observable in addition to coming from overseas and southern latitudes via ocean and air currents. This suggests that contaminants information, as understood and communicated by scientists, is not retained, as intended, by most locals. Low levels of concern regarding the current safety of eating country foods indicate that they are still regarded as being a healthy choice. However, locals have expressed concern about contaminants affecting water, air, earth, country foods, and the health of future generations and country foods, and 91% believe that that it is important to learn about contaminants and that contaminants will be a big issue in the future. While surveys provided some insight into local perceptions of contaminants, their use will be discontinued in favour of the value that interviews have to offer for conceptual mapping and focus group discussions.

peuvent être communiqués aux collectivités de manière accessible, compréhensible et pertinente. Menée dans un cadre participatif, cette étude communautaire et collaborative fait appel à des vidéos participatives, à des entrevues semi-directives et à des groupes de discussion. Les participants ont ainsi l'occasion d'entamer et de diriger un dialogue et de déterminer comment leurs connaissances sont représentées. Onze entrevues initiales, onze sondages et de nombreuses réunions officieuses ont eu lieu jusqu'à maintenant pendant quatre visites communautaires afin de déterminer quels renseignements les participants ont compris et retenus dans le cadre de tous les efforts de communication des résultats de recherche précédents, comme des présentations, des rapports et des discussions avec des chercheurs. Les résultats indiquent que « contaminants » et « contamination » sont considérés comme des termes très larges, tout comme les sources et les causes locales et observables ainsi que celles en provenance de l'étranger et du sud par les courants océaniques et atmosphériques. Cela laisse entendre que l'information sur les contaminants, telle qu'elle est perçue et communiquée par les scientifiques, n'est pas retenue en détail par la plupart des résidents locaux. Les gens s'inquiètent peu des risques liés à la consommation d'aliments du pays, ce qui signifie que ces aliments sont toujours considérés comme un choix santé. Toutefois, les résidents se sont dits préoccupés par les répercussions des contaminants sur l'eau, l'air, la terre, les aliments du pays, par la santé des générations futures et la salubrité des aliments du pays. Quatre-vingt-onze pour cent d'entre eux croient qu'il est important de s'informer sur les contaminants et que ceux-ci constitueront un enjeu de taille dans l'avenir. Bien que les études donnent un aperçu des perceptions locales des contaminants, leur utilisation sera interrompue en faveur des entrevues qui permettent des analyses conceptuelles et des discussions de groupe.

Key Messages

- The process of communicating contaminants research to Northern communities requires a participatory, collaborative and community-centred approach.
- While scientific research is viewed as important, community understandings of contaminants are complex and varied;

Messages clés

- Il faut adopter une approche participative, collaborative et communautaire pour communiquer les résultats des recherches sur les contaminants aux collectivités du Nord.
- Bien qu'on considère que la recherche scientifique soit importante, le processus de compréhension des contaminants par

explanations from both science and personal experiences of changes seen in the environment contribute to their understanding of contaminants and causes for concern.

- Communicating contaminants research needs to be explored from a community perspective that addresses the message in ways that are applicable and relevant to the daily lives of Northerners, in order for important information to be retained.

les collectivités est complexe et diversifié. Expliquer les changements qui se produisent dans l'environnement par la science et l'expérience personnelle contribue à la compréhension des contaminants et des causes.

- Il faut étudier la communication des résultats des recherches sur les contaminants selon une optique communautaire et aborder la question de manière pertinente et applicable au quotidien des résidents du Nord afin que ceux-ci en retiennent l'important.

Objectives

- Bring forward Inuvialuit knowledge and perceptions of contaminants, contaminant research, and how research is communicated and made accessible to communities.
- Discuss contaminants issues in the context of their applicability to the daily lives of community members, and in the broader context of local and scientific knowledge of climate variability and overall environmental research throughout the North.
- In conjunction with community members, explore culturally relevant and appropriate means of communicating contaminants research between Inuvialuit communities and researchers.
- Use the contaminants research being conducted in the Beaufort Sea region as part of NCP Environmental Monitoring projects, ArcticNet Phase II and IPY CFL studies as the sources of research results to be discussed with community members.
- Present the process and outcomes of this project in the form of a community-led participatory video accompanied by a guide/report, developed in conjunction with community participants and with the regional Inuit Research Advisor, that incorporates a communications protocol for disseminating contaminants information.
- Empower community members to engage in contaminants research occurring within and around their communities.

Introduction

For over two decades, Northerners have received information about contaminants and the potential impacts on wildlife and human health. Despite improved message sensitivity, years of considerable effort disseminating this complex information has resulted in only general awareness of contaminants issues (Myers and Furgal 2006). There has been little evaluation of past communication programs from the perspectives of Northern residents, and less consideration of the communication process. There continues to be a need to focus on the way the research process itself is constructed (Gearheard and Shirley 2007), including the use of a participatory approach to research that emphasizes reciprocal knowledge sharing (Jardine and Furgal 2010).

In order for researchers and frontline workers to best inform community members about contaminants research, the voices in the community need to be heard; it must not be assumed that the best way to communicate results to communities is known without consulting the community members themselves. Therefore, this project focuses on exploring ways to best communicate contaminants research to Northern communities using a bottom-up approach that actively involves community members in the research process. Additionally, this project aims to develop a genuine collaborative research relationship with the community (Inuit Tapiriit Kanatami & Nunavut Research Institute 2007) that encourages Northerners to be at the forefront of the research project, as there is a need for community-specific projects that can identify whether the objectives of contaminants communication efforts are being met (Furgal et al. 2005). Contaminants research conducted through the International Polar Year's Circumpolar Flaw Lead System Study, Environmental Monitoring Projects from the Northern Contaminants Program, and Phase II of ArcticNet are used as a case study to explore the process of communicating technically complex contaminants research results with the Inuvialuit community of Sachs Harbour, NT, in effective and culturally appropriate ways.

Participatory research approaches have been used to examine adaptive capacity to climate change (Berkes and Jolly 2001) and local observations of climate change and sea ice in Sachs Harbour (Nichols et al. 2004); these projects provide a beneficial point of departure in working with this community and with contaminants research. Using participatory video in conjunction with semi-structured interviews and focus groups will allow for participants and the PI to guide the discussion (Huntington 1998), enabling the dialogue to truly incorporate different ways of knowing. The importance of a collaborative, participatory approach being used in the context of extended stays in Sachs Harbour to build trustworthy relationships is key to successful reciprocal knowledge sharing with participants (Jardine and Furgal 2010), which distinguishes this project from previous contaminant-communication studies.

Activities in 2010–2011

From March 28–May 26, 2010, seven out of thirteen arranged semi-structured interviews took place, in addition to many informal, non-video recorded meetings, and survey development commenced with several interested participants. The intention of the collaboratively-developed survey was to supplement the information recorded in interviews from people who were not as comfortable being recorded. Filming of muskox and ice fishing was conducted on the land, in addition to the process of making muskox dry meat and cleaning muskox hides.

Survey development was unfortunately stalled until Reinfort returned to Sachs Harbour from November 8–December 2, 2010, during which time the details were finalized. Initially, surveys were going to be put in the mailboxes of everyone in town, however locals advised that this was not ideal as there is the tendency for surveys of any kind to be regarded as junk mail and thus discarded. Therefore, posters advertising the survey were placed around town, and advertising was also done by word of mouth. Surveys were made available for pick up in a box in the Hamlet Office, and an additional slotted box was available for completed surveys to be dropped off. It was decided that the surveys would remain anonymous, but participants were asked to put their name on the first detachable sheet so they could be entered into a prize draw. Once collected, the sheet with the name was separated from the survey and put into a separate box so the participant names would not be associated with their answers. Only eleven surveys were returned, although twenty-six were initially picked up, for a response rate of 42%. Additionally, one more semi-structured interview was done during this time, for a total of eleven interviews and eleven surveys to date.

On November 30, a community gathering was organized, where the survey prize-winners were announced and a short presentation was made on about this project, describing what had been done, and what remained to be done. Despite the number of people who were aware of the meeting, there was a small turnout of 8 people. Regardless, the discussions surrounding the project were productive and beneficial, such as suggestion of filming some of the contaminated areas around town while having locals talk about the importance of the location. Additionally, the small nature of the group and the ensuing dialogue offered insight into how the focus groups would operate, and provided a better way to engage and communicate with locals than a more formal meeting or presentation.

Video transcriptions and survey summarization began in January, 2011, to prepare them for coding analysis. From March 20–31, Reinfort worked at Trent University with Chris Furgal on coding using the qualitative analysis software, NVivo. During this time, interview and survey data were compared for data richness and quality; it was determined that the interview data was much more in-depth culturally and contextually, and due to the redundancy of the surveys, additional interviews are required. Until the additional interviews are conducted, the focus groups cannot be held.

Three posters have been presented on this project to date: one was presented by Reinfort at the 2008–2009 Northern Contaminants Program Results Workshop (Ottawa, September 28–30, 2009) and the same poster was presented by Gary Stern at the Circumpolar Flaw Lead System Study All-Hands Meeting (Winnipeg, November 1–5, 2009) where it was awarded an honourable mention. A second poster was presented by Reinfort at the 2009 ArcticNet Annual Scientific Meeting (Victoria, December 8–11, 2009), and a third poster was presented by Reinfort at the 2010 International Polar Year Oslo Science Conference (Oslo, June 8–12, 2010), where it received the Best Poster Award for Theme 6: Science Education, Outreach, and Communication; this poster was also shown at the 2009–2010 Northern Contaminants Program Results Workshop (Whitehorse, September 28–30, 2010). At the 2010 ArcticNet Annual Scientific Meeting (Ottawa, December 4–17, 2009), Reinfort gave both a plenary and topical presentation, and was interviewed by Laura Wright from the IPY-funded radio program "The Ends of the Earth" through CKLB Radio in Yellownife (Native Communication Society 2010).

a) Capacity Building

By using current contaminants research as a case study in how to communicate scientific results, participants in the project are engaged in contaminants issues in a way that is relevant and applicable to them. Conducted with a participatory approach that endeavours to challenge the roles of 'the researcher' and 'the researched' (Kindon 2003), this community-focused, collaborative study involves local participants throughout the project. Participatory video, used during semi-directive interview and focus group discussions, offers participants the opportunity to identify and develop the questions and topics to be discussed, engage in and lead the discussion, facilitate two-way dialogue, and determine how their knowledge is represented. Filming the discussions, editing the video footage, and storyboarding are other ways participants engage with the project. A survey questionnaire incorporating rank-ordered and open-ended questions to complement the video aspect was created with participants for distribution throughout the community.

There are opportunities for participants to make presentations to middle school classes, regarding contaminants research or their involvement in this project, highlighting the importance of communication within and among the community in a way that is relevant and applicable; indeed, many participants have highlighted the need to inspire younger generations to become interested and fluent in the languages of scientific and traditional knowledge. In emphasizing collaborative inquiry and celebrating local knowledge, this project aims to be an emancipatory process with the potential to increase local capacity in contaminant issues, encouraging Northern involvement, empowerment, and leadership in Arctic research.

b) Communications

Since this project is about the communication of contaminants research results to the community and involves participant input in all project stages, dissemination of research results is an ongoing and iterative process. The participatory paradigm and process through which communication is explored, in addition to the community-centred, bottom-up focus, distinguishes this project from previous communication efforts. It was developed for participants to consider the effectiveness and appropriateness of the project's methods and outcomes as a possible means for communicating contaminants research; as such, the process through which we explore communication is a means of communication in itself.

Informal discussions about the status and nature of this project are common when Reinfort visits locals in the community, as people are curious to know how things are progressing. During a more formal gathering in November, 2010, locals were supportive of the project's status, and were very engaged in asking questions and offering suggestions; this was likely facilitated in part due to the small nature of the group. Copies of all posters presented to date were made available to the community and are being kept at the HTC, alongside copies of information sheets, informed voluntary consent forms, surveys, and Reinfort's 2009–2010 Northern Contaminants Program synopsis of research report (Reinfort et al. 2010); this is to ensure that this project operates with transparency, enabling access of these materials for everyone in the community.

c) Traditional Knowledge

Knowledge sharing forms the basis of this communication project, because by sharing, knowledge is viewed as a collective benefit (Smith 1999). Local traditional knowledge is an integral part of the dialogue surrounding this project; however the focus moves beyond *what* (knowledge as topic) and focuses more on *how* (knowledge as process). Thus, this project incorporates how local knowledge is communicated between community experts and researchers, incorporated into scientific studies, and how knowledge is attributed and interpreted.

Additionally, if scientific information is expected to be adequately disseminated in Northern communities, it is pertinent to discuss culturally appropriate modes of communicating these results to different audiences (e.g. frontline workers, hunters, youth, Elders, etc.) while forming open, honest relationships. Since Indigenous knowledge encompasses cultural knowledge on social customs, contexts, ethics and worldviews, it is extremely important to the relational aspect of this project. Many locals have lauded the extended periods of time that Reinfort has spent in the community because it fosters respect, trust and friendship, thereby helping them feel more comfortable opening up and sharing their knowledge and experiences with the 'not-so-stranger from the south'. When a researcher comes into the community and spends time among the locals for longer periods, they experience what the locals experience, they live here instead of just visiting for a few days, and they get a sense of how everything is connected, how traditional knowledge connects the land and the people (Kim Lucas, personal communication). Furthermore, conducting the project with a 'bottom-up' focus enables the perceptions and knowledge of locals regarding contaminants information to be heard, valued, and attributed, thus advising researchers on how to disseminate their research cross-culturally in an appropriate and relevant manner.

Results

Interviews (n=11) are in the process of being transcribed, verified with participants and coded, and the analysis is in progress. Since the survey results (n=11) were deemed redundant in light of the interview content, survey data has thus only been analyzed preliminarily and only a short summary of what has been examined will be included here. These data will not be further analyzed. Survey data were being examined when it was decided that the focus should be switched primarily to the interviews. As such, interview results are not yet complete due to the need for additional interviews to obtain a sample size representative of the community.

Respondent attributes are from a wide range of the population, representing six females and five males, an age range of 20 to 78, a mean age of 46 and median age of 42. Responses to survey questions about contaminant visibility, impacts, interest and importance are summarized in Table 1. Just over half (55%) of respondents stated that contaminants are visible in their daily lives, yet the majority response (45%) indicated that the impacts of these contaminants are not seen, followed by 27% that were unsure. Most respondents were interested in learning about contaminants (82%), acknowledging that this is important to do so (91%) as they perceive it will be an critical future issue (91%). Table 2 summarizes respondent perceptions about the nature of contaminants messages, with the majority feeling that information from researchers is helpful (46%), sometimes confusing (37%), informative (55%), easy to understand (55%), complicated (46%), culturally appropriate some of the time (55%), and sometimes applicable to their daily lives (55%). These data indicate no obvious consensus, as some of the contradictory descriptors show similar responses; due to low sample size, the difference in percentage value is reflective of only one or two responses.

The overall majority of respondents are concerned about contaminants affecting various parts of their environment (Table 3), with the highest levels of concern for the affect on country food both at present and in the future (91% for each). Respondents are also concerned about contaminants being in the water, air and earth (82% for each), and are slightly more concerned about contaminants affecting the health of future generations (82%) than current health effects (73%). Additionally, this sentiment is also being echoed, but to a much greater extent, in the interviews that have thus far been transcribed. Furthermore, it is interesting to compare these

Table 1: Percentage (%) of respondents answers to survey questions regarding the visibility of contaminants, their impacts, and the importance and interest in learning about contaminants.

Survey Question	Yes	No	Yes and no	Don't know	Sometimes	Blank
Are contaminants seen in your daily life?	55	27	9	0	0	9
Do you see the impacts of contaminants in your daily life?	18	45	0	27	0	9
Are you interested in learning about contaminants?	82	0	0	9	9	0
Is it important to learn about contaminants?	91	0	0	0	9	0
Will contaminants be a big issue in the future?	91	0	9	0	0	0

Table 2: Survey responses to the question "Is information you receive about contaminants from researchers…?", expressed as a percentage (%).

	Yes	No	Sometimes	Don't know
Helpful	46	18	36	0
Confusing	27	36	37	0
Informative	55	36	9	0
Easy to understand	55	9	36	0
Complicated	18	46	36	0
Culturally appropriate	27	9	55	9
Applicable to your life	36	9	55	0

Table 3: Survey responses to the question "Are you concerned about contaminants…?", expressed as a percentage (%).

	Yes	No	Sometimes
In the water	82	0	18
In the air	82	18	0
In/on the earth	82	0	18
In country food	91	9	0
Affecting your health	73	18	9
In future country foods	91	9	0
Affecting the health of future generations	82	9	9

results to how important respondents perceive contaminants in their daily lives: 45% indicate contaminants are very important, 18% state they are somewhat important, 9% find them not really important, and 27% are unsure (data not shown).

Discussion and Conclusions

Despite a small sample size, the results presented in Table 1, 2 and 3 indicate the variability of perceptions that Sachs Harbour locals have with regard to contaminants, consistent with findings by Oakes (2008), Tyrrell (2006), Myers and Furgal (2005) and Furgal et al. (2003). In Arviat, NU, Tyrrell (2006) also found that no consensus exists with respect to the causes or effects of contaminants, acknowledging that Inuit understandings of contaminants are complex. Her findings are similar to those stated here, where contaminants are viewed broadly to include both local, observable concerns such as oil spills, garbage, melting permafrost, or health anomalies in wildlife, in addition to invisible pollutants and toxins traveling through air and water that escape local descriptors and whose impacts are uncertain. While some respondents state that the information presented by researchers is helpful, informative and easy to understand, it is also confusing and complicated; only 18% of survey respondents were able to identify contaminants being researched in the North. However, most locals acknowledge their interest in, and the importance of learning about contaminants, especially with regard to future generations and scientific research.

Although 91% of respondents are concerned about contaminants in country foods and 73% expressed concern for their personal health at present, many personal communications indicate that locals are very aware that country foods are both nutritionally and culturally superior to store-bought food and there remains the overall conviction that contaminants have not yet made their way to Banks Island. Yet there exists a deep concern for environmental, animal and human well-being in the future, including the worry that there will be no more animals left, which leads to the questions of what will happen to Inuvialuit culture, traditions, and identity.

In trying to consistently improve this project, it was decided that the surveys would not be used as this work moves ahead; the time spent working on the surveys could be viewed as a loss, or it could be looked at as a beneficial learning exercise. To aid older respondents, the surveys were read aloud in the manner of an interview with very strict questions; in retrospect, semi-directive interviews would be more valuable. With interviews, there can be the guarantee that a meeting has taken place, whereas the reliability of survey responses was unsure. After the fact, locals commented that they preferred one-on-one conversations and would rather take the time to do an interview than fill out pages of questions; this in itself is an example of a preferable method of communication. Collaborating on the development of the survey was the most beneficial learning experience for those involved; both locals and the PI gained knowledge of how to appropriately word the questions and the best vocabulary to use so that the end product reflected a community document. This in turn will aid the development of the joint guide/report that will be produced in association with the IRA.

