Supporting data for the report:

SYNOPSIS OF RESEARCH

Conducted under the 2015–2016 Northern Contaminants Program

Données à l'appui du rapport:

RÉSUMÉ DE RECHERCHE

effectuées en 2015–2016 dans le cadre du
Programme de lutte contre les contaminants dans le Nord

Supporting data for the report: Synopsis of Research Conducted under the 2015-2016 Northern Contaminants Program

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Foreword

This report provides a summary of the progress to date of research and monitoring studies pertaining to contaminants from long-range sources in northern Canada, and related communications, outreach, capacity-building and policy activities that were conducted in 2015-2016 under the auspices of the Northern Contaminants Program (NCP). The NCP mandate is to work to reduce and, wherever possible, eliminate contaminants in traditionally harvested foods, while providing information that assists informed decision making by individuals and communities in their food use. The projects reported herein cover the broad range of topics that contribute to understanding and addressing northern contaminants issues, as outlined in the NCP strategic plans (e.g., Blueprints), including dietary contaminant exposure, effects of contaminants on the health of people and ecosystems, contaminant levels and trends in the Arctic environment and wildlife and the influence of climate change, and community-based monitoring and research.

These projects were subject to a comprehensive technical, peer and northern social/cultural review process, involving external peer reviewers, technical review teams, regional contaminants committees and the NCP Management Committee. This review process ensures that each project supports the priorities and objectives of the Northern Contaminants Program, as outlined in the NCP blueprints and the annual call for proposals. All peer reviewers, review teams and regional contaminants committees use evaluation criteria to review and rate proposals. Consultation with northern community authorities and/or Aboriginal organizations is required for all projects involving field work in the North and/or analyses of samples, as a condition of approval for funding.

Preliminary results of projects funded in the 2015-2016 year are presented here. Submission of a report for this publication ensures program transparency, allows for timely sharing of results, and is a mandatory deliverable for all recipients of NCP project funding. These reports and any

Avant-propos

Ce rapport présente un résumé des progrès réalisés jusqu'à maintenant en matière de recherche et de surveillance relatives aux contaminants de sources éloignées dans le Nord du Canada, ainsi qu'en matière de communication, de sensibilisation, de renforcement des capacités et d'activités stratégiques connexes réalisées en 2015-2016 dans le cadre du Programme de lutte contre les contaminants dans le Nord (PLCN). Le mandat du PLCN consiste à réduire et, dans la mesure du possible, à éliminer les contaminants présents dans les aliments traditionnels récoltés, tout en procurant de l'information permettant aux personnes et aux collectivités de prendre des décisions éclairées au sujet de leur alimentation. Les projets dont rend compte le rapport portent sur une vaste gamme de sujets qui contribuent à mieux comprendre et prendre en compte les enjeux relatifs aux contaminants dans le Nord énoncés dans les plans directeurs du PLCN, notamment les suivants : l'exposition à des contaminants par voie alimentaire; les effets des contaminants sur la santé des individus et des écosystèmes; les niveaux de contaminants et les tendances dans l'environnement et chez les espèces sauvages dans l'Arctique; l'influence des changements climatiques; et la surveillance et la recherche communautaires.

Ces projets ont fait l'objet d'un processus exhaustif d'examen technique, par les pairs et socioculturel, auxquels ont participé des pairs examinateurs externes, des équipes d'examen technique, des comités régionaux sur les contaminants de même que le Comité de gestion du PLCN. Ce processus d'examen garantit que chaque projet appuie les priorités et les objectifs du PLCN, qui sont énoncés dans les plans directeurs du Programme et dans l'appel de propositions annuel. Pour obtenir un financement, tous les projets qui nécessitent du travail sur le terrain dans le Nord ou des analyses d'échantillons doivent faire l'objet d'une consultation avec les autorités nordiques et les organisations autochtones concernées.

Vous trouverez ici les résultats préliminaires des projets financés en 2015-2016. La présentation future peer-reviewed publications related to these studies will be available through the NCP Publications Database housed at the Arctic Science and Technology Information System (ASTIS) hosted by the Arctic Institute of North America (AINA) at www.aina.ucalgary.ca/ncp. Other project deliverables include submission of data/ data sets/ metadata to the Polar Data Catalogue at www.polardata.ca.