Moving forward, additional interviews will be integral to discovering the perceptions and conceptions of contaminants and how they are communicated in Sachs Harbour. The new NVivo software skills learned will help code this information and identify areas where cognitive mapping exercises will be used in focus groups; this in turn will provide a guide on how best to provide specific contaminant information to the groups without imposing a pre-conceived structural paradigm that could influence participants' understanding. The resulting focus group discussions will thus have the capacity to be more enlightening and instructive than if the survey data had eclipsed the realization that interviews provide richer information in laying the communication baseline for this work.

Expected Project Completion Date

Due to the changes mentioned, anticipated project completion is in October 2012.

Acknowledgements

Quyanainni to all of my collaborators in Sachs Harbour for your time and support; without you this project would not be possible. Funding for this project has been provided by The Social Sciences and Humanities Research Council of Canada (J.A. Bombardier CGS Masters), Northern Contaminants Program, Northern Scientific Training Program, ArcticNet, The University of Manitoba (Clayton H. Riddell Faculty of Earth, Environment and Resources; The Faculty of Graduate Studies; St John's College), and The Department of Fisheries and Oceans Canada.

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Continuing to Meet the Information Needs of Nunatsiavummiut

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Abstract

In 2010–11, the CRC continues to communicate and educate Nunatsiavummiut on contaminants, wild foods and health issues so that they may make informed decisions in their daily lives by providing information in a newsletter as well as speaking to people face to face. Also, the CRC is a member of two committees within NG, the Interim Research Advisory Committee and an NCP funded Nunatsiavut Health and Environment Review Committee (NHERC) (in 2011–2012 this committee will have a new and seemingly more productive and useful role, which is to bring all research information—proposed, current and results—to each community), where the CRC is providing advice and assistance to the development of a research protocol for Nunatsiavut as well as ensuring that contaminant issues/information are now provided to each of the communities and gathered in a regional hub, therefore strengthening the already existing relationship between the CRC and the region.

Résumé

En 2010–2011, la CRC poursuit son travail d’information et d’éducation – en personne et par l’intermédiaire d’un bulletin d’information – sur les contaminants, les aliments sauvages et les questions liées à la santé auprès des Nunatsiavummiut afin de leur permettre de prendre des décisions éclairées dans leur vie quotidienne. De plus, la CRC siège à deux comités du gouvernement du Nunatsiavut : l’Interim Research Advisory Committee et le Nunatsiavut Health and Environment Review Committee (NHERC), qui est financé par le PLCN. En 2011–2012, ce comité assumera un nouveau rôle qui, semble-t-il, sera plus productif et utile. Ce rôle consistera à fournir à chacune des collectivités tous les renseignements relatifs à la recherche : les études proposées et actuelles, ainsi que les résultats. Au sein du comité, la CRC offre des conseils et participe à la création d’un protocole de recherche pour le Nunatsiavut.

Elle s’assure également que toutes les collectivités sont informées des questions et des renseignements liés aux contaminants et que toute l’information est réunie dans un centre régional, ce qui renforce la relation que la CRC entretient déjà avec la région.

Key Messages

- The CRC strives to, in a culturally relevant manner, continue its communication efforts on contaminants, research and the environment, conduct research and promote mutually beneficial relationships between the communities of Nunatsiavut and outside scientists;
- Nunatsiavummiut have a number of concerns about their health and the environment around their communities. The NHERC has helped these communities come together with common issues, gain understanding of common issues in other regions and understand NCP's mandate.
- Two much needed research stations have been erected in Nunatsiavut during the summer/fall/winter 2010–2011. One has been built in Nain and another just south of Torngat Mountains National Park, on Labrador Inuit Lands in Saglek Fiord. Both of these stations will help facilitate and direct research in the region and well as build capacity and provide new opportunities for Nunatsiavummiut.

Messages clés

- La CRC entend, d'une façon adaptée aux particularités culturelles, poursuivre son travail d'information sur les contaminants, la recherche et l'environnement, à mener des recherches et à créer des relations mutuellement bénéfiques entre les collectivités du Nunatsiavut et les scientifiques de l'extérieur;
- Les Nunatsiavummiut ont plusieurs préoccupations sur leur santé et sur leur environnement. Le NHERC a aidé ces collectivités à découvrir quelles sont leurs préoccupations communes, à savoir quels sont les enjeux communs à d'autres régions et à comprendre le mandat du PLCN.
- Pendant l'été, l'automne et l'hiver de 2010–2011, deux stations de recherche dont on avait grandement besoin ont été construites au Nunatsiavut. L'une d'entre elles a été construite à Nain et l'autre, un peu au sud de la réserve de parc national du Canada des Monts-Torngat, sur les terres des Inuit du Labrador, dans le fjord Saglek. Ces deux stations aideront à favoriser et à cibler la recherche dans la région, permettront d'augmenter la capacité et fourniront de nouvelles possibilités aux Nunatsiavummiut.

Objectives

The objective of the Northern Contaminants Program (NCP) is to reduce or, wherever possible, eliminate contaminants in traditionally harvested foods while providing information that assists informed decision making by individuals and communities related to their food use.

This year the Nunatsiavut Government NCP Researcher:

- Assisted residents of Nain, Hopedale, Postville, Makkovik, Rigolet and Happy Valley-Goose Bay by providing information about risks, the means to reduce risks, and information on the benefits of traditionally harvested foods to support residents in making informed decisions;
- Assisted communities of the Nunatsiavut and the Lake Melville area in becoming involved with contaminant issues and activities that affect the people and the region
- Sits on the Nunatsiavut Government's Interim Research Advisory Committee which is responsible for reviewing proposals and ensures research in the region follows guidelines set by NG, is culturally sensitive, has all/any permits required by NG;
- Has become a member of the Nunatsiavut Inuit Health Survey Steering Committee
- Is a member of the BOD for Nasivvik;
- Assisted in securing funds for a much needed research centre. This research centre is equipped with the facilities that are much needed in the region. This includes a wet and dry lab, accommodations, library, freezers etc. The walk in freezer is currently being used as a community freezer to provide traditional wild food to the community
- As part of her ongoing work on the issue of local contaminant sources at abandoned military sites, the CRC continues to be the

first point of contact between the Provincial Government of NFLD and Labrador and the community of Hopedale, Nunatsiavut, ensuring that the residents of Hopedale are well informed of the results of work in Hopedale and ensuring all appropriate criteria for levels of contaminants such as PCB's are adhered to for clean up stage.

- Sits on the newly formed Hopedale Stakeholder Group. This group consists of members for the NG, Inuit Community Government of Hopedale, members of the Provincial Government of NL, Labrador Grenfell Health Association
- Assisted in the planning and coordination of the first ever Research forum—Tukisinnik—held in Nunatsiavut last June in Nain where researchers, scientists, governments and local representatives from Nunatsiavut came together to discuss research and the future of research

Assisted in interviews of local knowledge holders for a NCP funded project: Tukisimakatigennik (Understanding Together): Inuit Knowledge and scientific inquiry into contaminant trends in ringed seals (Phoca hispida) in Nunatsiavut

- Continues as Chair of Nunatsiavut Health and Environment Research Committee—coordinating proposal reviews—face to face or teleconferences, managing budget, informing communities and logistical needs
- Sits on the NCP Management Committee
- Sits on the kangidluasuk Student Program – helps in planning, youth selections, budgetary issues etc.
- Provides direct advise and assistance to researchers who are conducting research in Nain

Introduction

Nunatsiavummiut are sustained by the animals, birds, fish and plants of the region. Research has shown that contaminants are present in these food sources due to the environment being contaminated by varying sources of pollution (local and distant) which are then transported to the north via atmospheric and oceanic mechanisms. Also, climate change effects are becoming more evident in the Canadian Arctic. The levels of contaminants in these foods which sustain Nunatsiavummiut and potential effects they may have on residents of the coastal communities are of concern to the Inuit of Nunatsiavut. The Nunatsiavut Government helps to ensure that Nunatsiavummiut are heard and their concerns with regard to both national and local contaminants issues are assessed and communicated. The current issues for Nunatsiavut Inuit are similar to those of other Inuit regions, but there are also local concerns that need to be communicated.

Hopedale, Labrador, a community of approximately 625 residents, has a former US Air Force early-warning radar station near the community, has been voicing concern of possible contamination for a number of years. The assessment and subsequent remediation of this contamination is now being led by the Government of Newfoundland and Labrador. The CRC is working closely with the Provincial Government and the community to begin working on a clean up plan. Some remedial work has begun, but much more still needs to be done before full clean up of the site can begin. New results of last years work is showing that there is not only terrestrial contamination, but also marine contamination of PCB's. This means that we now need to more food basket studies in the community with regards to harvesting of marine mammals and fish. This work is being planned for this summer.

In order for Nunatsiavut Inuit to be informed about wise food choices the NG must coordinate efforts between Inuit Tapiriit Kanatami, NCP, university and government researchers and our communities. Following the objectives of the Northern Contaminants Program, the NG's Researcher acts as a key resource person and provides information to the population in a culturally relevant and plain language format on contaminant-related issues. The NHERC has proven to be a very helpful tool in ensuring that each Inuit community is represented and has a voice, not only when dealing with NCP related research, but also through our National Inuit Organization; ITK. ITK is also a member of this committee.

Activities 2010–2011

Communication

Avativut Newsletter

This newsletter is a publication that the NG Research Office has developed and used to communicate to the Labrador Inuit population about such things as the benefits and risks of wild foods, the most recent knowledge on contaminants, health and environmental issues and to update people on current research activities in the region. The existence of a regional person and their involvement in this publication has enhanced the NG's ability to communicate such information in a culturally-relevant and timely manner. The main focus of the Avativut newsletter is on the benefits of consuming wild foods so as to reinforce the understanding among the general population that they are still the most nutritious foods for Nunatsiavummiut to eat. Additional updates of new and ongoing research activities and relevant facts about health and environment issues in the region are also provided in this newsletter which is printed in English and Inuktitut (Labrador dialect). A section of the Avativut Newsletter is also set aside for environmental news from each of the Nunatsiavut communities, giving each community a chance to share their concerns and accomplishments with the coast regarding environment and health issues.

Participation in Research Projects

Although many of the issues that the NG is currently dealing with related to the issue of contaminants are associated with local source problems (e.g. Hopedale radar base) in the eyes of community members there remains the need to address these concerns. The public does not make the separation between local and long range sources and therefore communication activities in the region this year have had to deal with the issue of contaminants in a coordinated and combined manner. The NHERC has made some progress is explaining the difference through community representatives. Regional review of NCP proposals through NHERC has also raised awareness of projects in communities in Nunatsiavut, thus creating interest in having similar research done in other communities. Although there is some understanding of why research is important, it is necessary continue to communicate research information and explanations about why it is necessary. The NG hosted the first ever research forum in Nain this year and this helped provide understanding to research as through various activities and presentations during the forum. Much of the comments were geared around how good the forum was in providing information and insight to research and how this type of forum needs to happen regularly.

Tukisimakatigennik (Understanding Together): Inuit Knowledge and scientific inquiry into contaminant trends in ringed seals (Phoca hispida) in Nunatsiavut

A multidisciplinary science program has been developed in Nunatsiavut to better understand ringed seal behaviour, ecology, distribution and health. It is believed that contaminant exposures have changed, and are likely to continue to change as physical and biological processes in northern environments change with climate and other forces. It is argued that a collaborative approach to understanding changes in ringed seal contaminant trends and general health is possible through a linked Inuit knowledge and scientific inquiry into the topic and that this collaborative approach has the potential to significantly enhance the collective understanding of this issue. This project uses a mixed method of research design to document and analyse Inuit (Nunatsiavummiut) knowledge (IK) of ringed seal diet and ecology in Nain Nunatsiavut.

This year, we conducted several interviews with knowledge holders in Nain. The interview questions were reviewed by local researchers and the necessary changes were made to the questions to make them more appropriate for locals to better understand and answer the questions asked. These interviews were recorded using a voice recorder as well as mapped on a printed map of the surrounding hunting areas around Nain. Participants were given coloured markers to draw hunting routes, areas with abundance of ringed seals, pupping areas etc. Each colour represented a different component, for example, black was used to mark winter travel routes, purple was used to indicate abundance of seals during spring hunts and so on. The voice recordings were then transcribed by a local researcher. This project will continue to collect more Inuit knowledge and fill the missing information needed to fully and holistically understand changes in ringed seals.

ArcticNet Nunatsiavut Nuluak: Understanding and responding to the effects of climate change and modernization in Nunatsiavut.

Nunatsiavut Nuluak project, funded by ArcticNet and co-led by the Nunatsiavut Government and the Environmental Sciences Group of the Royal Military College of Canada, was initiated in the spring of 2006 to address Inuit concerns of environmental change and human activities which may be contributing to these changes in northern Labrador. The objectives of the program are to create a baseline inventory and comparative assessment of fiord based ecosystems (Saglek, Okak, Anaktalak and Nachvak Fiords) and document and incorporate Inuit knowledge and concerns in all facets of the program. Over the past few summers, 10 students each summer have had a chance to work side by side with Inuit from Nunatsiavut and Nunavik as well as researchers from several universities and government agencies through the kANGIDLUASUk student program. These areas included research on contaminants in the marine ecosystem, sampling of small organisms in water, vegetation sampling, research on glaciers, collection of samples and more. This program type will be taking place again this summer and planning for this has just begun.

Nasivvik Centre for Inuit Health and Changing Environments

The Nasivvik Centre is a multidisciplinary research and training centre funded by the Canadian Institutes of Health Research-Institute of Aboriginal Peoples' Health. The Centre is focused on building capacity in Inuit health research through trainee support and strategic funding initiatives in key environmental health areas of importance to Inuit communities.

The Nasivvik Centre also provides part of the funding for the Inuit Research Advisor (IRA) in Nunatsiavut, John Lampe. In cooperation with the CRC and the Nunatsiavut Government, the IRA position has led to better overall research coordination among projects funded under the various research programs going in Nunatsiavut and an enhancement of training opportunities associated with research. The CRC is a member of the Board of Directors for the Nasivvik and takes part in meetings and conference calls to deal with any issues regarding the centre including reviewing funding proposals.

Nunatsiavut Health and Environment Research Committee

The Nunatsiavut Contaminants Committee (Now the NHERC) began in late 2007. This committee consists of the CRC who is the Chair of the committee, the Nunatsiavut Inuit Research Advisor, Director, Nunatsiavut Government Environment Division, NG Dept. of Health, ITK, NCP and a representative from each of the 5 communities along the coast and Upper Lake Melville (ULM). The current co-chair is Ed Tuttauk from Northwest River (ULM). The CRC is responsible for securing funding for the committee and coordinating the committee activities, preparing for face to face meeting and teleconferences which include logistical planning, travel arrangements, orientation of new members, preparing minutes, disseminating proposals for review, collecting information, preparing documents and ensuring regional concerns are forwarded to the NCP. The NHERC, which has existed for nearly 5 (the first four years being a review committee) years in Nunatsiavut, has now evolved into an information for research mechanism, helping the region understand NCP's mandate as well as the importance of research and how it can benefit the region. Again this year, the NHERC is being combined into the CRC's overall scope of work for the region

Ongoing Daily Communications and Research Coordination

In addition to these specific activities, a number of ongoing communication responsibilities are fulfilled by the NG Research Office staff. Daily activities of the Research Office include responding to community concerns, providing information to the Nunatsiavut Government, communities, and individuals on issues relating to contaminants, the environment and health, and acting as a liaison for the various people proposing to, and currently conducting research in the region. Additionally, the research staff acts as a liaison for interactions between the regional organizations and ITK and the NCP. This involves regular interaction with various individuals and ongoing communications efforts.

Discussion And Conclusions

The CRC continues to be an essential part of the work of the Nunatsiavut Government. This is especially true for the residents of Hopedale, and will continue to be so for other Nunatsiavut communities who have concerns about contaminants. The NG Research Office continues to educate and empower the people of Labrador to better understand and deal with contaminants in their environment and traditional foods, and be aware of research and general environmental issues.

The Nunatsiavut Government Contaminants Researcher continues to:

- Support the activities undertaken by NG and NCP in providing information on research about contaminants, their effects on wildlife and humans through consumption of wild foods which are based on the varied language and geographic needs of individuals and communities of Labrador;
- Enhance decision making abilities of Labrador Inuit through the delivery of information on risks and benefits of contaminants and wild foods relevant to the region in an accurate, timely and accessible manner;
- Develop regionally relevant resource materials in consultation with the coastal communities and appropriate agencies (i.e. Department of Health and Social Development, DIAND-NCP, ITK etc.). These materials include educational materials such as a quarterly newsletter; all publications are produced in both Inuktitut and English;
- Use the research results from studies conducted in the region to aid in effective delivery of information;
- Be a member of the NG Interim Research Advisory Committee, responsible for interacting with and assisting outside researchers with community consultations. This assistance also includes negotiating research agreements between researchers and community organizations and reporting project results to communities in a timely and responsible manner. The Research Office determines, in consultation with community representatives who are responsible for communication on contaminant, health and environment issues, which medium(s) best suit the information needs of the community, etc. This person will continue to assist in the development of a Protocol and Guidelines for Research conducted in Nunatsiavut.
- Continue to act as Chair of the NHERC, ensuring that communities are involved with in and informed about community concerns in the region, coordinates all logistical and administrative aspects of the committee
- Take part in research projects and communication of research results when appropriate.
- Assist with the clean up of PCB contamination in the community of Hopedale by sitting on the newly formed Hopedale Stakeholder Group

Date Of Completion

This is an ongoing project in Nunatsiavut.

Acknowledgements

The NG CRC would like to thank Dr. Chris Furgal, Assistant Professor, Trent University, for his invaluable assistance and support in carrying out projects funded under the Northern Contaminants Program. Also, we thank Eric Loring, Inuit Tapiriit Kanatami, for his involvement and guidance in these activities. The Environmental Sciences Group for their contributions to the research projects in Hopedale. The support of the Department of Lands and Natural Resources ensures the continuation of the NG Research Office mandate. We would also like to give special thanks to Louisa Kojak Interpreter/Translator, NG, and Wilson Jararuse for the translation of communication materials and well as the Nunatsiavut Government's Community Liaisons for their assistance in activities related to the issues discussed in this report.

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CYFN: National/ Regional Coordination and Aboriginal Partnerships

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Abstract

Under the National/Regional Coordination and Aboriginal Partnership category, the Council of Yukon First Nations (CYFN) attended two Northern Contaminants Program (NCP) Management Committee meetings, numerous Yukon Contaminants Committee meetings, the annual NCP Results Workshop, and the Council of Yukon First Nations General Assembly. The NCP Management Committee requires well developed management, planning and implementation structures that lead to informed decision making regarding the Arctic food chain, long range contaminants and health related factors. The CYFN General Assembly is an annual opportunity to provide long range contaminant information and research results to community leaders, as well as receive feedback and comments from community representatives.

Résumé

Dans le cadre de la catégorie Coordination nationale et régionale et partenariats autochtones, le Conseil des Premières nations du Yukon a participé à deux réunions du comité de gestion du Programme de lutte contre les contaminants dans le Nord (PLCN), à de nombreuses rencontres du Comité des contaminants du Yukon, à l'atelier annuel sur les résultats du PLCN et à l'assemblée générale du Conseil des Premières nations du Yukon. Le Comité de gestion du PLCN nécessite de solides structures de gestion, de planification et de mise en œuvre, qui permettent de prendre des décisions éclairées concernant la chaîne alimentaire dans l'Arctique, les contaminants transportés sur de grandes distances et les facteurs sanitaires connexes. L'assemblée générale du Conseil des Premières nations du Yukon constitue une occasion annuelle de présenter, aux dirigeants des collectivités, des renseignements et des résultats de recherche sur les contaminants transportés sur de longues distances et de recevoir les commentaires des représentants des collectivités.

Key Messages

- Our traditional foods are safe to eat.

Messages clés

- Les aliments traditionnels du Yukon ne sont pas dangereux pour la santé.

Objectives

Communication of NCP research.

Introduction

The Northern Contaminants Program (NCP) was established in 1991 in response to concerns about human exposure to elevated levels of contaminants found in wildlife. The current focus of the NCP is to address northern community concerns. The Yukon is not a high priority area but it is still important that Yukon First Nations have access to information to make informed decisions on the risks and benefits of consuming traditionally harvested foods. Our main message in the Yukon has always been that our traditional foods are safe to eat.

CYFN maintains a website on long-range contaminants information that has been generated through the NCP. The website has been designed as an education and information tool that can be accessed by community members, health professionals, organizations, instructors, students and those interested in learning about the effects of atmospheric long rage transport of contaminants in the north. The URL is: www.northerncontaminants.ca

CYFN also distributed information to the CYFN General Assembly, including the NCP Synopsis Reports, Year-end Reports, CACAR reports and AMAP reports, in addition to the current work undertaken by the Yukon Contaminants Committee.

Activities in 2010–2011

During the 2010–2011 fiscal year:

CYFN provided information to communities about the NCP Program through reports to the communities; information was distributed through the general assemblies and the wider public audiences as opportunities became available.

Communications

1. CYFN Reports to Leadership on the projects from the Yukon Contaminants Committee, NCP Program and Priorities.
2. CYFN's General Assembly – a booth was set up and NCP reports were made available for the public – such as the NCP Synopsis Reports, CACAR Reports and AMAP Assessments.
3. The CYFN-NCP Website was updated. The link is: www.northerncontaminants.ca

Capacity Building

4. CYFN participates as part of the NCP Management Committee. The management committee is responsible for NCP policy and research priorities and making final decisions on the allocation of NCP funds.
5. CYFN also participated in the revisions of the NCP Blue-Prints, which guide the NCP Program funding envelopes.
6. CYFN is also a member of the Aboriginal Partners of the NCP – which deals with ethics and responsible research, community involvement in research and education, communications and community –based strategies within NCP. CYFN participates within projects or assists with community contacts when requested as well as assist in meetings and provides input into regional and national requests.
7. CYFN assisted with the draft communications plan for mercury in fish
8. CYFN participated in the Yukon Contaminants Committee meetings

Traditional Knowledge

CYFN is a First Nations organization. The involvement of CYFN in the NCP Program allows for participation of our leaders, Elders and First Nations communities when necessary. This allows the NCP to gain knowledge and partnership with First Nations members who have traditional knowledge.

Results

As a result of CYFN efforts in communicating NCP information, more community members are aware of the NCP program. CYFN participation within the NCP management structure increases capacity within CYFN because the program is based on partnership.

Discussion and Conclusions

The significance for CYFN in continuing to collaborate with INAC is to reassure our communities that our traditional foods remain safe to eat. The NCP was established in response to concerns that elevated levels of long-range-contaminants was being found in northern wildlife. It is essential that CYFN continues to remain as part of the management structure for NCP to monitor and remain engaged in the program.

NCP Performance Indicators

Please include information related to

1. CYFN membership includes 10 communities and provides information to all 14 First Nations in the Yukon when new information becomes available.
2. CYFN presented "Mercury, Health Risk Assessments and Communication: A Case Study from the Yukon" to the NCP Results workshop in September 2010.

Expected Project Completion Date

March 2011.

Acknowledgments

Please note that the NCP Management Committee has agreed that the NCP should be acknowledged in a formal way in presentations and other communications products (including papers).

References

Inuit Circumpolar Council – Canada Activities in Support of Circumpolar and Global Contaminant Instruments and Activities

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Abstract

This report outlines ICC Canada's activities funded by Northern Contaminants Program (NCP) in the fiscal year of 2010–2011. 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 Report III. Internationally, ICC Canada was very engaged in work related to the United Nations Environment Programme (UNEP), and was part of the Canadian delegation to the two Intergovernmental Negotiation Committee (INC) meetings on a legally-binding agreement for mercury. ICC also attended the meetings independently, and made

Résumé

Le rapport décrit les activités de la Conférence circumpolaire inuite financées dans le cadre du Programme de lutte contre les contaminants dans le Nord (PLCN) au cours de l'exercice 2010 2011. La Conférence circumpolaire inuite du Canada travaille aux échelles nationale et internationale pour régler la question des contaminants dans l'Arctique. Ses activités nationales consistent notamment à appuyer le comité de gestion du PLCN, à étudier les plans détaillés et les propositions, à participer à l'atelier national sur les résultats et à contribuer au troisième rapport de l'évaluation des contaminants dans l'Arctique canadien. Sur le plan international, la Conférence circumpolaire inuite du Canada participe grandement aux travaux liés au Programme des

several interventions. Work on persistent organic pollutants (POPs) is ongoing, with ICC Canada attending the 6th POP Review Committee (POPRC) of the Stockholm Convention, participating in working group activities of POPRC, and being involved in Environment Canada stakeholder meetings in preparation of the 5th Conference of the Parties for the Stockholm Convention. ICC Canada continued to support Arctic Council activities, such as work for the Mercury Assessment of the Arctic Monitoring Assessment Programme (AMAP), where ICC Canada has been co-authoring two chapters. ICC Canada is also continuing work on a communication strategy with other aboriginal partners, such as Inuit Tuttarvingat and ITK.

Nations Unies pour l'environnement et a fait partie de la délégation canadienne présente aux deux réunions du Comité de négociation intergouvernementale afin d'établir des accords juridiquement contraignants sur le mercure. La Conférence a aussi participé aux réunions à titre d'organisme indépendant et y a fait plusieurs interventions. Des travaux sur les polluants organiques persistants (POP) sont en cours. La Conférence circumpolaire inuite du Canada assistera d'ailleurs à la 6e réunion du Comité d'examen des POP de la Convention de Stockholm en plus de participer aux activités du groupe de travail sur les POP et de prendre part aux réunions des intervenants d'Environnement Canada en préparation de la 5e Conférence des parties à la Convention de Stockholm. La Conférence circumpolaire inuite du Canada a également continué à appuyer les activités du Conseil de l'Arctique, notamment les travaux entourant le rapport sur l'évaluation du mercure dans le cadre du Programme de surveillance et d'évaluation de l'Arctique, dont la Conférence a cosigné deux chapitres. La Conférence circumpolaire inuite du Canada continuera aussi à travailler à l'élaboration d'une stratégie de communication avec des partenaires autochtones comme Inuit Tuttarvingat et Inuit Tapiriit Kanatami.

Key Messages

- ICC Canada worked actively to support NCP by working on the Management Committee, Environmental Trends and Monitoring Subcommittee, Community-Based Monitoring Subcommittee, and contributed to the POPs and Hg CACAR III reports.
- ICC Canada was part of the Canadian delegation to the two Intergovernmental Negotiation Committee (INC) meetings on a legally-binding agreement for mercury.
- For the first time, ICC Canada was able to attend the Stockholm Convention's POP Review Committee meeting, thanks to NCP funding. At the meeting, endosulfan was recommended for addition to the Stockholm Convention on POPs.
- Work is ongoing on the NSERC supported Industrial R &D Fellowship study that is hosted by ICC Canada and investigates mercury isotopes in ice cores and snow samples to

identify mercury pathways and sources to the Arctic. Ice-core samples from NRCan representing a north-south gradient from the Canadian Arctic have been selected and will be processed this spring and early summer. Temporal comparisons between pre-historic (~3000 years before present) and industrial times will also be made. Snow samples will be obtained to allow for a spatial comparison between the eastern and western Canadian Arctic.

- ICC had a very successful General Assembly, where health and contaminants were being discussed and the Nuuk declaration was adopted, which will guide ICC's work for the next four years.

Introduction

Inuit are Arctic Indigenous peoples living in Russia (Chukotka), 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 Assessment Programme of Arctic Council, and represents Inuit at the United Nations Environment Programme and related meetings.

This is the year-end report on activities undertaken by ICC from April 1, 2010–March 30, 2011, which is a delivery requirement detailed under the 2010/11 NCP contribution agreement.

Eva Krümmel is the Senior Health Research Officer 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 Pitseololaq Moss-Davies and James Kuptana, as appropriate and necessary. Yvonne Moorhouse provides administrative support. Stephanie Meakin as Science Advisor continues to support Eva Krümmel when needed.

Detailed activities

1) NCP

a) General NCP work:

The following activities were originally proposed:

- attendance of Results Workshop, Management Meetings and related work, as covered in Capacity A and B proposals

Work that has been undertaken until March 30th 2011:

Eva Kruemmel attended the NCP Research Management Meeting April 13–15, 2010 in Halifax, reviewed proposals and documents as required and provided input and comments. Eva attended the NCP Result Workshop September 28–30, 2010 in Whitehorse, and gave a presentation on how NCP results are used to influence international agreements and the role that aboriginal organizations play in these agreements. Eva Kruemmel also participated in the Research Management Meeting November 3–4, 2010 in Yellowknife, and presented on the outcomes of the POP Review Committee meeting, which she attended in October 2010 (also see below).

In preparation in the proposal reviews for the new fiscal year (2011–2012), Eva Kruemmel participated in the technical review teams of the Environmental Monitoring and Trends and Community-Based Monitoring envelopes.

Proposed activities:
b) CACAR III: Reports on POPs, mercury and human health

- contributions to the POPs and mercury reports
- reviewing of chapters
- participation of related meetings and teleconferences

Work undertaken:
Several chapters for the CACAR III reports on POPs and mercury have been finalized and three chapters of the Hg report, as well as the physical environment part of the POPs report, are currently being reviewed. Eva Kruemmel contributed to both reports a section on the Aboriginal perspective and on community-based monitoring/research. The POPs contribution was sent out for comments and input to various collaborators and partners, and was subsequently submitted in September 2010. Eva Kruemmel attended the associated CARCAR POPs meeting in Whitehorse taking place during the NCP Results Workshop. The mercury contribution was also sent out for comments and was submitted October 31st, 2010. Further developments on the global mercury negotiation process took place in January (see below), and an updated version was prepared and submitted in March 2011.

2) AMAP

Proposed activities:
a) General:

- participation at WG and HoD meetings
- contributions to framework review and other documents

Work undertaken:
ICC Canada provided comments for the AMAP Strategic Framework review and attended the Brainstorming session September 19–20 in Helsinki. Eva Kruemmel participated at AMAP HoD meeting November 17–18 in Reykjavik, Iceland and the AMAP WG meeting January 2011 in Tromsø, Norway, reviewed the documents that were discussed during the meetings, and provided comments.

ICC Canada also reviewed the joint AMAP/UNEP report on POPs and Climate Change and provided input.

Proposed activities:
b) AMAP Hg Assessment:

- revisions for chapters 1 and 8
- participation in ongoing reviews, meetings and teleconferences

Work undertaken:
Eva Kruemmel provided input and incorporated revisions for chapters 1 and 8 as required, including the print reviews that were sent out end of March 2011. She reviewed and commented on the Hg Assessment Highlights report, Executive Summary and Layman's report, and participated in the discussions on the respective documents at the AMAP HoD meeting in November 2011 in Reykjavik.

ICC Canada also provided comments on revisions for all documents.

Proposed activities:
c) SAON:

- attendance of relevant meetings, teleconferences
- work within the CBM group, development of proposals and recommendations for SAON report
- contributions to and review of drafts for SAON report

Work undertaken:
ICC Canada participated in all the relevant SAON teleconferences, and had several small meetings to discuss community-based monitoring (for example with Helen Joseph, David Hik, Marty Kress, Peter Pulsifer, Scot Nickels, Eddie Carmack, etc). However, it was not possible to send somebody to the SAON meeting in Copenhagen on May 25–26. Instead, Eva Kruemmel attended in the teleconference on May 26th, reviewed documents and provided input.

ICC Canada also could not participate in the SAON meeting held in Reykjavik August 25–26, but worked with Peter Pulsifer and Shari Gearhead from ELOKA on a comprehensive contribution on community-based monitoring/research for the upcoming SAON report. This contribution was sent to the SAON Steering Group before the meeting for their consideration, and was subsequently used in the Plan for Initiation of the Operational Phase of SAON, which has been submitted to the Arctic Council Secretariat.

Together with her partners at ELOKA, ITK and other aboriginal organizations, Eva Kruemmel developed a task proposal on a comprehensive review of community-based monitoring. The proposal was accepted at the SAON SG meeting January 17–18, 2011 in Oslo, Norway, which Eva Kruemmel attended. Further activities have been initiated to work with other project leaders who have submitted proposals on CBM.

Eva Kruemmel is also engaged with the national (Canadian) SAON group, participated in all of the teleconferences and is in frequent contact with Helen Joseph (DFO), who is leading the group.

Proposed activities:
d) AMAP Health Expert Group:

- participation at relevant meetings (where possible) and consultations with the group
- reviewing and contributing to papers produced by the group

Work undertaken:
Due to an overlap of the AMAP Health Expert Group meeting taking place June 5–6 in Tromsø with the preparatory meetings for UNEP's Intergovernmental Negotiation Committee meeting, which started June 5th in Stockholm, Sweden, ICC Canada was not able to attend the Health Expert Group meeting. However, ICC Canada is continuing to monitor the activities of the group and is in contact with several of the Health Expert Group members. ICC Canada is planning to attend the upcoming AMAP Health Expert Group meeting in Umeaa, Sweden, June 2011 (and also the joint meeting with the SDWG Arctic Human Health Expert group), and will provide input as required and possible.

Proposed activities:
e) SWIPA:

- reviewing of SWIPA report, participation at Sea Ice meetings as appropriate and possible

Work undertaken:
Eva Kruemmel attended the SWIPA Integration Team meeting in November 16–17th 2010 (with the AMAP HoD meeting) in Reykjavik, Iceland, reviewed the SWIPA documents that were discussed, and provided input. ICC Canada also attended the AMAP WG meeting in Tromsø, Norway, participated in SWIPA discussions at the meeting, and provided input into the relevant documents.

3) UN related

Proposed activities:
a) Global mercury agreement:

- attendance at INC 1 in Sweden 7–11 June 2010 and INC 2 in Feb 2011
- consultations with the government, UNEP, scientists and partner organizations, attending of teleconferences and meetings
- reviewing of documents, researching papers and mercury related research
- development of position papers and assistance in policy development

Work undertaken:
Eva Kruemmel prepared comments for Environment Canada on the ICC Canada position with regards to the mercury negotiations at INC-1 (Attachment 1), participated in preparatory calls and facilitated government consultation efforts with other Aboriginal organizations.

ICC Canada attended the Intergovernmental Negotiation Committee meeting (INC 1) June 7–11, and preparatory meetings on June 5 (NGO information session) and 6 (UNEP technical information meeting) in Stockholm, Sweden. ICC Canada's President, Duane Smith, attended INC 1 as part of the Canadian delegation, and Eva Kruemmel attended as an independent observer for ICC and provided technical support. ICC also worked with the other non-governmental groups (NGO's) and Indigenous groups present at the meeting. Eva Kruemmel's travel was supported by the Zero Mercury Working Group (ZMWG), which also coordinated NGO information meetings and activities. ICC gave two interventions at INC 1: one opening statement in collaboration with the other Indigenous groups present (Attachment 2.1), and another one independently focusing on atmospheric emissions and their importance for Inuit (Attachment 2.2). After the meeting, ICC Canada prepared a report for Environment Canada outlining how Aboriginal organizations could better participate in the mercury negotiation process (Attachment 3).

ICC Canada also sent out a de-briefing note to Aboriginal partners in Canada, and participated in a de-briefing teleconference organized by Environment Canada.

ICC Canada worked with the ZMWG to provide comments for the upcoming study on mercury emissions ("Paragraph 29 study"), and generally reviews mercury related documents and provides input to ensure Inuit viewpoints are represented.

ICC Canada participated in Environment Canada's stakeholder consultation activities for INC-2, and prepared comments (Attachment 4). Eva Kruemmel also participated in a UNEP stakeholder call on INC-2, which took place November 30th, 2010.

Eva Kruemmel attended INC-2, which took place in Chiba, Japan January 24–28, as part of the Canadian delegation. ICC was further represented independently at the meeting by Parnuna Egede from ICC Greenland, and made an intervention (Attachment 5).

After INC-2, ICC Canada prepared a report on ICC Canada's views of INC-2 for Environment Canada (Attachment 6), participated in the debriefing teleconference, and sent a report on the meeting to the aboriginal partners (including ITK, CYFN, and Gwich'in).

Proposed activities:
b) LRTAP:

- providing stakeholder comments to government
- consultations with government, partner organizations, researchers
- reviewing documents

Work undertaken:
ICC Canada reviewed the pertinent documents for the 28th Session of the Executive Body (EB) to the Convention on Long-Range Transboundary Air Pollution (CLRATP), which took place Dec. 13–17, 2010, and provided stakeholder comments (Attachment 7). ICC Canada also exchanged emails with Kevin Telmer (professor at University of Victoria) on some questions with regards to mercury use in gold mining, and forwarded his comments to Environment Canada (with his permission). Although ICC Canada expressed an interest in a de-briefing from the meeting, further information from Environment Canada on the outcomes has not been forthcoming so far.

Proposed activities:
c) POPRC:

- attendance of POPRC -6, 19–22 October 2010
- reviewing of documents and scientific papers
- consultations with government, partner organizations, scientists
- writing of reports, position papers etc.

Work undertaken:
ICC Canada reviewed documents and scientific papers of relevance for the Stockholm Convention and POP Review Committee (POPRC) and has been in contact with scientists doing relevant research to be informed on the latest results and developments.