Further information about the Northern Contaminants Program is available on the NCP website at www.science.gc.ca/ncp

d'un rapport aux fins de la présente publication assure la transparence du programme ainsi qu'une communication rapide des résultats. Il s'agit en outre d'un livrable obligatoire pour tous les bénéficiaires d'une aide financière dans le cadre du PLCN. Ces rapports et les futures publications révisées par les pairs qui touchent ces études seront versés dans la base de données des publications du PLCN, qui est hébergée par le Système d'information sur les sciences et les techniques de l'Arctique (SISTA), à l'adresse www.aina.ucalgary.ca/ncp. Les autres livrables que doivent remettre les bénéficiaires comprennent des données, des ensembles de données et des métadonnées à verser dans le catalogue des données polaires (www.polardata.ca).

Pour plus d'information sur le Programme de lutte contre les contaminants dans le Nord, voir : www.science.gc.ca/plcn.

Official Languages Disclaimer

These synopsis reports are published in the language chosen by the project leaders. The full reports have not been translated. The Abstracts and Key Messages are available in English and French. Complete individual project synopses are available in either official language, upon request. Requests for individual reports can be made to: PLCN-NCP@aadnc-aandc.gc.ca

Avertissement concernant les langues officielles

Les rapports de synthèse ont été publiés dans la langue choisie par les directeurs de projet. Les rapports complets n'ont pas été traduits, mais des résumés et des messages clés sont présentés en français et en anglais. Des sommaires complets sur chaque projet sont disponibles sur demande dans l'une ou l'autre des langues officielles. On peut présenter une demande pour obtenir des rapports à : PLCN-NCP@aadnc-aandc.gc.ca.

Introduction

The Northern Contaminants Program (NCP) engages Northerners and scientists in researching and monitoring of long-range contaminants in the Canadian Arctic, that is, contaminants that are transported to the Arctic through atmospheric and oceanic processes from other parts of the world and which remain in the Arctic environment and build up in the food chain. The data generated by the NCP is used to assess ecosystem and human health, and the findings of these assessments are used to address the safety and security of traditional country foods that are important to the health and traditional lifestyles of Northerners and northern communities. The findings also inform policy, resulting in action to eliminate contaminants from long-range sources. The NCP contributes scientific data and expertise to contaminants-related international initiatives such as the Arctic Monitoring and Assessment Programme (AMAP), and to international agreements such as the UNEP Minamata Convention on Mercury, the Stockholm Convention on Persistent Organic Pollutants, and two protocols under the United Nation Economic Commission for Europe Convention on Long-range Transboundary Air Pollution, working globally to improve the health of Arctic people and wildlife over the long term.

The NCP is directed by a management committee that is chaired by Indigenous and Northern Affairs Canada (INAC), and consists of representatives from four federal departments (Environment, Fisheries and Oceans, Health and INAC), five territorial, provincial and regional governments (Yukon, Northwest Territories, Nunavut, Nunavik and Nunatsiavut), four northern Aboriginal organizations (Council of Yukon First Nations, Dene Nation, Inuit Tapiriit Kanatami and Inuit Circumpolar Council), five regional contaminants committees, and Canada's only Arctic-focused Network of Centres of Excellence (ArcticNet). The management committee is responsible for establishing NCP policy and science priorities and for making final decisions on the allocation of funds. Regional contaminants committees established in Yukon, Northwest Territories, Nunavut, Nunavik and

Le Programme de lutte contre les contaminants dans le Nord (PLCN) mobilise les résidants du Nord et les scientifiques pour qu'ils participent à la recherche et à la surveillance axées sur les contaminants dans l'Arctique canadien, c'est-à-dire les contaminants qui sont transportés jusque dans l'Arctique par voie aérienne ou par les océans, et qui proviennent d'ailleurs dans le monde; ces contaminants demeurent dans l'environnement arctique et s'accumulent dans la chaîne alimentaire. Les données produites par le PLCN servent à évaluer la santé des écosystèmes et la santé humaine, et les conclusions de ces évaluations permettent d'assurer la salubrité et la sécurité des aliments traditionnels qui sont importantes pour la santé et le mode de vie traditionnels des résidants et des collectivités nordiques. Les conclusions guident également les politiques, qui donnent lieu à des mesures visant à éliminer les contaminants de sources éloignées. Le PLCN contribue à la collecte de données et à l'apport d'une expertise scientifique dans le cadre d'initiatives internationales sur les contaminants, comme le Programme de surveillance et d'évaluation de l'Arctique (PSEA), et d'ententes internationales comme la Convention de Minamata sur le mercure du Programme des Nations Unies pour l'environnement, la Convention de Stockholm sur le polluants organiques persistants et deux protocoles conclus en vertu de la Convention sur la pollution atmosphérique transfrontalière à longue distance de la Commission économique des Nations Unies pour l'Europe. Ces contributions à des travaux internationaux visent à améliorer la santé des résidants et des espèces sauvages à long terme.