Eva Kruemmel participated in the 6th POPRC meeting October 10–15 in Geneva, Switzerland, and made an intervention on short-chained chlorinated paraffins (SCCPs) (Attachment 8).

POPRC 6 was successful in recommending endosulfan to being listed under the Stockholm Convention Annex A (for elimination) with exemptions. India continued to protest the process and did not participate in the vote.

Hexabromocyclododecane (HBCD) was also conversely discussed, but finally the Risk Profile was adopted and a Risk Management Evaluation will now be produced.

SCCPs Risk Profile was presented to the POPRC for the 3rd time, and several members were of the opinion that there is not enough evidence that it poses a threat. In its intervention, ICC reminded the members of the Stockholm Convention's objective to protect human health and the environment, particularly using the precautionary approach when in doubt, and asked members to move SCCPs ahead. In the end, it was decided to further investigate SCCPs and continue work on the Risk Profile. One study as part of the toxic interactions item will be planned, which will look at the classes of short-chained and medium-chained chlorinated paraffins and their combined health effects as a case study. This will likely feed into the Risk Profile, which will be updated until POPRC-7 and will then be up for decision again at POPRC-8. The case study will also be used to determine a standardized way on how toxicological effects of mixtures will be addressed in future Risk Profiles.

Other ICC activities included the successful contribution to a contact group on recommendations for risk reductions for PFOS and PFOS-related substances, whose recommendations where later endorsed by the Committee, and which will now be decided on by the Stockholm Convention COP 5 (to take place May 25–29, 2011).

ICC's intervention on SCCPs was commended by many members and observers and was particularly acknowledged by the Chair in a private conversation later that day.

Three weeks after the POPRC 6 meeting, Eva Kruemmel presented the outcomes of the meeting to the NCP Management Committee when it met November 3 -4, 2010 in Yellowknife.

ICC Canada also signed up for several POPRC working groups, and submitted comments for the POPRC group on SCCPs in March 2011 (Attachment 9).

Proposed activities:

4) IPY

a) Science conference in Oslo:

- co-founding session T1-8 Contaminants in Polar Physical and Biological Environment, Humans and Climate Influence
- preparations for session, determining of program, participations at preparatory meetings and teleconferences

Work undertaken:
Eva Kruemmel reviewed abstracts for the session T1-8 on Contaminants in Polar Physical and Biological Environment and then co-convened the session on June 9th at the International Polar Year (IPY) conference in Oslo. Since the IPY conference took place concurrently with UNEP's INC 1 meeting on mercury, Eva Kruemmel flew in from Stockholm to Oslo for the day.

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:
Eva Kruemmel continues to work on her post-doctoral study on mercury pathways in the Arctic with a group of collaborators consisting of Christian Zdanowicz (Geological Survey Canada), Alexandre Poulain (supervisor, University of Ottawa) and Holger Hintelmann (co-supervisor, Trent University). The group is currently preparing to analyze snow and ice samples from the Canadian Arctic for mercury isotopes. First measurements on snow from Greenland took place to develop and test the method, and additional samples have been acquired and are currently being prepared for analysis. Several ice-core samples, which will provide a north-south gradient from the Canadian Arctic have been selected in the cold room at NRCan and will be prepared for analysis in the clean room at the University of Ottawa this spring. Samples will then be sent to Trent University for analysis (likely to take place early summer). The ice cores also will allow to compare pre-historic (~3000 years before present) with industrial times for the different locations. Snow samples representing an east-west gradient are also being obtained. The sample analysis will be

crucial to investigate potential temporal and spatial differences in isotopic fingerprints of mercury in ice and snow in the Arctic.

Results of this study will feed into general work on mercury and will also be used to inform policy development on mercury, such as UNEP's INC negotiations on a global mercury agreement.

Eva Kruemmel has also done several literature searches and reviewed the publications for input into work on CACAR III contributions, briefing notes, and other relevant work.

Preparations for the Stockholm Convention Conference of the Parties (COP) 5th meeting also started this fiscal year already, since COP5 is taking place April 25–29 this year. ICC Canada participated in stakeholder calls (on March 17 and 25) and another meeting with Environment Canada and two other NGOs (on March 15). ICC Canada also sent stakeholder comments to prepare for COP-5 to Environment Canada on March 30th (Attachment 10).

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
- translation of AMAP brochure into Inuktitut

Work undertaken:
ICC organized a health session and had presentations on contaminants at its General Assembly (GA) June 28th to July 2nd in Nuuk, Greenland. Contaminant presentations were given by Per Bakken, United Nations Environment Program, Chief of Chemicals Branch, and Dr. Henning Sloth Petersen, Danish health expert to Arctic Council, member of the AMAP Health Expert Group. Presentations informed circumpolar Inuit from Russia (Chukotka), Alaska, Greenland and Canada about ICC's health-related activities, dealt with health concerns for Inuit with regards to contaminants and food security, and provided an overview about international activities on contaminants (such as the Stockholm Convention and mercury negotiations).

At the GA, ICC adopted the Nuuk declaration, which will guide ICC's work for the next four years. Specifically, the Nuuk declaration instructs ICC to:

"address the growing opportunity for Inuit to meaningfully engage in Arctic science and research, and at the same time play a role in promoting ethical and responsible research practices that stress the importance of bringing knowledge back to Inuit communities;

work with circumpolar and national partners towards the development of a strategy to implement the proper integration of community-based monitoring and research (CBM/R) into research activities in the Arctic

***Address** the negative impact on Inuit food security brought on by the effects of contaminants, climate change, and regulatory decisions taken by others on polar bears, seals, and other mammals and **Urge** ICC to incorporate Inuit food security issues into its work on health, nutritious foods, sustainable utilization of wildlife, contaminants, biological diversity, and climate change;*

maintain its international, national, and regional efforts to reduce the worldwide emissions of contaminants that end up in the Arctic and negatively affect Inuit, and engage in activities that advance and strengthen the provisions of international instruments such as the global Stockholm Convention on Persistent Organic Pollutants, the International Agreement on Mercury Pollution (currently under negotiation), the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter;".

The full declaration can be obtained from ICC's website at www.inuitcircumpolar.com

ICC Canada had several meetings/teleconferences with Chris Furgal (Trent University), Inuit Tuttarvingat, and ITK to determine how the national Inuit organizations can work together to better communicate environment- and health related messages to regions and communities. The group agreed on the development of a short review paper on current communication processes of the three Inuit organizations (possibly also including Pauktuutit). Chris Furgal has been tasked with the development of test communication material on mercury. The group is planning to then set up a contaminant communication steering group, which will consist of representation from the national Inuit organizations as well as the Inuit regions. Representatives from NCP's Regional Contaminant Committees have been informed about the plans and are interested in participating in the process. Work on this is ongoing.

Associated with the work of Nipingit, the National Committee on Research Ethics, ICC Canada prepared a poster with the support of Inuit Tuttarvingat to draw attention to research activities in the Canadian Arctic and how they are being used in international policy development. The poster is part of a series of national and regional posters on research in the north, which have already been distributed to Arctic communities to engage Inuit and ask them to consider a career in research. ICC Canada is currently working to update its website with necessary information to support the dissemination of the international poster.

ICC Canada prepared a six-page information booklet on mercury and how it affects Inuit, which was distributed at UNEP's INC-1 and INC-2 negotiations on mercury and other venues, including the NCP Results Workshop.

General communication work also always includes the preparation of briefing notes on contaminant issues ICC Canada works on, which are being distributed to ICC Canada Board members and the Executive Council. Meeting reports for all meetings that have been attended are also being prepared and sent to the appropriate ICC representatives.

ICC Canada is still awaiting the electronic version/text of the AMAP brochure that was meant to be translated into Inuktitut.

7) Other activities

ICC Canada was asked to give a presentation on Aboriginal health during the Aboriginal Awareness Week at University of Ottawa, organized at the Faculty of Medicine. Eva Kruemmel attended the meeting on April 19th and presented a talk tiled "A Circumpolar Perspective on Aboriginal Health: Where We Are Now and What Is Needed".

Eva Kruemmel participated at the Expert Consultation on Northern Transboundary Air Quality Issues – International Air Quality Advisory Board (IAQAB) conference taking place August 17–19, 2010 in Whitehorse via the internet (WEBEX), and gave a presentation on International Agreements on Global Contaminants and Implications for Inuit Health.

Eva Kruemmel attended (via WEBEX) the INCATPA meeting taking place August 25–26 in Toronto.

After the 6th POPRC meeting, Eva Kruemmel was asked by the Alaskan Community Action on Toxics (ACAT) to participate at a teleconference on Oct. 27th 2010, and to present ICC's views from the POPRC meeting. Eva Kruemmel participated in the call, gave a background on ICC, explained the work ICC is doing with NCP and AMAP, and detailed ICC's efforts at the Stockholm Convention on POPs as well as POPRC.

ICC Canada (Stephanie Meakin and Leanna Ellsworth) presented at Environment Canada during their speaker series on Aboriginal Peoples and the Environment on December 7th, 2010. The presentation dealt with ICC Canada's work on climate change, health, contaminants and biodiversity and inclusion of traditional knowledge.

Together with Looee Okalik (ITK), Eva Kruemmel was invited to present to a class at Carleton University course called "Arctic Passages: The Changing Dynamics of Canada's North on March 22nd, 2011". Eva Kruemmel's talk was titled "Inuit Circumpolar Council Canada.

Activities on Health and Contaminants", and included information about ICC Canada's work with NCP. NCP funding was also acknowledged.

NCP Performance Indicators

The NCP proposal supported:

- administrative work by Yvonne Moorhouse, who is an Inuit youth employed at the ICC office

- contributions to ICC's General Assembly in Nuuk, Greenland
- contributions to two chapters of the AMAP Mercury Assessment
- contributions to the CARCAR III POPs and Mercury reports
- several presentations that were given as described in the report

Expected Project Completion Date

Work is ongoing.

Acknowledgments

NCP was acknowledged in all presentations given as part of the funded work.

References

Stow, J., Krümmel, E.M., Wilson, S. What controls mercury in the Arctic, and what are the effects on Arctic biota? Chapter 1: Why are we doing this assessment? Mercury Assessment, Arctic Monitoring Assessment Programme. Under review, to be published 2011.

Stow, J., Krümmel, E.M., Leech, T., Donaldson, S. What controls mercury in the Arctic, and what are the effects on Arctic biota? Chapter 8: What is the impact of mercury contamination on human health in the Arctic? Mercury Assessment, Arctic Monitoring Assessment Programme. Under review, to be published 2011.

Attachments

1. ICC Canada Stakeholder Comments to Environment Canada on INC-1
2. INC-1 Interventions (2.1 and 2.2)
3. ICC's INC-1 Report to Environment Canada
4. ICC Canada Stakeholder Comments to Environment Canada on INC-2
5. INC-2 Intervention by ICC
6. ICC's INC-2 Report to Environment Canada
7. ICC Canada Stakeholder comments to Environment Canada for the 28th Session of the Executive Body (EB) to the Convention on Long-Range Transboundary Air Pollution (CLRATP), UNECE
8. ICC's intervention at POPRC 6
9. ICC Canada comments on SCCPs for POPRC working group
10. ICC Canada Stakeholder Comments to Environment Canada on COP 5 of the Stockholm Convention on POPs

Improving communication, capacity and outreach with frontline workers in the Inuvialuit Settlement Region

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Inuit Research Advisor, IRC, Inuvik (January-March 2010)
Jennifer Johnston (May 2010–Dec 2010), Tamara Hansen (January 2011),
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Abstract

Building on the communication, capacity building and outreach initiatives that have been successful in the Inuvialuit Settlement Region (ISR), the Inuit Research Advisor (IRA) undertook similar projects for the 2010–2011 year. Two major projects ensured that proper communication and outreach strategies continued to take place with frontline workers and communities. The first project was the writing, publishing and distributing of the Inuvialuit Regional Corporation (IRC) Research Newsletter on a bi-annual basis throughout the year. The second project was the regional IRA tour to host community meetings and network with frontline workers and other community members.

The projects gave local and southern researchers, frontline workers and communities the opportunities to communicate. Each of the projects give these groups the opportunity to share information and make suggestions about research in terms of subject matter, how communities want research results communicated as well as availability and training opportunities. The results of this work increased awareness of research in the region and gave more people in the ISR the opportunity to

Résumé

En tirant profit des initiatives de communication, d'amélioration des capacités et de sensibilisation qui ont été menées avec succès dans la région désignée des Inuvialuit (RDI), le conseiller en recherche inuite (CRI) a mené des projets similaires pour l'année 2010–2011. Deux projets majeurs ont permis de s'assurer que les stratégies appropriées de communication et de sensibilisation étaient toujours mises en œuvre auprès des travailleurs de première ligne et dans les collectivités. Le premier projet consistait en la rédaction, la publication et la distribution du bulletin semestriel sur la recherche de la Société régionale inuvialuite (SRI). Le deuxième projet visait la visite du CRI régional dans les collectivités afin d'organiser des rencontres communautaires et de faire du réseautage avec les travailleurs de première ligne et d'autres membres de la collectivité.

Les projets ont donné aux chercheurs de la région et à ceux venus du Sud, aux travailleurs de première ligne et aux membres des collectivités l'occasion de communiquer. Chaque projet donne l'occasion à ces groupes d'échanger de l'information et de faire des suggestions concernant la recherche pour ce qui

improve communication and partnerships across departments and organizations. Most importantly we learned from the ISR communities what contaminants information they were lacking and in what form/manner they need information communicated to be best understood and incorporated into their daily lives.

est des sujets, de la manière dont les collectivités souhaitent qu'on communique les résultats des recherches ainsi que sur la disponibilité et les possibilités de formation. Les résultats de ces travaux ont permis d'accroître la sensibilisation à la recherche menée dans la région et ont donné à plus de gens dans la RDI l'occasion d'améliorer les communications et les partenariats entre les ministères et les organisations. Plus important encore, nous avons appris des collectivités de la RDI les renseignements dont ils avaient besoin sur les contaminants et la manière dont ces renseignements doivent leur être communiqués pour favoriser la compréhension et l'inclusion dans la vie quotidienne.

Key Messages

- Contaminants information must be delivered within the cultural context of the Inuvialuit Settlement Region (ISR) in order that it is relevant and able to be incorporated into community member's daily lives.
- Local people must be involved in the delivery of this messaging in order that it is heard and respected.
- Many communities lack *basic* information on long range contaminants and would benefit from information and education, for an example the difference between long range and point source contaminants, contaminant pathways, etc.
- There are language and literacy challenges in the ISR and this must be taken into consideration when dispersing contaminants information.
- Utilizing Traditional Knowledge in NCP research from data collection to analyses and dissemination of knowledge would ensure all information was relevant, culturally competent, timely and clearly communicated.

Messages clés

- Afin d'assurer leur pertinence et de voir à ce qu'ils puissent être incorporés dans la vie quotidienne des membres des collectivités, les renseignements sur les contaminants doivent être transmis en fonction du contexte culturel de la région désignée des Inuvialuit (RDI).
- Les habitants de la région doivent participer à la diffusion de ces messages afin que la population y porte attention et les respecte.
- De nombreuses collectivités ne possèdent pas assez de renseignements de base sur les contaminants de longue portée et elles bénéficieraient de recevoir des renseignements et de l'éducation à ce sujet, par exemple sur la différence entre les sources de contaminants de longue portée ou de source ponctuelle, les routes des contaminants, etc.
- Il y a des obstacles liés à la langue et à l'alphabétisation dans la RDI, et ceux-ci doivent être pris en considération lorsqu'on diffuse des renseignements sur les contaminants.
- En utilisant des connaissances traditionnelles dans les recherches dans le cadre du Programme de lutte contre les contaminants dans le Nord pour la cueillette des données, ou encore l'analyse et la diffusion des connaissances, on veillerait à ce que tous les renseignements soient pertinents, à jour, diffusés clairement et qu'ils tiennent compte de la culture.

Objectives

- Hire and train new IRA and develop work plan within the context of the IRA's community based role.
- Complete two 2010 newsletters (spring and winter) and incorporate information learned from community consultations.
- Conduct community tours and meetings with frontline workers to all six of the Inuvialuit communities.
- Continued work on the Inuit Advisory Committee (ArcticNet).
- Continued work on the other selection committees and reviews (NWT RCC)
- Attend NCP Annual Results Workshop (poster presentation).
- Attend ArcticNet Annual Scientific Meeting (post presentation).
- Community capacity building among front-line workers, communicators, community members and researchers.
- Deliver synthesized contaminants messages as directed by the NWT RCC.
- Investigate, plan and carry out how to best communicate about contaminants, specifically working with Breanne Reinfort and her research in Sachs Harbour.

Introduction

The Northern Contaminants Program/ Inuit Research Advisor position is an essential position within the Inuvialuit Settlement Region. It is essential due the history of research in the north, the cultural challenges experienced by southern researchers, and the importance and place of country foods within the Inuvialuit way of life. This position helps to bridge the cultural, socio-economic, and historical differences between southern research paradigms /researchers and Traditional Knowledge and Inuvialuit communities. It also is an essential link in that it is a grassroots position for gathering community based and community driven ideas with regards to contaminants information and knowledge transfer. The NCP funded IRA position executes two projects that support these ends, the bi-annual newsletter and the community tours.

The bi-annual newsletter is a way to inform in plain language, community members of the research happening in their communities, provides a voice for local people including local people involved in or initiating community based research, is a forum for other regional information sharing and most importantly provides a vehicle for basic information/education on contaminants and contaminants related issues and their potential effects on Inuvialuit way of life. The newsletter has been consciously adapted to include a local language as well as English in order to access the Elder population as well as contribute to keeping alive a local language. The newsletter is also interactive seeking to draw readers in and engage them in issues affecting and related to their communities.

The community tours are the way information is gathered on what is currently important to Inuvialuit communities. During the tours/consultations, information is gathered on what contaminants are on the radar and why, information is shared about research initiatives in the region, and it is also an opportunity for local people to express any challenges they may be having with researcher(s) along with any success stories. The feedback is all documented and brought back both the funders as well as Inuvialuit Institutions. With this information funders are better able to support the community driven needs and be better aware of capacity identified through the program.

This program and position has also aided in the development of the Inuvialuit Research Agenda, being an important link to and direction for the various Inuvialuit institutions. Having a clearer idea of community's knowledge base and capacity with regards to contaminants as well as other research subject matter helps to build capacity and further support the goals of the Inuvialuit Final Agreement. The tours and newsletters also tie into the Inuvialuit Indicators website (www.inuvialuitindicators.ca) helping to give a better overall picture of Inuvialuit communities and Inuvialuit culture and therefore way of life. With this picture Inuvialuit can better protect important traditions from the past as well as develop new ways to help sustain their cultural way of life.