Le PLCN est dirigé par un comité de gestion présidé par Affaires autochtones et Développement du Nord Canada (AADNC). Il compte des représentants de quatre ministères fédéraux (Environnement, Pêches et Océans, Santé Canada et AADNC), de cinq gouvernements provinciaux ou territoriaux (le Yukon, les Territoires du Nord-Ouest, le

Nunatsiavut support this national committee. Funding for the NCP's $4.1 million annual budget comes from INAC and Health Canada. Details about the management structures and review processes used to effectively implement the NCP, and the protocol to be used to publicly disseminate health and harvest information generated by the NCP can be found in the NCP Operational Management Guide (available upon request from the NCP Secretariat).

Nunavut, le Nunavik et le Nunatsiavut), de quatre organisations autochtones nordiques (le Conseil des Premières Nations du Yukon, la Nation dénée, Inuit Tapiriit Kanatami et la Conférence circumpolaire inuite), de cinq comités régionaux sur les contaminants et du Réseau de centres d'excellence axé sur l'Arctique, ArcticNet. Le Comité de gestion est responsable de l'établissement de la politique et des priorités scientifiques du PLCN de même que des décisions finales sur l'affectation des fonds. Les comités régionaux sur les contaminants du Yukon, des Territoires du Nord-Ouest, du Nunavut, du Nunavik et du Nunatsiavut appuient ce comité national. Le financement de 4,1 millions de dollars qui est affecté chaque année à la recherche aux termes du PLCN provient d'AADNC et de Santé Canada. On trouve dans le Guide de la gestion des opérations du PLCN (disponible sur demande au Secrétariat du PLCN) des détails sur les structures de gestion et les processus d'examen servant à mettre en œuvre le Programme, de même que le protocole à utiliser pour diffuser publiquement l'information sur la santé et la récolte produite dans le cadre du Programme.

Background

The 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.

Contexte

Le PLCN a été créé en 1991 en réponse aux inquiétudes que suscitait l'exposition des humains à des niveaux élevés de contaminants par les poissons et les espèces sauvages, qui composent une part importante du régime alimentaire traditionnel des Autochtones dans le Nord. Les premières études indiquaient qu'il existait un large spectre de substances – polluantes organiques persistants, métaux lourds et radionucléides – dont plusieurs ne provenaient pas de l'Arctique ou du Canada, mais étaient tout de même présents en quantités étonnamment élevées dans l'écosystème de l'Arctique.

Le Programme a pour objectif premier de réduire et, dans la mesure du possible, d'éliminer les contaminants présents dans le Nord dans les aliments traditionnels ou prélevés dans la nature tout en fournissant aux individus et aux collectivités de

Under the first phase of the NCP, research was focused 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 were synthesized in the first Canadian Arctic Contaminants Assessment Report (1997).

Extensive consultations were conducted in 1997-1998 to find the common elements between the concerns and priorities of northern communities and the scientific needs identified as critical for addressing the issue of contamination in Canada's North. As a result, research priorities were developed 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, initiatives got under way to redesign the NCP, and implement new program features which continue to this day: 1) the NCP blueprints that represent the long-term vision and strategic direction for the NCP; and 2) an open and transparent proposal review process. These features 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.

In 1998-1999, the NCP began its second phase, which continued until 2002-2003. Results of this phase were synthesized in the Canadian Arctic Contaminants Assessment Report II (CACAR II, 2003). During that time, the NCP 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 was placed on characterizing and quantifying the benefits associated with

l'information leur permettant de prendre des décisions éclairées au sujet de leur alimentation.

Dans la première phase du PLCN, les recherches ont consisté à recueillir les données nécessaires pour établir la concentration des contaminants, leur portée géographique et leur source dans l'atmosphère, l'environnement et la population du Nord, de même que la durée probable du problème. Les données nous ont permis de comprendre les modèles spatiaux et les tendances temporelles de la contamination dans le Nord, ainsi que de confirmer ce que nous soupçonnions, à savoir que les contaminants provenaient principalement d'autres pays. Les données, qui comprenaient des renseignements sur les avantages associés à une consommation régulière d'aliments traditionnels ou prélevés dans la nature, ont également servi à évaluer les risques pour la santé humaine que posent les contaminants contenus dans ces aliments. Les résultats ont été résumés dans le premier Rapport de l'évaluation des contaminants dans l'Arctique canadien (RECAC) en 1997.

Des consultations complètes ont été réalisées en 1997-1998 dans le but de trouver des éléments communs entre les préoccupations et priorités des collectivités nordiques et les besoins scientifiques, éléments jugés essentiels pour s'attaquer au problème de la contamination dans le Nord du Canada. Les priorités en matière de recherche ont donc été établies à partir des espèces les plus pertinentes en ce qui concerne l'exposition des humains dans le Nord, et en fonction des lieux géographiques et des populations les plus à risque.

En 1998, des initiatives ont été mises en œuvre dans le but de revoir la conception du PLCN et de mettre en œuvre de nouveaux éléments de programme encore présents aujourd'hui : 1) les plans directeurs du PLCN, qui présentent la vision et l'orientation stratégique à long terme du Programme; et 2) un processus d'examen des propositions ouvert et transparent. Ces éléments garantissent que le PLCN demeure pertinent sur le plan scientifique et conscient des aspects socioculturels, tout en réalisant des progrès réels à l'égard de ses vastes objectifs stratégiques.

En 1998-1999, le PLCN a entrepris sa deuxième phase, qui s'est poursuivie jusqu'en 2002-2003 et traditional diets. Communications activities were also emphasized and supported. Under the leadership of the northern Aboriginal organizations, the dialogue between northerners and the scientific community, which had been initiated during the early days of the NCP, continued to build awareness and an understanding of contaminants issues, and helped to support communities to deal with specific contaminant issues at the local level.

In 2009, the NCP released the Canadian Arctic Contaminants and Health Report. This report compiled research funded under the Human Health subprogram since the CACAR II release in 2003. It covered topics including health status of the Canadian Arctic population, human exposure to contaminants, toxicology, epidemiology, and risk-benefit evaluation.

Efforts on a third series of assessments got under way in 2010, leading to the release of the CACAR III: Mercury in Canada's North, in December 2012; the CACAR III: Persistent Organic Pollutants in Canada's North, in December 2013; and the CACAR III Contaminants In Canada's North: Summary for Policy Makers, in April 2015.

dont les résultats ont été présentés dans le RECAC II, en 2003. À cette époque, le PLCN soutenait la recherche qui s'intéressait à des questions concernant les répercussions et les risques pour la santé humaine associés aux niveaux de contamination chez certaines espèces largement consommées dans l'Arctique. Pour assurer une évaluation des risques équilibrée, l'accent a été mis sur la caractérisation et la quantification des bénéfices associés aux régimes alimentaires traditionnels. Le Programme a également soutenu des activités de communication. Sous la gouverne d'organisations autochtones nordiques, le dialogue entre les résidants du Nord et la communauté scientifique, initié dès le début du PLCN, a continué de favoriser la sensibilisation et la compréhension des questions relatives aux contaminants et aidé à soutenir les collectivités confrontées à des enjeux précis à l'échelle locale.

Le PLCN a publié son Rapport de l'évaluation des contaminants et de la santé dans l'Arctique canadien en 2009. Ce rapport présentait des recherches financées aux termes du sous-programme sur la santé humaine depuis la publication du RECAC II en 2003. Il couvrait notamment les sujets suivants : l'état de santé de la population dans l'Arctique canadien, l'exposition des humains à des contaminants, la toxicologie, l'épidémiologie et l'évaluation des risques et des avantages.

Une troisième série d'évaluations a été entreprise en 2010 et a mené à la publication du RECAC III sur le mercure dans le Nord canadien en décembre 2012, du RECAC III sur les polluants organiques persistants dans le Nord canadien en décembre 2013 et du RECAC III, Les contaminants dans le nord du Canada : Sommaire à l'intention des décideurs, en avril 2015.

International Impact

The NCP effort to achieve international controls of contaminants has remained strong throughout the program's history. NCP continues to generate data that allows Canada to play a leading role in the following initiatives, and contribute through cooperative actions under the Arctic Council, in particular through the circumpolar Arctic Monitoring and Assessment Programme (AMAP).

The legally binding POPs protocol, under the United Nations Economic Commission for Europe (UN ECE) Convention on Long-range Transboundary Air Pollution, was successfully negotiated and 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 (UNEP) was completed with the signing of the POPs Convention in Stockholm, Sweden, May 23, 2001; the UNEP Stockholm Convention on POPs entered into force in May 2004.

The Minamata Convention on Mercury, a legally-binding agreement to cut emissions and releases of mercury to the environment, was signed by Canada in October 2013 and now includes 128 signatory nations and 12 ratifications, in an international effort to reduce global mercury pollution and protect the environment and human health. Through use of its data, information and expertise, the NCP made important contributions towards this historic signing. The Convention will enter into force 90 days after 50 countries have ratified the treaty (Canada has not yet ratified). In the meantime, preparations for the entry into force are ongoing.