Activities

Communications

- Ongoing networking with key players within IRA role: program contacts, local and regional contacts, front-line workers and professionals including Hamlets, Nursing Stations, Community Corporations, Aurora Research Institute, etc.
- Developed new Inuit Research Advisor pamphlet for distribution
- Attended regular Regional Inuit Research Advisor Conference Calls and meetings
- Attended Regular NWT RCC Conference Calls and disseminate information to appropriate audiences
- Traveled to communities for information gathering and sharing on contaminants/environmental concerns.
- Attendance at the Northern Contaminants Results Meeting with introductions to various NCP researchers and contacts took place as well as a meeting with other funders and information gathering and sharing.
- Follow-up with contacts from Results committee: Derek Muir, Eva Krummel, Lois Harwood.
- Contact with Rebecca Pokiak with plans to discuss new projects in the region with the hopes of supporting community based research
- Dialogue with NCP Derek Muir's regarding the Ringed Seal samples program, trouble-shooting ways to improve sample size
- Prepared IRA poster for ArcticNet Annual Scientific Meeting in December
- Participated in IRIS teleconference
- ArcticNet meetings to arrange IRIS conference
- Presented at IRIS I meeting and attended same

Capacity Building

- Ongoing review of licenses through Aurora Research Institute
- Contribution Agreement amendment and submission
- Completion of deliverables to funders, i.e. reports, financial statements, proposals.
- On-going relationship building within other departments of IRC – Game Council, Inuvialuit Lands Administration with hopes of developing a coordinated approach to research in general.
- On-going reading/literature review on long-range contaminants sources, pathways, affects, and best practices in communications.
- Completion of two IRC Research Newsletters translated into Siglitun as well as English with basic information on contaminants, pathways, etc.

Traditional Knowledge

- Consult with Sachs Harbour community members with regards to a partnership between NCP Researcher and Traditional Knowledge holders in the research of the ringed seal population currently being conducted in Sachs Harbour.
- Developed outline for a Traditional Knowledge study of ringed seals in Sachs Harbour
- Developed frame work for gathering Traditional Knowledge and its' application collaboration with southern research.
- UPDATE: Completed next year's NCP IRA funding proposal and included a Pilot Project that seeks to partner Traditional Knowledge with NCP research in gathering, interpreting and disseminating of information on ringed seals in Sachs Harbour.
- Attendance at NCP Social Cultural Review of the upcoming year NCP Proposals in Yellowknife February 21–25, 2011.

Results

- Presented at the following conferences: IPY Conference, ArcticNet Annual Scientific Meeting, Aboriginal Health Transition Fund Workshop and the IRIS I Workshop.
- Gathered important information from community visits/meetings held in Aklavik, Tuktoyaktuk, Paulatuk, Sachs Harbour, Ulukhaktok, and Inuvik
- Gathered data regarding current needs and capacity of communities in the ISR to access and incorporate knowledge on contaminants and applied this information to next year's projects.
- Developed Ringed Seal Project to partner Inuit Traditional Knowledge holders with NCP Researchers in Sachs Harbour.
- Poster presentation at ArcticNet Annual Scientific Meeting
- Produced 2 bilingual newsletters (English and Siglitun)

  Background: The newsletter is for communication, education and knowledge transfer purposes within the Inuvialuit Settlement Region (ISR). Feedback from community members suggested the requirement for basic education and information on long-range contaminants. The newsletters will present this information in a user friendly and engaging manner. In addition, community members agreed previous newsletters were geared to more of a Southern audience; therefore the new design will consider literacy and language issues in the region as well as incorporate regionally relevant content. Each issue will be in both plain language English as well as translated into one of the three Inuvialuktun dialects. Content will include basic information on contaminants and any messaging deemed appropriate by the NWT RCC, information about specific research happening in the ISR communities as well as information on long term regional projects like the Integrated Regional Impact Study (IRIS I), the Beaufort Regional Environmental Assessment (BREA), and the Integrated Ocean Management Assessment (IOMA).

  Overall with community visits the following was ascertained: there was no access to any official contaminants resources for people to access in the community. Responses to the question of concerns or issues around contaminants ranged from bio-physical related issues to social issues. All responses were documented, many were non-contaminants related issues. Despite this, all was documented as all the information is considered relevant and presents as an indicator of some community members' level of knowledge, awareness of issues and current priorities. This information in turn may help with overall approach to contaminants messaging in the future.

Discussion and Conclusions

The annual community visits were very informative in directing how and what contaminants information should be communicated. The community visits also helped to direct the changes in the bi-annual newsletter distributed throughout the ISR.

NCP Performance Indicators

Number of northerners engaged in projects: Total of 90 people participated in community meetings

Number of meetings /workshops held in the North: 6 community meetings

Number of students involved in NCP work: 5

Expected Project Completion Date

March 31, 2011.

Acknowledgements

Northern Contaminants Program is recognized via its' logo in all related communications including presentations, posters, pamphlets, and meetings/workshops.

IRC Activities:

- Input provided for ArcticNet Visioning Document through Inuit Advisory Committee.
- Continue to foster relationships with front-line workers, communities and staff within the Beaufort Delta Region

- On-going reading/literature review on long-range contaminants sources, pathways, affects, and communications.
- Presented at International Polar Year Workshop in Inuvik in January 2011
- Presented at the Aboriginal Health Transition Fund Workshop in Yellowknife in January 2011
- Participation in the development of IRC's Research Agenda and Policy
- Correspondence and coordination with researchers interested in partnerships, capacity building, etc., in the Inuvialuit communities as well as outlining terms of partnership.
- Produced article for the Inuvialuit Tusaayaksat magazine regarding Youth responses/perspectives from IRC Mental Health and Addictions Study in 2009
- Participation in the development of IRC's Research Agenda and Policy
- Participation on Integrated Ocean Management Project conference calls and in person meetings
- Help in preparation of numerous workplans for the social, cultural and economic IOMP working group.
- Attended meetings with the IOMP Social Cultural and Economic working group
- Attended BREA meetings
- Participated in in-house research meeting with ILA, ICC and Stephanie Irbacher-Fox
- Attendance and Poster Presentation at ArcticNet Annual Scientific Meeting (ASM) in Ottawa in December 2010.

Nunatsiavut Inuit Research Advisor

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Abstract

The Inuit Research Advisor (IRA) program continues to serve as the first step in a more coordinated approach to community involvement and coordination of Arctic science in Nunatsiavut. Nunatsiavut Government (NG) encourages researchers to consult/meet with Inuit Community Governments and NG Departments/Divisions in developing their proposals. Comprehensive reviews of proposals are initiated involving appropriate NG departments, Inuit Community Government(s)/Corporation(s).

Together with IRAs in the other Inuit regions of Canada, the Nunatsiavut IRA works towards achieving a new way of knowledge sharing and engagement of Inuit in Arctic science in the region. In addition to NCP support, the program is co-funded by ArcticNet and the Nasivvik Centre for Inuit Health and Changing Environments.

Résumé

En tirant profit des initiatives de communication, d'amélioration des capacités et de sensibilisation qui ont été menées avec succès dans la région désignée des Inuvialuit (RDI), le conseiller en recherche inuite (CRI) a mené des projets similaires pour l'année 2010–2011. Deux projets majeurs ont permis de s'assurer que les stratégies appropriées de communication et de sensibilisation étaient toujours mises en œuvre auprès des travailleurs de première ligne et dans les collectivités. Le premier projet consistait en la rédaction, la publication et la distribution du bulletin semestriel sur la recherche de la Société régionale inuvialuite (SRI). Le deuxième projet visait la visite du CRI régional dans les collectivités afin d'organiser des rencontres communautaires et de faire du réseautage avec les travailleurs de première ligne et d'autres membres de la collectivité.

Les projets ont donné aux chercheurs de la région et à ceux venus du Sud, aux travailleurs de première ligne et aux membres des collectivités l'occasion de communiquer. Chaque projet donne l'occasion à ces groupes d'échanger de l'information et de faire des suggestions concernant la recherche pour ce qui est des sujets, de la manière dont les collectivités souhaitent qu'on communique les résultats des recherches ainsi que sur la disponibilité et les

possibilités de formation. Les résultats de ces travaux ont permis d'accroître la sensibilisation à la recherche menée dans la région et ont donné à plus de gens dans la RDI l'occasion d'améliorer les communications et les partenariats entre les ministères et les organisations. Plus important encore, nous avons appris des collectivités de la RDI les renseignements dont ils avaient besoin sur les contaminants et la manière dont ces renseignements doivent leur être communiqués pour favoriser la compréhension et l'inclusion dans la vie quotidienne.

Key Messages

- In 2010–11 the IRA undertook various tasks to liaison with the Northern Contaminants Program (NCP), ArcticNet, Nasivvik Centre, and Nunatsiavut Government (NG) in the areas of research promotion and coordination, public education and information. The IRA distributes all promotional items, notices etc. from the three funding agencies to all of the NG Assembly and employees.
- The IRA has also served as liaison for partners such as Inuit Tapiriit Kanatami (ITK), Inuit Circumpolar Council (ICC) Canada, Nunatsiavut Inuit Community Governments/Corporations, International Polar Year (IPY), researchers, students, and other organizations.
- The IRA oversaw the management of the Nunatsiavut Government Research Office, 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 80 researchers from 1st April 2010 to 31st March 2011.
- The IRA served as liaison, contact and assistant to research projects taking place in Nunatsiavut. This assistance ranged from linking the researchers with appropriate individuals and/or organizations such as NG departments and Inuit Community Governments in Nunatsiavut to providing input on research proposals and plans.

Messages clés

- Afin d'assurer leur pertinence et de voir à ce qu'ils puissent être incorporés dans la vie quotidienne des membres des collectivités, les renseignements sur les contaminants doivent être transmis en fonction du contexte culturel de la région désignée des Inuvialuit (RDI).
- Les habitants de la région doivent participer à la diffusion de ces messages afin que la population y porte attention et les respecte.
- De nombreuses collectivités ne possèdent pas assez de renseignements de base sur les contaminants de longue portée et elles bénéficieraient de recevoir des renseignements et de l'éducation à ce sujet, par exemple sur la différence entre les sources de contaminants de longue portée ou de source ponctuelle, les routes des contaminants, etc.
- Il y a des obstacles liés à la langue et à l'alphabétisation dans la RDI, et ceux-ci doivent être pris en considération lorsqu'on diffuse des renseignements sur les contaminants.
- En utilisant des connaissances traditionnelles dans les recherches dans le cadre du Programme de lutte contre les contaminants dans le Nord pour la cueillette des données, ou encore l'analyse et la diffusion des connaissances, on veillerait à ce que tous les renseignements soient pertinents, à jour, diffusés clairement et qu'ils tiennent compte de la culture.

- The IRA assisted in the planning, preparing and executing of the Tukisinnik Community Research Forum held the first week of June 2010 in Nain, Nunatsiavut. The forum was the first of its kind in Arctic Canada. The focus was to explore the relationship between natural, social and health science research and the communities in Nunatsiavut and the future potential for the research sector in the region. Tukisinnik translates from Inuktitut as 'to understand.' More than 90 community members, natural, social and health science researchers and government representatives attended the forum. You may request a copy of the report from Tom Sheldon, Director, Environment Division, NG.

Objectives

- Provide liaison support for and promote research in Nunatsiavut. The IRA has communicated with over 80 researchers and made poster presentations at the NCP and ArcticNet Annual meetings.
- Promote more community-based research in the region. There have been more community led research projects such as the projects led by the Inuit Community Governments of Nain and Rigolet and the Inuit Community Corporation in North West River, the NG's Department of Education and Economic Development, Environment Division, and the Department of Culture, Recreation & Tourism. We have also had two research projects led by beneficiaries of the Labrador Inuit Land Claims Agreement.
- Assist in the development of local capacity for research in Nunatsiavut. The IRA has a list of research assistants and interpreters/translators from each Inuit Community who are willing to work with researchers on their projects.
- Provide information regarding research in Nunatsiavut and opportunities for local involvement.
- Liaise with national organizations and other Inuit regions in matters related to Arctic science and research.

Activities in 2010–2011

- Managed the Nunatsiavut Government Research Office and served as Chair to the NG Research Advisory Committee, making contact with virtually all researchers, students and organizations visiting or wanting to conduct research in the Labrador Inuit Land Claims Area.
- Undertook socio-cultural review of NCP proposals through NHERC in February and March 2011.
- Attended the Memorial University Presents Workshop, April, Nain;
- Assisted in planning, preparing and executing the Nunatsiavut Government research Forum "Tukisinnik – to understand Workshop", June 2010, Nain;
- Attended the 18th Annual NCP Results Workshop, September 28–30, Whitehorse. The IRA made a poster presentation.
- Attended the Blueprint review session for Education and Communications in Whitehorse on September 30.
- Attended the Elders Gathering in October 2010 in Happy Valley-Goose Bay and gave a presentation entitled "Developing holistic research and associated education programs to support communities and Government".

- Assisted in organizing and presented at the Nunatsiavut Climate Change Researchers Meeting in Ottawa in December.
- Attended ArcticNet's Seventh Annual Scientific Meeting (ASM2010), 14–17 December, Ottawa. IRA had a poster presentation.
- Attended ArcticNet's Inuit Advisory Committee (IAC) Meeting in Ottawa on February 6–7.
- Attended the Pan-Arctic Results Workshop, in Ottawa in February 2011. The IRA, along with two others, presented at the workshop.
- Developed and distributed a 2008–09 Compendium of Supported Research Projects that was undertaken in Nunatsiavut.
- Kept Nunatsiavut Government Assembly, Staff and Research Advisory Committee informed of all NCP, ArcticNet and Nasivvik activities and opportunities.
- Participated in teleconferences with other regional IRAs.
- Promoted NCP, ArcticNet, Nasivvik activities and opportunities at the Nunatsiavut community and regional level through word of mouth and the distribution of promotional materials.
- Assisted in the preparation of the Nunatsiavut NCP Newsletter (Avativut)
- See attached Research Contact list for all contacts the IRA made with researchers during the 2010–11 fiscal year.

Results

The IRA program in Nunatsiavut continues to provide a coordinated process by which Inuit and researchers can become connected for more effective and meaningful research in the disciplines of environmental science, contaminants and human health.

NCP Performance Indicators:

- *The number of northerners engaged in the IRA project*: 100 plus.
- *The number of meetings/workshops you held in the North*: 10.
- *The number of students (both northern and southern) involved in your NCP work*: 20.
- *The number of citable publications (e.g., in domestic/international journals, and conference presentations, book chapters, etc)*: 2 conference poster presentations.

Expected Project Completion Date

This is an ongoing project.

Attachment

2010–11 Nunatsiavut IRA Researcher Contact List

1. Juliana Coffey, Torngat Wildlife, Plants and Fisheries Secretariat, Inuit observations of Land and Sea: Kavisilik (Atlantic salmon) and IKaluk (Arctic charr);
2. Dianne Kinnon, National Aboriginal Health Organization, Respiratory Health Initiatives Environmental Scan – First Nations, Inuit, and Métis;
3. Perry Trimper, Stantec/ Environmental Monitoring and Research (IEMR), To Survey Population Trend of the Harlequin Duck (Histrionicus histrionicus) in Labrador;
4. Tim McNeill, Nunatsiavut Government, Community Engagement Project Proposal: Towards Constructive Change in Inuit Communities;
5. Dr Johanna Wolf, Memorial University, Climate change adaptation in Labrador: The role of values and cultural identity;
6. Oxana Latycheva, Asthma Society of Canada, Exploration of First Nations and Inuit Perspectives on Community Respiratory Health Awareness Initiatives;
7. John Reid, New Economy Development Group/ Fur Institute of Canada, 2010 Identification of Climate Change Impacts and Adaptation Measures by the Community Based Members and Organizations of the Fur Institute of Canada;
8. Kristie Jameson, Food Security Network of Newfoundland & Labrador, NiKigijavut Hopedalimi "Our Food in Hopedale";

9. Sarah Erickson & Tom Sheldon, Nain Inuit Community Government/ Nunatsiavut Government, The development of an Inuit focused community monitoring program in Nain, Nunatsiavut: a pilot study for building capacity while adapting for a healthy future;
10. Dr Astrid E.J.Ogilvie and Susan A. Crate, University David King Hall, Collaborative Proposal: Understanding Climate-Driven Phenological Change – Observations, Adaptations and Cultural Implications in Northeastern Siberia and Labrador/ Nunatsiavut (PHENARC);
11. Audrey R. Giles, Ph.D., University of Ottawa, Throwing a lifeline: Aquatic-based injury & drowning prevention with Aboriginal communities in Nunatsiavut;
12. Heather Igloliorte, Carleton University, A Century of Labradorimiut Artistic Production: 1890 to 1990 (working title);
13. Guy Playfair, Innu Nation Environment Office, Conducting Research in Nitassinan;
14. Dear Ms. Lisa Densmore, Government of NL, Nunatsiavut Government's Research Process;
15. Rachel Hirsch, University of Alberta, Bridging the research-policy-practice gap: Assessing the use of indigenous knowledge in Arctic climate change policy communications;
16. Lori Vitale Cox, Elsipogtog First Nation, NB, Northern Circles Tool Kit pilot activity;
17. Vincent Brodeur, Direction de l'expertise Énergie-Faune-Forêts-Mines-Territoire du Nord-du-Québec, George River Herd Population Census – Hebron Area;
18. J. Brian Dempson, Fisheries and Oceans Canada, Research and Assessment of Arctic charr in north Labrador;
19. Juliana Coffey, Torngat Wildlife, Plants and Fisheries Secretariat, Exploratory Snow Crab Survey NAFO Division 2H;
20. Brian Pritchard, Memorial University, Archaeological Identities and Interaction: Understanding Indigenous- European Relations and cultural Developments in central Labrador;
21. Meghan Buckham, Kerr House, Traill College, "Understanding the Role of Knowledge in Policy Development: The Role of Inuit Knowledge in Environmental Policy Development in Nunatsiavut";
22. John A. Munro, PhD., The Grieves at Kaipokok Bay;
23. Sherilee Harper, University of Guelph, Health Impacts of Climate Change: A pilot exploratory study limited to assessing health priorities and characterizing community health systems in Nunatsiavut, Labrador, Canada;
24. Perry Trimper, Aivek Stantec Limited Partnership/ Environmental Monitoring and Research (IEMR), Harlequin Duck Breeding Pair and Brood Surveys – 2010;
25. Alana Johns, University of Toronto, Within and Beyond the Inuktitut Word;
26. Cynthia Zutter, PhD, Grant MacEwan University, Historic Paleoenvironmental Landscape Analysis; Okak Bay, Labrador;
27. Isabel Lemus-Lauzon, Université Laval, climate change and cultural change in Labrador, Canada: paleoecology and traditional ecological knowledge;
28. Perry Trimper, Stassinu Stantec Limited Partnership/ Aurora Energy Resources, Access Road Breeding Songbird Surveys – 2010;
29. Charlie Mattina, Lakehead University, Climate Change and Tourism Change in Northern Communities: A Vulnerability and Resilience Assessment;
30. Bruce Rodrigues, Dept. of Environment and Conservation, 2009–10 National Peregrine Falcon Survey (With additional small mammal, invertebrate and botany collections.);
31. Dr. Tom Gordon, Memorial University, The Music of the Moravian Inuit of Labrador;
32. Dr. Tom Gordon, Memorial University, Choral Traditions of the Labrador Inuit;
33. Paul MacDonald, Environment Canada, Monitoring Seabird Populations in Labrador – 2010;

34. Perry Trimper, Aivek Stantec Limited Partnership/Aurora Energy Resources, Caribou survey of Michelin claim block and access road;
35. Perry Trimper, Stassinu Stantec Limited Partnership/Aurora Energy Resources, Access Road Corridor and Port Site Rare Plant Survey ();
36. Perry Trimper, Stassinu Stantec Limited Partnership/Aurora Energy Resources, Ecological Land Classification – Proposed Michelin Access Road Corridor and Port Site;
37. Lela Evans, Aurora Energy Resources Inc. – Michelin Project, Hydrology Data Collection: Measurement of Water Velocity and Depth at Regular Intervals Across Selected Streams, Water Elevation, and Visual Surveys of Select Floodplains;
38. Lela Evans, Aurora Energy Resources Inc. – Michelin Project, Passive Data Collection: Deployment and Retrieval of Self-contained Passive Radiological and Air Samplers;
39. David Scruton, Sikumiut Environmental Management Limited/ Aurora Energy Limited, Freshwater Water Quality Monitoring, 2010;
40. David Scruton, Sikumiut Environmental Management Limited/ Aurora Energy Limited, Stream Crossing Survey of the Proposed Aurora Energy Mine Access Road;
41. Mr. Matthew Pryde, Health Canada, Community Physical Activity Asset Map (Nunatsiavut);
42. Alain Cuerrier, PhD, Université de Montréal, Climate change impact on Canadian Arctic tundra: how berry producing shrubs and medicinal plants are responding to warming and how it will affect Inuit health: An eco-health approach;
43. Agata Durkalec, Trent University, Understanding Inuit community health and safety during travel on sea ice: A case study of Nain, Nunatsiavut;
44. Dr. Michael Ungar, Dalhousie University, Adversity and resilience among early teens: What predicts positive outcomes in later adolescence?;
45. James Woollett, Laval University, Environmental Archaeology in Okak Bay and Dog Island;
46. Jennifer Mitchell, Torngat Wildlife, Plants and Fisheries Secretariat, Plant Identification in Makkovik (also referred to as "Plant Bioblitz");
47. Patricia Canning, PhD, R. Psych., Centre of Excellence for Children and Adolescents with Special Needs, Getting up-to-date information on body weights and heights of children in your jurisdiction with additions tothe collection data form that will enable us to analyse children's growth during infancy, toddlerhood and into preschool age.;
48. Thomas M. Artiss, University of Cambridge, A Social Life of Songs: Perspectives on Inuitization and Change from a Radio Station in Nain, Labrador;
49. Toni White, Torngâsok Cultural Centre, Rigolet Dialect Research Project;
50. Gioia Montevecchi, BSc, MSc Med AHSR, Memorial University, Factors Influencing Access to Health Care Services in Labrador;
51. Jennifer Organ, School For Resource and Environmental Studies, Community Freezers as a Catalyst Towards Food Security: Perspectives from Inuit Residents of Nain, Nunatsiavut. Please Note: This project is being conducted within a larger project entitled 'Food Security, Ice, Climate and Community Health: Climate change impacts on traditional food security in Canadian Inuit Communities.' By Chris Furgal and funded under ArcticNet;
52. Lori Ann Roness, Lori Ann Roness Consulting, on behalf of The Atlantic Aboriginal Economic Development Integrated Research Program, AAEDIRP, Assessing the Effectiveness of Labour Force Participation Strategies;

53. Lori Ann Roness, Lori Ann Roness Consulting, The Atlantic Aboriginal Economic Development Integrated Research Program, AAEDIRP, Examining Partnership Arrangements Between Aboriginal and Non-Aboriginal Businesses;
54. Tanya Brown, Program Leader- ArcticNet Nunatsiavut Nuluak, Environmental Sciences Group;
55. Catherine Carry, National Aboriginal Health Organization, potential partners in a project with Dr. James Ford;
56. Sonya Corbin Dwyer, Ph.D., Memorial University of Newfoundland, requested a copy of the Research Application;
57. Aaron Dale, Torngat Wildlife, Plants and Fisheries Secretariat, requested compensation guidelines for participants in/contributors to the research;
58. Erica Pufall, University of Guelph, Engaging Northern communities in the monitoring of country food safety;
59. Ed Tuttauk, Sivunivut Inuit Community Corporation Inc., Traditional Knowledge: A Blueprint for Change;
60. Leroy Metcalfe, Sikumiut/ESRF – Socio-Economic Effects of Oil and Gas Exploration and Development, Offshore Labrador;
61. Dr. Martin J. Whitehouse, Swedish Museum of Natural History, research process;
62. Colin McManus, University of Toronto Institute for Aerospace Studies, drive robot around and collect sensor data of the environment (e.g., camera images, laser scans);
63. Martin Lougheed, Inuit Tapiriit Kanatami, systematic grey-literature review of climate change and adaptation;
64. KC Bolton, McGill, a review of climate change research in Nunavut, Nunavik, and Nunatsiavut;
65. Hayley Hung, Ph.D., P. Eng., Environment Canada, NCP passive air sampling for POPs proposal – seeking collaboration;
66. Dr.Lawrence F. Felt, Memorial University, weather reports in the Moravian holdings in the Moravian church;
67. Natan Obed, Nunavut Tunngavik Inc., draft terms of reference for Inuit Knowledge Centre National Committee;
68. Kirk Dombrowski, CUNY Graduate Center and John Jay College, CUNY, research in Happy Valley Goose Bay, very similar to the survey they used in Nain last year;
69. Christina MacLeod, University of Auckland, THE TORNGAT MOUNTAINS: THE END OF COMPREHENSIVE LAND CLAIMS AND THE GATHERING OF CANADA'S PARTNERS 2006;
70. Jamie Snook, research document for his Masters of Arts degree, the past and present Torgnat Joint Fisheries Board members and the Torngat Wildlife and Plants Co-Management Board members. The project materialized from their desire to have their land claim implementation perspective documented;
71. Chelsee Arbour, Memorial University, Archaeology;
72. Kristeen McTavish, Trent University, Katelyn Friendship, RavenQuest Consulting, URQSUK Project;
73. Ashlee Cunsolo Willox, University of Guelph, access data from the Changing Climate, Changing Health, Changing Stories project for three chapters of doctoral dissertation;
74. Dianne Kinnon, Inuit Tuttarvingat, National Aboriginal Health Organization, Inuit Traditional Healing Practices;
75. Kara Layton, University of Guelph, collect intertidal specimens;
76. Jamie Brake M.A., B.A., Nunatsiavut Government/kavamanga, Documenting Traditional Knowledge Relating to Labrador Inuksuit and Other Stone Markers;
77. Chris Callahan, Environment and Conservation, Wildlife Division, Monitoring of Willow Ptarmigan (Lagopus lagopus) populations in Labrador: home range delineation and seasonal occupancy";

78. Dr. Dorothy Durnford, Environment Canada, Updating Environment Canada's atmospheric mercury model, GRAHM, with an ocean/sea ice component;
79. Kristy Sheppard, Royal Roads University, Identifying a Tourism Product Development Model for the Inuit Community of Rigolet;
80. Jennifer Mitchell, Torngat Wildlife, Plants and Fisheries Secretariat, Torngat Mountains caribou collaring;
81. Belinda Webb, Royal Roads University, Determining the critical success factors to implementing a tourism strategy in Newfoundland and Labrador;
82. Marc Choquette, Healthy Living in Schools and Substance Abuse among Youth;

Nunavik Nutrition and Health Committee: Education and Communicating on Nutrition, Health and Contaminants in Nunavik

Project Leader:

Elena Labranche, Chairperson, Nunavik Nutrition and Health Committee

Project Team Members:

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Abstract

This year, the Nunavik Nutrition and Health Committee has convened a thematic workshop for its members on health risk communication. This project aimed to support community understanding of environment and health research conducted in the region on the issues of contaminants, nutrition and health over the past years while enhancing the abilities of the region to deal with these issues in the future. Many health research projects conducted under the NCP have taken place in Nunavik. Among them is the *Nunavik cohort study on exposure to environmental contaminants and child development (Muckle et al.)*. In association with the release of these important results to the regional committee, the NNHC activities in 2010–2011 aimed at integrating and prepare a communication plan to disseminate this information in the larger public and environmental health context and continuing other identified ongoing public education and communication initiatives related to contaminants, food and health.

Résumé

Le Comité de la nutrition et de la santé du Nunavik a organisé cette année à l'intention de ses membres un atelier thématique sur la communication des risques en matière de santé. Le projet visait à aider les collectivités à comprendre les recherches menées dans la région au cours des dernières années en matière d'environnement et de santé, entre autres les contaminants et la nutrition, tout en renforçant la capacité de la région de prendre des mesures à cet égard dans l'avenir. Bon nombre des projets de recherche en santé menés dans le cadre du Programme de lutte contre les contaminants dans le Nord (PLCN) ont été mis en œuvre au Nunavik. Mentionnons notamment l'Étude des cohortes du Nunavik sur l'exposition aux contaminants environnementaux et le développement de l'enfant (Muckle et al.). Parallèlement à la communication de ces importants résultats au comité régional, les activités du CNSN en 2010–2011 visaient à intégrer et à préparer un plan de communication en vue de diffuser cette information au grand public dans le contexte de la salubrité de l'environnement et de poursuivre les autres initiatives d'éducation et de communication liées aux contaminants, aux aliments et à la santé.

Key Messages

- The Nunavik Nutrition and Health Committee is the key regional committee for health and environment issues in Nunavik;
- The committee originated in 1989 and supports the activities of the Public Health Director in advising and educating the public on food and health issues, including benefits and risks associated with contaminants and country foods;
- The committee continues to be active within the NCP, reviewing and supporting research in the region, ensuring liaison with researchers and helping in the communication of research results in a way that is appropriate and meaningful *to* Nunavimmiut.

Messages clés

- Le Comité de la nutrition et de la santé du Nunavik est le principal comité régional chargé des questions de santé et d'environnement au Nunavik.
- Le comité a été créé en 1989 et appuie les activités du directeur de la Santé publique, soit conseiller et éduquer le public sur les questions liées aux aliments et à la santé, y compris les avantages et les risques associés aux contaminants et aux aliments du pays.
- Le comité continue de jouer un rôle actif dans le PLCN en analysant et en soutenant les recherches menées dans la région, en assurant la liaison avec les chercheurs et en contribuant à communiquer les résultats des recherches aux Nunavimmiut de manière appropriée et pertinente.

Objectives

This work was supportive of the objectives identified in the 2010–2011 Blueprint for Communications and Education under the Northern Contaminants Program.

Specifically, this project's objectives were:

- Building further capacity among frontline workers and communicators;
- Delivering synthesized contaminants messages; and
- Learning how best to communicate about contaminants.

Introduction

As the Northern Contaminants Program continues to develop a stronger focus on health research projects, and the messages that these projects develop become increasingly complex (e.g. interactions of contaminants, health and nutrients, etc) the need to enhance local and regional capacity to understand and make decisions on these issues (i.e. use the results of research projects funded under the NCP and continue to provide advice to people with regards to their country food consumption) grows. Additionally, with the development of other major Arctic research initiatives (e.g. Arctic Net, International Polar Year), there is the need to ensure coordination of activities with ongoing NCP research projects when possible, and the development of integrated communication strategies to continue to inform and educate the public about contaminants and health issues while at the same time gathering community perspectives that could be addressed by new research under the NCP. It is for these reasons that the NNHC organized education activities related to enhancement of regional knowledge synthesis and health risk communications capacity.

The NNHC has a longstanding membership made of community representatives, public health and other regional government officials, medical doctors, nurses, and researchers. The continuity of this group has been a key to its ability to operate effectively and address the regional issues related to environment, contaminants, nutrition and health. Due to the natural process of staff turnover in the region and other factors, some new members have joined the committee in recent years. It is important for the committee members to be able to discuss and debate topics of importance for the region with a strong common understanding of these issues and how to address them. In support of this, the committee has, in past years, held thematic training sessions for its membership (e.g. Ethics training in 2005). For 2010–2011, the committee organized a training workshop on public health risk communication in support of its responsibilities linked with the dissemination of information on contaminants, nutrition and health associated with the studies identified above, as well as others.

Activities in 2010–2011

1. Training on Public Health Risk Communication

In 2010–2011, a two days training on Public Health Risk Communication was organised in Kuujjuaq in October. In recent years, communication about risks to human health has commanded increasing public attention and reaction. Establishing a productive dialogue on risks has become more challenging as risk issues and the related scientific information have become more complex and multi-faceted. The workshop, facilitated by researchers and experts in the field of environmental health risk communication from three Canadian Universities, introduced the participants to the basic fundamentals of health risk communication. Through the use of examples and discussions among participants designed for northern health communicators and professionals, the workshop provided practical skills and support for those needing to communicate with the public around issues such as contaminants and human exposure. Topics covered included: an introduction to what risk communication is; what the goals of risk communication are; the factors that influence the process of risk communication; and planning a communication strategy. The workshop was beneficial to the NNHC members and other participants engaged in communication and information exchange with the public around potential and known risks to public health. It was in direct support of the committee responsibilities related to contaminants, nutrition and health issues in the region associated with communicating results of the NCP projects.

This training helped committee members learn how best to communicate about contaminants in the region, and communicate in the broader public health and environmental health context. It supported capacity development among the membership to make members more knowledgeable on the potential impacts (positive and negative) of such communications.

The Workshop was facilitated by Cindy Jardine from the Centre for Health Promotion Studies at the University of Alberta, Michelle Driedger from the Department of Community Health Sciences at the University of Manitoba and Chris Furgal from the Departments of Environmental Resource Sciences/Studies and Indigenous Studies at Trent University.

2. Synthesis and Communications Planning Workshop on Nunavik Child Cohort Study results

In November 2010, a full day was dedicated to the presentation of final results from the *Nunavik cohort study on exposure to environmental contaminants and child development (Muckle and al.)*. This meeting was organised by the Child Cohort Working Group and brought together scientists involved in the research and NNHC members who discussed and began to develop the communication plan and public health messaging for public dissemination. For this first step all committee members were invited to participate to that day. Following that presentation, the working group including NNHC members, researchers and field workers have actively worked on the revision of key findings of the study, the development of public health messages to be provided to frontline workers, organizations and communities, the revision of the communications tools developed in 2004 by the NNHC and the PHD for communication of results from a previous follow-up of Nunavik children and if found relevant by the working group, the development of new tools and products to present the study results and public health messages to appropriate frontline workers, organizations and communities and the development a detailed communication plan for frontline workers, organizations and communities.

3. Collaboration with the nutrition program in childcare center team on the communication plan 2009–2012.

In June 2009, the nutrition program in childcare center teams presented their communication plan 2009–2012 to NNHC. This communication strategy includes three main objectives: 1) to promote the Nutrition Program as a whole (intervention and research components); 2) to recruit participants for the research project and to improve retention rate on the second data collection; 3) to communicate research results to parents, daycare staff, Nunavummiut population, health professionals and scientific community. The committee collaborates with them at different levels for their communication activities. A more global public communication will take place when more final results will be ready.

4. Production of Nunavik Health Newsletter on Nutrition, Health and Contaminants.

The Nunavik Regional Board of Health and Social Services' regional nutritionist developed and disseminate a health newsletter containing news and information on health and nutrition. The Risk Communication Workshop happened to be more expensive than planned and no funding was left for the newsletter production under this NCP project. This is why a homemade newsletter was prepared by the regional nutritionist this year. The public health department covered the fees for printing and distribution. This newsletter was disseminated in March for Nutrition Month.

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.

Nunavik Nutrition and Health Committee: Coordinating and Learning from Contaminants Research in 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. In 2010–2011, the committee continued to develop regional long-term strategies for communication activities based on regional needs and priorities in cooperation with the NCP Secretariat.

Résumé

Le Comité alimentaire et de la santé du Nunavik (anciennement connu sous le nom du Comité ressource BPC) fut créé en 1989 pour s'occuper d'enjeux lié à l'alimentation, aux contaminants, à l'environnement et à la santé du Nunavik. Depuis sa création, le comité a élargie ses horizons pour prendre une approche plus globale dans la gestion des enjeux de la santé et de l'environnement incluant les risques et bienfaits. Aujourd'hui, le comité agit à titre de conseillés au près des régions et de représentants pour plusieurs agences et organisations concernés par la santé et l'alimentation ainsi que ceux conduisant des recherches sur ces enjeux. Il guide et est l'agent de liaison pour les chercheurs et les agences, autant à l'extérieur et à l'intérieur de la région. Il coordonne le travail sur les enjeux prioritaires, communique avec et éduque le public sur les projets de recherches et thématique concernant l'environnement et à la santé et représente les intérêts du Nunavik à l'échelle nationale et internationale.

Key Messages

- The Nunavik Nutrition and Health Committee is the key regional committee for health and environment issues in Nunavik;
- The committee advises the Nunavik Public Health Director about educating the public on food and health issues, including benefits and risks associated with contaminants and country foods;
- The committee continues to be active within the NCP, reviewing and supporting research in the region, ensuring liaison with researchers and helping in the communication of research results in a way that is appropriate and meaningful to *Nunavimmiut*.

Messages clés

- Le Comité alimentaire et de la santé du Nunavik le comité principal pour les enjeux de santé et d'environnement au Nunavik.
- Le comité conseille le directeur de la santé publique du Nunavik pour renseigner la population sur des questions liées à la santé et l'environnement, incluant les risques et bienfaits associés aux contaminants et à l'alimentation traditionnel.
- Le comité continue d'être actif au sein du Programme de lutte contre les contaminants dans le Nord, révisant et supportant les recherches en région, assurant le lien avec les chercheurs et les aidant dans la communication de résultats appropriés et significatif 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 2010–2011 year.

Activities in 2010–2011

In 2010–2011, the committee met face to face four times. Three of the meetings were held in Kuujjuaq, in June 2010, October 2011 and March 2011. These meetings lasted one to two days and were on different topics linked to nutrition, contaminants and Nunavimmiut health.