Répercussions internationales

Les efforts du PLCN en vue de parvenir à un contrôle international des contaminants ont été soutenus tout au long de l'histoire du Programme. Le PLCN continue de produire des données qui permettent aux Canadiens de jouer un rôle de premier plan au sein des initiatives suivantes et de contribuer à des actions en collaboration qui relèvent du Conseil de l'Arctique, en particulier le Programme de surveillance et d'évaluation de l'Arctique (PSEA).

Le protocole sur les polluants organiques persistants (POP), qui a force de loi et relève de la Convention sur la pollution atmosphérique transfrontalière de la Commission économique des Nations Unies pour l'Europe (CEE-ONU), a été négocié et signé par 34 pays (y compris le Canada) à la Conférence ministérielle de la CEE-ONU à Arhus, au Danemark, en juin 1998. Le Canada a ratifié cette entente en décembre 1998.

Le 23 mai 2001, un outil international ayant force de loi sur les POP en vertu du Programme des Nations Unies pour l'environnement (PNUE) a été achevé avec la signature de la Convention de Stockholm sur les POP, en Suède : la Convention de Stockholm sur les POP du PNUE est entrée en vigueur en mai 2004.

En octobre 2013, dans le cadre d'un effort international visant à réduire la pollution par le mercure à l'échelle mondiale et à protéger la santé humaine, le Canada a signé la Convention de Minamata, un accord exécutoire visant à réduire les émissions et la libération de mercure dans l'environnement signé par 128 pays, et ratifié par 12. Les données, les renseignements et l'expertise issus du PLCN ont grandement contribué à la signature de cet accord historique. La Convention entrera en vigueur 90 jours après que 50 pays l'aient ratifiée (le Canada n'a pas encore ratifié la Convention). Les préparatifs en vue de l'entrée en vigueur de la Convention sont en cours.

10 Key Findings of the Northern Contaminants Program

(from *Contaminants in Canada's North: Summary for Policy Makers*, 2014)

1. Concentrations of 'legacy POPs' are generally going down across the Arctic.
2. As 'new POPs' come under regulation, their levels in the Arctic decline.
3. Mercury levels in the Arctic are stabilizing but are still several times higher than during pre-industrial times.
4. Climate change can affect how POPs and mercury cycle in the Arctic environment and accumulate in wildlife.
5. The complex movement of contaminants in the Arctic environment and wildlife is now better understood.
6. Current levels of POPs and mercury may be a risk for the health of some Arctic wildlife species.
7. While exposure to most POPs and mercury is generally decreasing among Northerners, mercury remains a concern in some regions.
8. Traditional/country foods continue to be important for maintaining a healthy diet for Northerners.
9. Environmental exposure to contaminants in the Arctic has been linked to health effects in people.
10. Continued international action is vital to reducing contaminant levels in the Arctic.

10 principales conclusions du Programme de lutte contre les contaminants dans le Nord

(conclusions tirées du rapport de 2014 *Les contaminants dans le nord du Canada : Sommaire à l'intention des décideurs*)

1. Les concentrations de POP hérités du passé diminuent en général partout dans l'Arctique.
2. À mesure que les « nouveaux POP » sont réglementés, leurs niveaux dans l'Arctique diminuent.
3. Les niveaux de mercure dans l'Arctique se stabilisent, mais sont encore plusieurs fois plus élevés qu'à l'ère préindustrielle.
4. Les changements climatiques peuvent avoir des incidences sur le cycle des POP et du mercure dans le milieu arctique et sur leur accumulation.
5. Le mouvement complexe des contaminants dans le milieu arctique et chez les espèces sauvages est maintenant mieux compris.
6. Les niveaux actuels de POP et de mercure représentent peut-être un risque pour la santé de certaines espèces sauvages de l'Arctique.
7. L'exposition au mercure et à la plupart des POP diminue de façon générale chez les habitants du Nord, mais le mercure reste problématique dans certaines régions.
8. Les aliments traditionnels/prélevés dans la nature restent importants pour le maintien de la saine alimentation des habitants du Nord.
9. L'exposition aux contaminants présents dans le milieu arctique est associée à des effets sur la santé des habitants.
10. Il est essentiel de poursuivre l'action internationale pour réduire le niveau des contaminants dans l'Arctique.

Future Directions of the Northern Contaminants Program:

(adapted from *Contaminants in Canada's North: Summary for Policy Makers*, 2014)

In terms of *Environmental Monitoring and Research*, the NCP will

- continue to play a critical role in the detection of new chemical contaminants of concern to the Arctic and continuously review and refine its list of contaminants of concern.
- enhance the measurement of long-term trends of mercury and POPs by filling gaps in geographic coverage.
- carry out more research to understand the effects of climate change and predict their impacts on contaminant dynamics and ecosystem and human health risks.
- expand community-based monitoring that builds scientific capacity in the North, and optimizes the use of traditional knowledge.