The fourth meeting happened in February 2011 in Wendake. This meeting was held in the South to be able to meet the researchers in person. The meeting was convened to review NCP proposals for 2011–2012, 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 2010–2011:

Review of Research Proposals and Liaison with Researchers

In 2010–2011, the committee reviewed all research projects to be carried-out in the region or involving data from the Nunavik population proposed under the NCP. As discussed above, this review included meeting with the researchers to discuss and question aspects of their proposed work to better understand and discuss their proposals.

Food Insecurity

Food insecurity is a major concern in the region. The committee is seeking information to know more about the real situation of food insecurity. The NNHC will try to maximize the use of current databases to improve the knowledge on that issue. Some members of the NNHC are part of a food security working group looking at the analysis of existing data available in the region. Furthermore, NNHC collaborated and supported a project for the *Review of Food Support Mechanisms in Nunavik* leaded by a post-graduated student at Trent University, Vinay Rajdev directed by Chris Furgal. Preliminary results were presented to the committee during the March meeting.

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 Cohort Study on Exposure to Environmental Contaminants and Child Development

During the year, a working group including NNHC members, researchers and field workers have actively worked on the revision of key findings of the study, the development of public health messages to be provided to frontline workers, organizations and communities, the revision of the communications tools developed in 2004 by the NNHC and the PHD for communication of results from a previous follow-up of Nunavik children and, if found relevant by the working group, the development of new tools and products to present the study results and public health messages to appropriate frontline workers, organizations and communities and the development a detailed communication plan for frontline workers, organizations and communities. The communication activities will occur in 2011–2012.

Results from the Intervention Study of Inuit Children in Nunavik Daycare Centers

At the June meeting, Dr Turgeon-O'Brien and her team presented results on *Food consumption frequencies of traditional and market foods and blood contaminant levels of Inuit children attending daycare centers in Nunavik (2006–2008)* to the committee.

The same results have been presented to the NCP Results Workshop in September 2010.

Current Portrait of Lead Exposure in Nunavik: Needs Assessment for Intervention

The committee supported the work of Ariane Couture, a master student in community health at Laval University working on the current portrait of lead exposure in Nunavik to evaluate the needs for repeating the intervention that took place about 10 years ago. Although the blood lead levels among the Nunavik population have decreased by half in the last 12 years, about 10% of people and 2% of women of child-bearing age still have a blood lead concentration above the limit recommended by Health Canada. This decrease in blood lead may be explained by Health Canada's ban on lead ammunitions for hunting in 1998, and the efforts of the Nunavik health authorities to inform the population about the toxic effects of lead on health. Many years after the implementation of these health measures, it was necessary to assess the current needs for public health intervention while taking into account the available data on lead exposure, and to reflect on courses of action adapted to hunting and business practices in the Nunavik territory. The final results were presented to the committee at the October meeting. Lead pellets are back on the shelves in many Nunavik communities. This can be explained by the fact that they are cheaper, more efficient according to many hunters and legal. However, the study shown that most people knew that lead pellets were in some way harmful to health and the big majority of people cleans around the wound before consuming the animal. The committee strongly believes there is an urgent need to address this issue with concrete regional actions.

Research on the perceptions of Inuit parents regarding the Nutrition Program in Childcare Centres of Nunavik

The study focuses on the parents' perceptions of the Nutrition Program in childcare centers regarding its relevancy and the influence that the program might have on the development of healthy eating habits among children. The program in childcare centers consists in offering healthy menus including country foods every week (according to availability) and training the cooks, educators and directors in the field of nutrition. In parallel of that public health intervention program, a research project is conducted on contaminant nutrient interaction issues. The knowledge of parental perceptions and beliefs about the contribution of the Program could guide the subsequent planning and implementation of a participatory program to support the inuit families in the area of good nutrition. This study will ultimately help to understand how Inuits can promote healthy eating among their own community which may contribute to the reduction of some acute health problems among its members.

At the June meeting, Dr Hamelin gave an update to the committee on the project *Perception of Parents of the Nutrition Program in Childcare Center* realized by Amélie Bouchard Dufour, master degree student at Laval University. Dr Hamelin and her student planned to present to the Nasivvik workshop in Vancouver and to an international conference on nutrition and children in Nevada this summer. The committee asked Dr Hamelin to withdraw the actual abstract sent to these two conferences because the results were not presented to the region before. The committee agreed that the master degree student can go to these two conferences if she presents only methodological and contextual information related to her research.

In the research, the questions from C*anadian Community Health Survey (CCHS) cycle 4.1, 2007 questionnaire* were used to measure food insecurity. A very high rate among people who were interviewed in that study answered yes to at least one question which classify them as food insecure according to the Canadian guidelines. Since the percentage is way higher than the other percentages found in the region before (with other questionnaires), the committee thought that this result should be more contextualized and better understood before being released.

The results validation was done in the two communities in September 2010. The final results will be presented through the article to the committee at the beginning of 2011–2012.

Public Health Agency of Canada (PHAC) – Call of proposals on Innovation Strategy: Achieving Healthier Weights in Canada's Communities.

Dr Hamelin made a proposal to the Public Health Agency of Canada (PHAC) for the call of proposals on Innovation Strategy: A*chieving Healthier Weights in Canada's Communities*. Dr Hamelin presented her intention to the committee at the June meeting. The committee welcomed and recognized the importance of intervention oriented projects to support the health of Nunavimmiut.

Proposal on Obesity and the Cardio-metabolic Profile of the Aboriginal Women among Inuit and First Nation Women: Implementation of an aerobic exercise training program combined with nutritional intervention

Marie-Ludivine Chateau-Degat made a presentation to the committee at the October meeting on a proposal to implement an aerobic exercise training program combined with nutritional intervention and evaluation the impact of such a program on obesity and the cardio-metabolic profile of the Aboriginal women (Inuit and Cree). The committee did not come to a clear conclusion on that project proposal.

Anisakids and Anisakidosis – IPY project
In October, Manon Simard presented to the committee results from an IPY project made in collaboration with Erica Pufall from the University of Guelph. After that presentation, the public health authorities made a literature review and met with the researchers to evaluation the public health implications of these results.

Testing for foodborne pathogens in Eastern Canadian Arctic food animals by Safaa Lamhoujeb, Bureau of Microbial Hazard, Health Canada
At the October meeting, Manon Simard presented the outcomes of this project to the committee members. A method was developed to check for many bacteria in country food. So far, Health Canada does not have much information on bacteria in country food. The feasibility of the use of this method for monitoring would be something to consider if country food become distributed and more available.

Vitamin D Research Project – McGill University
The committee supported Dr Celia Rodd, from McGill University, research project to investigate the high rates of vitamin D deficiencies or rickets in the region and to work on improving the vitamin D status.

Nunavik Environmental Health Agent
The Nunavik Regional Board of Health and Social Services is collaborating with the Public Health Agency of Canada to hire an environmental health agent for Nunavik. The negotiations are not finalized yet. We are hoping to be able to hire someone before the end of 2011.

Review of criteria for NCP proposals evaluation
The committee looked at criteria and score system from grids used in other regions or for national northern projects. At the March meeting the committee discussed about our actual scoring system as well as the ones used in other northern regions. According to the conclusions of that discussion, a new grid will be prepared by the Nunavik public health director and presented to all committee members in spring 2011.

NNHC Members' Participation in Workshops and Meetings
Several committee members are active in research and policy issues relative to food, nutrition and health, and contaminants and attended workshops and meetings this past year to promote the activities of the committee and its specific initiatives, learn about other regional and international initiatives and communicate the results of regional research projects. Members attended the NCP Management Committee meetings, the NCP results workshop 2010, Food Security Reference Group Meetings, Nutrition North Canada meetings, among others.

Acknowledgments

The committee would like to thank all Nunavimmiut for their ongoing participation and support in contaminants, health and environment research. Furthermore, the NNHC is grateful to the Northern Contaminants Program and the Nunavik Regional Board of Health and Social Services for ongoing support and funding of its activities related to health, contaminants and nutrition in the region.

NSMA Participation on the NWT Regional Contaminants Committee

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Abstract

The North Slave Métis Alliance received Northern Contaminants Program funding to provide a Regional Contaminants Committee Representative with office space and equipment, supplies, communications, administrative support, and to contribute to the representative's salary, benefits and training.

Key Messages

The key take-away messages of the NCP program are:

1. The health benefits of a traditional country food diet continue to outweigh contaminant related risks.
2. Understanding contaminant related risks enables community members to make well informed dietary and life style choices.

Résumé

L'Alliance des métis esclaves du Nord a reçu des fonds du Programme de lutte contre les contaminants dans le Nord pour soutenir les représentants régionaux du comité contre les contaminants. Les fonds permettent d'offrir des locaux et de l'équipement de bureaux, du support administratif et communicationnel et de contribuer aux salaires, avantages sociaux et à la formation.

Messages clés

L'amorce des messages clés du PLCN sont:

1. Les bénéfices d'une alimentation traditionnelle saine sur la santé humaine surpasse les risques liés aux contaminants.
2. Comprendre les risques liés aux contaminants permet aux membres de la communauté d'établir des choix éclairés sur leur alimentation et mode de vie.

3. Understanding the quality and completeness of contaminant related information enables community members to judge the level of caution that needs to be exercised in making their life style and dietary choices.
4. Monitoring shows that efforts to reduce "legacy" contaminants have been generally successful, but continues to identify new contaminants and trace their distribution.

3. Comprendre la qualité et l'intégralité de l'information liés aux contaminants permet aux membres de la communauté de décider de l'importance qu'ils apportent à leur alimentation et leur mode de vie.
4. Les efforts déployés démontrent que la surveillance des contaminants est généralement un succès, mais nous continuons d'identifier de nouveaux contaminants et de relever leur dispertions.

Objectives

Provide a consistent representative in the community who:

- Has a phone number, email address, mail address and keeps regular office hours, so that community members have a trusted and well informed person that is easy to find and talk to about contaminant related issues.
- Is familiar with the Northern Contaminants Program, its research projects, and contaminant related information.
- Maintains a library of contaminant related information, and assists community members to find information they seek.
- Is familiar with community members' harvesting practices, harvesting locations, dietary preferences, and food preparation and storage techniques.
- Receives and responds to community questions and requests.
- Participates in monthly Regional Contaminant Committee Meetings.
- Communicates community concerns to the Regional Contaminant Committee.
- Participates in an annual review of research proposals.
- Assists the community to prepare and submit community based monitoring proposals.
- Attends an annual research results workshop.

Introduction

The Regional Contaminant Committee serves an important role in assisting Canada and its Aboriginal Communities in the North to communicate with each other regarding environmental contaminants.

Activities in 2010–2011

- Participated in annual research proposal evaluation.
- Attended annual results workshop, accompanied by an elder from the community.
- Capacity Building
- Provided community members with access to understandable information.
- Provided education and training to community members, leadership, and staff.
- Contribute to office functionality
- Communications
- Member emails (49) newsletters (2) and phone calls (29)
- NSMA AGA and board meetings (3)
- Telephone and in person committee meetings (10)
- Great Slave Lake fisheries meeting
- Traditional Knowledge
- Inherent in communications

Results

- Attend Social/Cultural Review meetings,
- work with researchers to provide logistical support,
- work with researchers to improve proposals,
- work with researchers to enhance community involvement
- Attend NCP Results workshop
- Provide input to funding priorities, criteria.
- Bring forth community members concerns to the NWT RCC.
- Mercury in fish – Great Slave Lake and other smaller lakes
- Mercury in caribou and moose
- Fire retardants
- Ozone depletion
- Climate change impacts on contaminant transport
- Oil sands development and cancer
- Uranium development and radioactivity
- Point source, local source, as important as long range transport.
- Invasive species – insects and plants – can be contaminated, or disease vectors, and transported long range by road, rail, and aircraft.
- Possible contamination of diesel fuel
- Report to NSMA leadership on NCP activities, research findings.

Discussion and Conclusions

NWT RCC Members represent the people in their regions at the NCP Results Workshop and at NWT RCC meetings. The North Slave Métis Alliance (NSMA) represents the indigenous Métis community which has used and occupied the North Slave region (that area between and including Great Bear Lake and Great Slave Lake, the Mackenzie River and Contwoyto and Artillery Lakes) since before the establishment of effective Crown control. Our members are all descended from the historic Métis community which took either Métis Scrip or Treaty 11 in Fort Rae, in 1921. Groups of Métis residing in Lac La Martre, Snare Lake, and Yellowknife were represented by Métis counselors during the signing of Treaty 11. Our community is defined by shared language, culture, genealogy, territory and history, not by municipal boundaries, administrative regions, or by other First Nation Settlement Areas.

The majority of our members currently reside in the City of Yellowknife (including the historic Métis settlements in Rainbow Valley, School Draw, and Willow Flats, Yellowknife River, along the Ingraham Trail), but some do still live, and many have roots in Lac La Martre, Snare Lake, Rae Lakes, Fort Rae, Edzo, Dettah, Snowdrift, Fort Reliance, Fort Providence, Hay River, and Fort Resolution. Old Fort Providence, Old Fort Rae, and Old Fort Island are historic North Slave Métis settlements that are currently not serviced (police, fire, education, healthcare, communications) and are therefore not occupied full time.

Some members reside temporarily outside of the NWT for employment or educational purposes, and there are strong family connections between NSMA members and the South Slave Métis, as well as the Métis in BC, Alberta, Saskatchewan, and Manitoba.

As is typical of all Métis communities, the NSMA population is highly mobile, and communication is a challenge. Without the RCC it is highly unlikely that the indigenous North Slave Métis community would be a able to maintain an awareness of issues, and have their communal voice heard by decision makers and researchers. It is essential that the RCC continue to operate, and we continue to encourage the establishment of multi-year funding as envisioned by the MVRMA as part of the CEAM/CIMP obligations of Government.

NCP Performance Indicators

- *the number of northerners engaged in project*: 196
- *the number of meetings/workshops held in the North*: 15
- *the number of students (both northern and southern) involved in NCP work*: 3
- *the number of citable publications*: 0

Expected Project Completion Date

Ongoing, annual.

5.

Beluga Communication Package for Inuvialuit Settlement Region (ISR): A social component

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Abstract

The traditional hunt for belugas is an important cultural event in the Inuvialuit Settlement Region (ISR). The beluga whale remains an important part of healthy diets for many Inuvialuit. The Hendrickson Island Beluga Study near Tuktoyaktuk, NT within the ISR, has been monitoring beluga whales and contaminants over the last decade. In recent years, members of the monitoring team have collaborated with local representatives to develop a holistic approach on studying beluga whale health and incorporates perspectives from both scientific information and from local knowledge. One of the tangible outputs from these efforts is bringing the two knowledge systems together in the form of a contextualized communication package for the community and as a pilot example for other science programs to use. Foremost to the success of this project is the need to train a local youth to help integrate recent studies on beluga health with the knowledge held by Inuvialuit knowledge holders, to further our understanding of beluga health in the ISR.

Résumé

La chasse traditionnelle aux bélugas est une activité culturelle importante dans la région désignée des Inuvialuits (RDI). Le béluga est un élément important d'un régime alimentaire sain pour un grand nombre d'Inuvialuits. L'étude menée à l'île Hendrickson, située près de Tuktoyaktuk dans les Territoires du Nord-Ouest, au sein de la RDI, a permis de surveiller les bélugas et les contaminants pendant la dernière décennie. Au cours des dernières années, des membres de l'équipe de surveillance ont collaboré avec des représentants locaux en vue de mettre au point une démarche globale pour l'étude de la santé des bélugas, tout en y intégrant les perspectives des scientifiques et le savoir des habitants locaux. De ces efforts ont découlé des documents de communication regroupant ces deux systèmes de connaissances à l'intention de la collectivité et un projet pilote duquel peuvent s'inspirer les autres programmes scientifiques. Le plus important pour que le projet réussisse consiste à former des jeunes de la région pour qu'ils intègrent les résultats des récentes études sur la santé des bélugas au savoir des dépositaires de connaissances des Inuvialuits et à faire progresser notre compréhension de la santé des bélugas dans la RDI.

Key Messages

- Local knowledge and traditional knowledge interviews were conducted in partnership with the Hendrickson Island Beluga Study
- A pamphlet was used to assist in communication and highlighting local and traditional knowledge of beluga whales
- Strengthening linkages between the Hendrickson Island Beluga Study and Inuvialuit knowledge fosters dialogue and collaboration essential for understanding beluga health
- Integrating local knowledge and observations with scientific results will be the focus of the next phase of the program
- Mentoring two Tuktoyaktuk project leaders has been ongoing and is central for building local capacity for linking community members with scientists; and integrating local knowledge with scientific information.

Messages clés

- Des entrevues sur le savoir local et traditionnel ont été menées en partenariat avec les responsables de l'étude sur les bélugas de l'île Hendrickson.
- Une brochure a servi à communiquer le savoir local et traditionnel sur les bélugas et à le mettre en valeur.
- Renforcer les liens entre les responsables de l'étude sur les bélugas de l'île Hendrickson et le savoir des Inuvialuits favorise une collaboration et un dialogue essentiels à la compréhension de la santé des bélugas.
- Intégrer les connaissances et les observations locales aux résultats scientifiques sera l'élément central de la prochaine étape du programme.
- On continue d'encadrer deux chefs de projet de Tuktoyaktuk, une initiative au cœur du renforcement des capacités pour ce qui est d'établir des liens entre les membres de la collectivité et les scientifiques, et d'intégrer le savoir local ainsi que les données scientifiques.

Objectives

a) Work closely with beluga research scientists to learn what their findings are concerning the health of beluga whales in and near the community of Tuktoyaktuk; to synthesize findings and develop a community and regional strategy that integrates all programs (NCP, ArcticNet and IPY).

b) Carry out Traditional Knowledge interviews by local community members to document locally-held knowledge regarding beluga whales.

c) Work closely with the community of Tuktoyaktuk in asking community members what information they would like to receive from scientists.

d) Provide northern youth with training to increase their involvement and participation in beluga research.

e) Provide an ongoing opportunity for the inclusion and integration of local and traditional knowledge with scientific information.

f) develop a new way of communicating science information back to communities

Introduction

Beluga whale research taking place in the Inuvialuit Settlement Region (ISR) provides an excellent opportunity to bring scientists and community members together in the development of a comprehensive communication package that includes contaminant data and local insights about the overall health of the beluga whale, such as behaviour, timing of migration, and qualitative characteristics of muktuk, meat and organs. This communication effort is partnered and conducted northern residents. The long-term presence of the local participants in the community provides the opportunity for insight from elders and youth into the science data being collected on belugas.