In terms of *Human Health Research, Monitoring and Risk Assessment*, the NCP will

- address ongoing public health concerns related to contaminants and food safety, in partnership with territorial/regional health authorities by:
  - weighing the risks associated with exposure to POPs and mercury against the wide ranging benefits of consuming traditional/country foods, and
  - expanding monitoring of contaminant exposure among human populations across the North, and research on potential health effects in collaboration with Northern communities, to provide current information to public health officials

In terms of Communications and Outreach, the NCP will

- communicate research results and information about contaminants and risk to Northerners in the context of broader environmental (e.g. climate change) and health messages. Timely and culturally sensitive

Orientations futures du Programme de lutte contre les contaminants dans le Nord :

(orientations adaptées du rapport de 2014 *Les contaminants dans le nord du Canada : Sommaire à l'intention des décideurs*)

Pour ce qui est de la *surveillance environnementale et de la recherche*, le PLCN :

- continuera à jouer un rôle crucial dans la détection de nouvelles substances chimiques contaminantes préoccupantes dans l'Arctique et examinera et peaufinera continuellement sa liste de contaminants préoccupants;
- améliorera la mesure des tendances à long terme du mercure et des POP en comblant les lacunes dans la couverture géographique;
- effectuera plus de recherches pour comprendre les effets des changements climatiques et prévoir leurs incidences sur la dynamique des contaminants et les risques pour l'écosystème et la santé humaine;
- élargira la surveillance communautaire qui renforce les capacités scientifiques dans le Nord et optimise l'utilisation des connaissances traditionnelles;

Pour ce qui est de la *santé humaine, de la surveillance et de l'évaluation du risque*, le PLCN :

- en collaboration avec les autorités sanitaires régionales et territoriales, répondra aux préoccupations actuelles en matière de santé publique en lien avec les contaminants et la salubrité des aliments :
  - en comparant les risques associés à l'exposition aux POP et au mercure au large éventail d'avantages que présente la consommation des aliments traditionnels/prélevés dans la nature;
  - en élargissant la surveillance de l'exposition des populations humaines de tout le Nord aux contaminants ainsi que les travaux de recherche sur les effets éventuels sur la santé, en collaboration avec les collectivités nordiques, afin de fournir de l'information à jour aux responsables de la santé publique;

messages will be developed and communicated in association with regional health authorities and other appropriate spokespeople; these communication initiatives will be evaluated for their effectiveness.

- ensure that NCP data and information is effectively communicated to key international networks, such as AMAP, and the Global Monitoring Plans under the Stockholm and Minamata Conventions for the purpose of evaluating the effectiveness of global regulations.

Pour ce qui est de la communication et de la sensibilisation, le PLCN :

- communiquera les conclusions des recherches et de l'information sur les contaminants et les risques aux habitants du Nord dans le contexte de messages sanitaires et environnementaux sur des sujets plus vastes (p. ex. les changements climatiques). Des messages opportuns et adaptés à la culture des collectivités seront élaborés et diffusés en collaboration avec les autorités sanitaires régionales et les autres porte- paroles appropriés, et l'efficacité de ces initiatives de communication sera évaluée;

- veillera à ce que ses données et son information soient efficacement communiquées à des réseaux internationaux importants, comme le PSEA et les plans de surveillance mondiaux prévus par les conventions de Stockholm et de Minamata afin d'évaluer l'efficacité de la réglementation mondiale.

Human Health

Santé humaine

Development of Blood Guidance Values for Persistent Organic Pollutants for the Canadian Arctic (Year 2)

Élaboration de valeurs-guides relatives à la concentration sanguine des polluants organiques persistants dans l'Arctique canadien (deuxième année)

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Abstract

The Adult Inuit Health Survey (2007-2008) collected data on blood levels of heavy metals and persistent organic pollutants (POPs) in participants from the Canadian North. The population-level risks of contaminant exposures can be assessed using biomonitoring equivalents which are the corresponding human internal concentrations of: oral health based reference values or points of departure used to derive those oral health-based reference values. The purpose of this project is to develop new BEs for chlordane and toxaphene and to use these values to assess the biomonitoring data collected in the Canadian North with respect to population-level risks. During the 2014-2015 fiscal year, information needed to derive biomonitoring equivalents, such as intake reference standards, was collected from the published and grey literature. Several reference values were available from

Résumé

L'Enquête sur la santé des Inuits adultes (2007-2008) a permis de recueillir des données sur les niveaux de métaux lourds et de polluants organiques persistants dans le sang des participants du Nord canadien. Les risques d'exposition aux contaminants pour la population peuvent être évalués au moyen d'équivalents de biosurveillance, qui sont les concentrations internes humaines correspondantes des normes de référence pour la santé orale ou les valeurs utilisées pour établir ces normes de référence. Ce projet vise à établir de nouveaux équivalents de biosurveillance pour le chlordane et le toxaphène ainsi qu'à utiliser ces valeurs pour évaluer les données de biosurveillance recueillies dans le Nord canadien en ce qui a trait aux risques pour la population. Au cours de l'exercice 2014-2015, les renseignements nécessaires pour obtenir les équivalents de biosurveillance ont été recueillis

organizations such as Health Canada, the United States Environmental Protection Agency (U.S. EPA), and European authorities. Also developed was a pharmacokinetic modeling strategy and identification of pharmacokinetic parameters needed to model internal contaminant behaviour based on absorption, distribution, metabolism and excretion. During the second year of the project 2015-2016, the collected data was used to carry out one-compartment pharmacokinetic modeling to derive biomonitoring equivalents for individual chlordane and toxaphene isomers. Biomonitoring equivalents were compared with biomonitoring data from the Inuit Health Survey and the Canadian Health Measures Survey (CHMS) Cycle 1 (2007-2009). The approach was finalized at a team working meeting held at Health Canada in November 2015 and results were presented at the Northern Contaminants Workshop in December 2015. In the third and final year of the project, we will: (1) Further refine the biomonitoring equivalents based on population-specific body fat percentage data, (2) Compare the biomonitoring equivalent value for an identified contaminant based on more complex pharmacokinetic modeling strategies, (3) Examine important dietary sources of exposure among Inuit for those contaminants shown to exceed Biomonitoring equivalents, and (4) Communicate findings with our Inuit partners and developing a knowledge translation package.

dans la documentation publiée et non publiée. Plusieurs valeurs de référence ont été obtenues auprès d'organisations comme Santé Canada, l'United States Environmental Protection Agency et les autorités européennes. De plus, on a établi une stratégie de modélisation pharmacocinétique ainsi que d'établissement des paramètres pharmacocinétiques nécessaires pour modéliser le comportement des contaminants internes sur la base de l'absorption, de la distribution, du métabolisme et de l'excrétion. Au cours de la deuxième année du projet, 2015-2016, les données recueillies ont servi à réaliser une modélisation pharmacocinétique à un compartiment en vue de dériver des équivalents de biosurveillance pour les isomères du chlordane et du toxaphène. Les équivalents de biosurveillance ont été comparés aux données de biosurveillance issues de l'Enquête sur la santé des Inuits et le premier cycle (20072009) de l'Enquête canadienne sur les mesures de la santé (ECMS). La démarche a été achevée lors d'une réunion d'équipe tenue dans les locaux de Santé Canada en novembre 2015. Les résultats ont été présentés à l'atelier sur les contaminants du Nord de décembre 2015. Durant la troisième et dernière année du projet, nous : 1) préciserons les équivalents de biosurveillance selon les données sur le pourcentage de gras de la population, 2) comparerons les valeurs des équivalents de biosurveillance à un contaminant précisé dans une stratégie de modélisation pharmacocinétique, 3) étudierons les grandes sources d'exposition dans l'alimentation des Inuits pour les contaminants dont la valeur excède les équivalents de biosurveillance, et 4) communiquerons nos conclusions à nos partenaires en plus de concevoir une trousse d'application des connaissances.

Key messages

- BEs are the corresponding internal concentrations of oral health-based reference values or of the PODs used to derive oral health-based reference values. These values can be used to assess population-level risks of contaminant exposures.

Messages clés

- Les équivalents de biosurveillance sont en fait les concentrations internes humaines correspondantes des normes de référence pour la santé orale ou des polluants organiques persistants utilisés pour dériver les normes de référence pour la santé orale. Il est possible d'utiliser ces valeurs pour évaluer les risques que pose l'exposition aux contaminants pour les populations.