Researchers in Inuit communities are all encouraged to have a strong communication strategy, incorporate traditional knowledge and build capacity with local community members. To reduce community fatigue in communication of many different science projects in relation to beluga whales the community of Tuktuyuktuk has requested that these beluga research projects, be communicated in a unified communication strategy/ package. Thus, all beluga programs could be presented together to enhance the clarity of the progress being made on beluga research. There are a large number of beluga health related research programs taking place at Hendrickson Island (hunting area for community of Tuktoyaktuk) that fit under the umbrellas of IPY, NCP, ArcticNet and DFO funded projects, that are required to present research results back to the communities. These programs have coordinated their reporting and licence applications with the Tuktoyaktuk Hunters and Trappers Committee and other ISR agencies since 2008. The next phase of these coordinated efforts has been to work with local partners to create a holistic communication package (that includes TK) that summarizes all beluga related research offer a new an unique perspective on developing successful communication practise.

The Beluga Communication Package for Inuvialuit Settlement Region (ISR) is led by Myrna Pokiak and Rebecca Pokiak with involvement from Lisa Loseto, Scott Nickels, Mark Andrachuk, Eric Loring and Sonja Ostertag. Rebecca Pokiak became involved in this project after the Beluga Research team did work out at Hendrickson Island in 2008. The Hendrickson Island Beluga Study is a partnered monitoring program with the community of Tuktoyaktuk and Fisheries and Oceans Canada; monitoring contaminants in beluga whales has been ongoing for the past 10 years.

Integrating Knowledge of Beluga Whales

Scientists have studied the population dynamics and contaminants levels of the eastern Beaufort Sea beluga population for two decades (e.g. NCP funded beluga monitoring), and Inuvialuit have been studying and learning about belugas for thousands of years. Our goal is to find new ways to bring together all knowledge-holders to improve our understanding of beluga whale health. This project has provided opportunities for local knowledge of belugas to be documented by R Pokiak, which will increase opportunities for the integration of current beluga knowledge from various disciplines. R Pokiak and L Loseto have linked local knowledge holders and scientists to increase our overall understanding of beluga whale health.

Activities 2010–2011 and Results/ Discussion

This project has been assisting scientists with gathering information on beluga's health through community research and communication. Local knowledge on beluga whales is valuable and needed to understand beluga health. Our objective was to have a communication piece that highlights both scientific information and local observations and knowledge. We prepared a brochure called "Sharing Knowledge on Belugas and Beluga Health" (Appendix A), which provided information about the traditional uses of beluga whale and the current beluga whale studies taking place on Hendrickson Island. The brochure also included a description of the project on gathering local knowledge of beluga whales, and invited community members of Tuktoyaktuk to participate in this project. In 2009, the beluga research team prepared a brochure, which described the sampling program on Hendrickson Island and the studies that are taking place at various institutions. These pamphlets were distributed to the Inuvialuit Game Council (IGC), FJMC, Inuvik HTC and the DFO Inuvik Area office in 2009 and 2010.

Cohesive Beluga Whale Research

In 2010, a team of scientists traveled to Hendrickson Island to comprehensively sample beluga whales harvested by local hunters. We continued to work closely with other science programs to integrate and present them under one umbrella to communities for approval. Since our sampling efforts took place on Hendrickson Island, we focused our communication efforts with the community of Tuktoyaktuk, as hunters from other ISR communities do not visit Hendrickson Island.

Hendrickson Island Beluga Sampling Team 2010

Program	Field Personal	Operations
FJMC Whale Monitoring	Two families	Record morpho, Jaw (age)
NCP Stern, Tomy	F. Pokiak and Family	Tissue sampling chemicals
NCP Ross/Loseto	L. Loseto, M. Noel	Tissue sampling health
Raverty	S. Raverty	Tissue sampling disease
Ostertag/Chan	S. Ostertag, L. Chan	Brain sampling/ mercury
Youth	R. Walker, B. Voudrach, K. Snow	Mentoring/training

Tuktoyaktuk TK Beluga Interview Team 2010

Program	Field Personal	Operations
NCP TK/Communication	R. Pokiak, M. Pokiak	Interview, contact with HI camp
Youth TK interview training	D. Bearnhardt	Mentoring/training

The beluga sampling program continued with a holistic field approach in July 2010. The integration of field efforts enhanced communication and awareness among science and community sampling programs. All participants worked closely together to sample whales in partnership with the hunters. On the island were several families who participated and helped with the program. The coordinated presence at the field camp helped facilitate communication with those who wanted to learn more about the program.

TK Interviews

Community involvement is very important in this project. We believe it is very important to *listen* to community members and see what they want from scientists and how they think information should be passed back to the local people; we want to be part of this project because the beluga whale is a very important part of our livelihood. It is the primary source of food for our people, and the hunt has survived generations of change. It builds pride and respect for our culture and the Inuvialuit have studied the beluga whales for centuries.

Through the summer of 2010, we conducted and transcribed 10 community interviews, along with Darcy Bearnhardt, a summer student from Tuktoyaktuk. We created community awareness about this project by handing out brochures, having interviews, and contacting families that were preparing beluga meat and muktuk to talk about whales.

Drawing on scientific findings, we asked the interviewees a series of questions relating to Beluga whale health and Traditional Knowledge. We divided the questions into sections (skin, blubber, meat, brain and behaviour, size disease, observations etc.) and asked open ended questions so it would lead into a conversation from one question. Both Myrna and Rebecca knew the interviewees and the interviewee's knew us so a sense of comfort was there for both parties. The community members involved also liked that it was people from the community leading the project.

Hunters were asked questions about the behaviour of the whales that they harvested. Hunters were able to provide unique and valuable information about whale behaviour, these observations were integrated with mercury exposure data to assess whether animal behaviour varied with mercury exposure. This study provided a unique opportunity to integrate local observations with laboratory results to answer new and relevant questions regarding beluga health and behaviour.

Some of the observations that were noted in the 2010 interviews were the hunters are noticing a lot more mothers and calves. There is an increase in wind and it is more constant, and the summers seem to be getting shorter and the winters longer.

Rebecca presented the results from this project at the NCP Conference in Whitehorse and the Arctic Net Conference in Ottawa in December 2010.

Outcomes on Community Research Needs

The community would like to see information brought back to the community through newsletters, information distribution throughout the whole Inuvialuit Settlement Region communities, and would like the information to be shared with students in the schools. They would also like to find a holding place for all in the information be it a museum, IRCR, a library etc.

> "Be good to see (the information gathered) to be spread around the different communities and maybe a chance… for the younger people to realize why our elders are trying to teach them." –Peter Nogasak

What has the project team done to encourage the integration of all forms of beluga knowledge?

- Working together: R. Pokiak/ M. Pokiak and L Loseto working together and learning from each other
- Preparing presentations for communities: R. Pokiak providing guidance to L. Loseto and S. Ostertag on the content and style of presentations for community councils
- Beluga behaviour questionnaire: S. Ostertag working with hunters and monitors at Hendrickson Island
- Working towards a workshop where all information is presented and community knowledge is gathered
- Future research questions will be developed by community members and scientists

Training Youth as part of TK and Science program at Hendrickson

Training youth occurred in two program aspects: a) the field sampling at Hendrickson Island and b) the TK interviews and transcribing in Tuktoyaktuk. Sampling and qualitative research methods has been an important aspect of the Hendrickson Island Beluga Study and this project. In 2010, three youth assisted with sampling harvested beluga whales with the beluga research team. One student stayed on Hendrickson Island for one week as a component of her summer employment with the Aurora Research Institute, and the two other students were employed to assist the research team with sampling. The students learned how to measure and sample harvested whales, record beluga sounds with a hydrophone, collect sediment samples and to obtain fish otoliths for aging. R Pokiak was trained in conducting semi-structured interviews. A fourth student, was trained in transcribing interviews and worked closely with R Pokiak and M Pokiak in conducting TK interviews.

Thus four youth were trained in several aspects of the beluga program, from sampling along side hunters to interviewing their families. All youth were invited to participate in the NCP and ArcticNet meeting, however due to school commitments not all were able to participate.

Communication

In efforts to begin to synthesize findings we have worked as a team to examine information and how to best present it back to the communities and to science meetings. M. Pokiak and R. Pokiak have prepared and presented findings at several meetings (below). In preparing and sharing with the science members, new synergies and connections were found between results and knowledge groups. While working on integration remains in early stages, the preparing and presenting oral presentations and the communication of early results have progressed the integration process. The science team is focusing efforts in 2011–2012 to finalize health results and work closely with R. Pokiak and M. Pokiak on how to share in a forum meeting with the community of Tuktoyaktuk.

Summer Communication Events

Presentation to Mangilaluk School (children in Grade 1 and 2): S. Ostertag and Nellie Pokiak

Poster presentation: Youth K. Snow prepared a poster about Hendrickson Island field work shared in Kitti Hall for Ocean's Day and Tarium Niryutait Marine Protected Area (TN MPA) announcement. The poster has been distributed to all ISR HTC's and the Joint Secretariat office.

Fall Communication Events

A summary of field activities was submitted to the Tukoyaktuk HTC and FJMC in September 2010 (Appendix B).

NCP meeting Whitehorse, Sept 28–30 2010, Whitehorse Joint Oral presentation:

Pokiak, R., Ross, P.S., Pokiak, M. Loseto, L.L. Noel, M., Hickie, B., Macdonald., R., Ostertag, S., Letcher, R., Stern, G., Raverty, S., Froiun, H., Helbing, C., Chan, L., Pokiak, M., Loring, E., Nickels, S., Andrachuk, M. Integrated Beluga Health Study, Northern Contaminants Program meeting, Sept 28–30 2010, Whitehorse.

Winter Communication Events

ArcticNet Annual Science Meeting, Dec 13–17 2010, Ottawa ON. L. Loseto, S. Ostertag, R. Pokiak, E. Loring, M. Andrachuk and youth BJ Voudrach all attended. Presentation given by R. Pokiak:

Pokiak, R., Pokiak, M., Loring, E., Nickels, S., Andrachuk, M., Loseto, L. Traditional Knowledge on Beluga Health in the Inuvialuit Settlement Region. ArcticNet ASM, Dec 13–17 2010, Ottawa ON, Oral presentation.

L. Loseto provided information on the program to the Fisheries Joint Management Committee: January 19 2011.

FJMC-Pre tour for Community based monitoring program: Feb 22–25, Inuvik, Aklavik, Uluhaktok, Paulatuk. L. Loseto joined FJMC for a community tour to discuss community needs and plans for an ISR CBM program to be further discussed in an April meeting partnered with ArcticNet IRIS.

Conclusion

The Northern Contaminants Program continues to encourage new and innovated tools to communicate scientific information back to communities. With many research programs and scientists working on beluga whales in the ISR it important programs communicate with one another and develop and effective communication strategy with community partners. Working with a community lead, R. Pokiak as well as elders such as N. Pokiak has pushed the beluga health research program to try new ways of communicating which as strengthened the ability of scientists to share knowledge with communities. While the program continues to develop new communication packages and build local capacity for research, it is now moving toward the objectives of encouraging community members to share their knowledge with science. This part of the program is lead by two community youth who will learn and grow, which should encourage more community participation and facilitate new ways of sharing knowledge.

Gwich'in Tribal Council Communication & Education of the NCP

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NWTRCC.
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Abstract

The Gwich'in Community Liaison for the Northern Contaminants Program is the Director – Lands and Resources. This position enables the Gwich'in to be a member of the NWT Regional Contaminants Committee (RCC) and participate in research programs established by the Northern Contaminants Program (NCP).

The Director – L & R has continued to promote dialogue and information between the Gwich'in communities, Designated Gwich'in Organizations (DGO's), Gwich'in Renewable Resource Councils (RRC's), the Gwich'in Tribal Council (GTC), NCP representatives, and NCP scientists and researchers.

The Director – L & R has participated in NWT RCC meetings including funding proposal reviews and communication material reviews, and provided relevant contaminant information materials to Gwich'in communities and organizations. The Director – L & R has also attended the NCP annual results workshop held in Whitehorse, Yukon in September 2010.

Résumé

La directrice des Terres et des Ressources est l'agent de liaison des collectivités Gwich'in pour le Programme de lutte contre les contaminants dans le Nord (PLCN). Ce poste permet aux Gwich'in d'être membres du Comité régional des contaminants des Territoires du Nord-Ouest et de participer aux programmes de recherche établis dans le cadre du PLCN.

La directrice des Terres et des Ressources a continué de promouvoir le dialogue et l'échange d'information entre les collectivités Gwich'in, les organismes Gwich'in désignés, les Conseils sur les ressources renouvelables des Gwich'in, le Conseil tribal des Gwich'in (CTG) ainsi que les représentants, les scientifiques et les chercheurs du PLCN.

Elle a participé aux réunions du Comité régional des contaminants des Territoires du Nord-Ouest où l'on a notamment examiné des propositions de financement et du matériel de communication et fourni des documents d'information sur les contaminants aux collectivités et organismes des Gwich'in. Elle a également assisté à l'atelier annuel sur les résultats du PLCN organisé à Whitehorse, au Yukon, en septembre 2010.

Key Messages

- The Nunavik Nutrition and Health Committee is the key regional committee for health and environment issues in Nunavik;
- The committee originated in 1989 and supports the activities of the Public Health Director in advising and educating the public on food and health issues, including benefits and risks associated with contaminants and country foods;
- The committee continues to be active within the NCP, reviewing and supporting research in the region, ensuring liaison with researchers and helping in the communication of research results in a way that is appropriate and meaningful to Nunavimmiut.

Messages clés

- Le Comité de la nutrition et de la santé du Nunavik est le principal comité régional chargé des questions de santé et d'environnement au Nunavik.
- Le comité a été créé en 1989 et appuie les activités du directeur de la Santé publique, soit conseiller et éduquer le public sur les questions liées aux aliments et à la santé, y compris les avantages et les risques associés aux contaminants et aux aliments du pays.
- Le comité continue de jouer un rôle actif dans le PLCN en analysant et en soutenant les recherches menées dans la région, en assurant la liaison avec les chercheurs et en contribuant à communiquer les résultats des recherches aux Nunavimmiut de manière appropriée et pertinente.

Objectives

The objectives of this project are to facilitate the process of collaborative study, assessment and communication of information to residents of the Gwich'in Settlement Area (GSA) about the presence and possible effects of contaminants in the air, land, water and wildlife. The Director – L & R goals are:

1. To promote the role of the Gwich'in Tribal Council (GTC) as a partner in the NCP;
2. To assist the Gwich'in Communities to identify proposed research projects & development and/or contaminant concerns;
3. To inform and educate the public and the Gwich'in Participants about contaminants within the GSA;
4. To increase capacity at the regional/local level;
5. To coordinate and/or assist with regional contaminant studies, where applicable;
6. To identify complementary environmental issues and funding sources;
7. To review NWT Proposals for the NCP for social/cultural criteria prior to full technical reviews;
8. To actively participate in all NWT RCC meetings and related tasks.

Introduction

This was the twelfth year that the GTC has been actively involved in the Northern Contaminants Program. Over the course of involvement with the NCP the Gwich'in representative for the GTC has established a very good track record. The Gwich'in are concerned about long range contaminants and want to continue to be well informed about levels of contaminants in their traditional foods and/or the environment within which they practice their traditional and cultural activities. Participation in the NCP through the NWT RCC provides a valuable opportunity for two-way communication about contaminants in the GSA and the NWT.

Activities in 2010–2011

- The Director – L & R participated in several teleconferences of the NWT RCC and two in person meetings.
- The Director – L & R attended the NCP results workshop in Whitehorse, Yukon in 2010.

- On-going communication of the results from the CACAR 2.
- Continued to relay information to the Gwich'in communities and Aboriginal partners of the NWT RCC, which will relay major concerns to the NCP management committee and vice versa.
- The Director – L & R attended Gwich'in Renewable Resource Council meetings in 2010 and early 2011 to discuss the NCP with the community members and to continue to relay the importance of the NCP to community members. Communities visited were Fort McPherson, Tsiigehtchic, Aklavik and Inuvik.
- The Director – L & R attended the GTC Annual Assembly in August 2010 in Aklavik and displayed NCP resource information and reports and discussed the program with Participants of the Gwich'in Annual Assembly requesting information about the NWT RCC and Northern Contaminants Program in general.
- The Director – L & R included in the annual report the membership of the GTC on the NWT RCC, the objectives of the committee and the GTC's role on the NWT RCC.
- A proposal was submitted to NCP for continued participation of the GTC in NCP activities and the NWT RCC for 2011/12.

Results

In addition to the activities outlined above, the Director – L & R highlighted several concerns from Gwich'in communities and organizations to the NWT RCC during the teleconference calls and funding proposal reviews. These concerns ranged from long term monitoring of contaminant levels in important traditional foods such as caribou, moose, berries, fish and marine mammals such as beluga whales and seals to local contaminants concerns including water quality issues, to relationships between contaminants and human health concerns.

The Gwich'in Participants continue to harvest traditional foods for subsistence as the cost of living in Gwich'in communities is very expensive. The traditional diet for Gwich'in participants consists of caribou, moose, fish and berries that are gathered throughout the GSA, including beluga and caribou that is harvested from the Beaufort Coast. Contamination through long range transport of different chemicals used in industrial nations are of great concern to the Gwich'in Participants and continued research within the GSA and Beaufort Delta and Coast to track these levels are very important to the Gwich'in Participants.

Discussion and Conclusions

In 2010–2011, the Director – L & R has continued to address concerns of the residents of the Gwich'in Settlement Area by gathering, organizing, and distributing information when requested, not only to the participants of the GSA, but also to the NCP NWT RCC, scientists and researchers and the GTC. The Director – L & R attended workshops and meetings to enhance capacity to carry out the duties of the NCP NWT RCC membership. Furthermore, based on requirements of the information by the residents of the Gwich'in Settlement Area, it has been demonstrated that this position is an integral part of the NCP and the Gwich'in Settlement Area.

The GTC NCP NWT RCC representative was nominated Chair for the 2010/11 term and assisted the NCP Secretariat in agenda development and chairing the NWT RCC meetings. The GTC NCP NWT RCC representative also attended the NCP Management Committee meeting held in April 2010 and November 2010 to discuss the funding proposal submissions and also the mid year reallocation of funding.

The GTC is confident that the Director – L & R will continue this successful relationship in the future with NCP NWT RCC. The Director – L & R sits on other committees and working groups in the NWT and the Yukon and information and capacity gathered through the NWT RCC assist the Director – L & R in being able to participate in a meaningful manner on these committees and working groups, including Protected Area Strategy Working Group, Cumulative Impact Monitoring Program Working Group, NWT Water Stewardship Strategy Working Group Yukon Environmental and Socio Economic Assessment Board Review Committee, etc.

Based on the natural disasters affecting other parts of the World, specifically Japan and the nuclear radiation crisis, more concerns with regard to nuclear radiation contamination through long range transport will be brought up by Participants in the near future, including the effects to traditional country foods and human health.

Expected Project Completion Date

The Director – L & R will continue to represent the Gwich'in Participants by continuing to be a part of the NWT RCC, and address concerns relating to contaminants in the Gwich'in Settlement Area, including the Beaufort Delta.