- In this work, BEs have been derived for chlordane (cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, oxychlordane) and toxaphene (Parlars No. 26, 50, 62) using a one-compartment pharmacokinetic model.
- The BE values for chlordane and toxaphene have been compared with biomonitoring data from the Inuit Health Survey (2007-2008). Existing, published BE values for dichlorodiphenyltrichloroethane/dichlorodiphenyldichloroethylene (DDT/DDE), hexachlorobenzene (HCB), and pentabromodiphenyl ether-99 (PBDE-99) were also compared with the Inuit Health Survey. The results of these comparisons will be presented to our Inuit partners.
- The BEs for chlordane and toxaphene have been compared with biomonitoring data from CHMS Cycle 1 (2007-2009). There were no observed exceedances for cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, oxychlordane, toxaphene Parlar No. 26, or Parlar No. 50.
- In the final year of the project, we will focus on:
  - Refining BE values based on population-specific body fat percentage data.
  - Comparing the BE value for an identified contaminant based on two and multi-compartment pharmacokinetic modeling.
  - Examining important dietary sources of exposure among Inuit for those contaminants shown to exceed BE values.
  - Communicating findings and developing a knowledge translation package.

- Dans le cadre des présents travaux, les équivalents de biosurveillance ont été dérivés pour le chlordane (cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor et oxychlordane) et le toxaphène (parlar nos 26, 50 et 62) à l'aide d'une modélisation pharmacocinétique à un compartiment.
- Les valeurs des équivalents de biosurveillance pour le chlordane et toxaphène ont été comparées aux données de biosurveillance issues de l'Enquête sur la santé des Inuits (2007-2008). Les valeurs actuelles publiées des équivalents de biosurveillance pour le dichlorodiphényltrichloroéthane/dichlorodiphényldichloroéthylène (DDT/DDE), l'hexachlorobenzène (HCB) et le pentabromodiphényl éther-99 (PBDE-99) ont aussi été comparées à celles issues de l'Enquête sur la santé des Inuits. Le résultat de ces comparaisons sera présenté à nos partenaires inuits.
- Les équivalents de biosurveillance pour le chlordane et le toxaphène ont été comparés aux données issues du premier cycle (20072009) de l'Enquête canadienne sur les mesures de la santé (ECMS). Aucun excédent n'a été noté pour le cis-chlordane, le trans-chlordane, le cis-nonachlor, le trans-nonachlor, l'oxychlordane et le toxaphène (parlar nos 26 et 50).
- Au cours de la dernière année du projet, nous mettrons l'accent sur les aspects suivants :
  - Préciser les équivalents de biosurveillance selon les données sur le pourcentage de gras de la population;
  - Comparer les valeurs des équivalents de biosurveillance à un contaminant précisé dans une stratégie de modélisation pharmacocinétique;
  - Étudier les grandes sources d'exposition dans l'alimentation des Inuits pour les contaminants dont la valeur excède les équivalents de biosurveillance;
  - Communiquer nos conclusions à nos partenaires et concevoir une trousse d'application des connaissances.

Objectives

- Develop pharmacokinetic models for the following contaminants:
  - Chlordane (cis-chlordane, trans-chlordane, oxychlordane, cis-nonachlor, trans-nonachlor)
  - Toxaphene (Parlar No. 26, 50, and 62)
- Derive BEs based on conversions of oral health-based reference values to internal concentrations using the pharmacokinetic models.
- Compare the derived BEs for chlordane and toxaphene with biomonitoring data from the Inuit Health Survey and the CHMS to determine the percentage of Inuit adults and Canadian adults from general population exceeding values.
- Use existing derived biomonitoring equivalents for DDT/DDE, HCB, and PBDE-99 to compare with Inuit Health Survey biomonitoring data.
- Conduct subgroup analyses for women of child-bearing age, young adults, middle-aged, and the elderly.
- Perform calculations using different threshold values.
- Present results of research to regional health authorities and the Steering Committee of the Inuit Health Survey.

Introduction

The International Polar Year Inuit Health Survey for Adults collected data on blood concentrations of environmental contaminants in 2,595 participants from the Canadian North. Laird et al. (2013) compared the observed blood levels with those in the general Canadian population, previous Inuit environmental studies, and trigger/intervention guideline values from Health Canada, U.S. Centers for Disease Control (CDC), or Occupational Safety and Health Administration (OSHA). Guidance values were available only for polychlorinated biphenyls (PCBs, specifically Arochlor 1260), cadmium, mercury and lead. Eight percent of the study sample exceeded the lead guideline level of 100 $\mu g \cdot L^{-1}$, 70% exceeded the cadmium guideline level of 1 $\mu g \cdot L^{-1}$, 35% exceeded the mercury guideline of 5.0 µg·kg body weight-1·week-1, and 27.9% women of child-bearing age exceeded the Arochlor 1260 guideline of 5 $\mu g \cdot L^{-1}$ (Laird et al. 2013, Laird et al. 2013b). For DDT/DDE, toxaphene, chlordane, and polybrominated diphenyl ethers (PBDEs), the exposure distributions were not interpretable within the context of established or evidence-formulated guidance values. Therefore, the health implications of the observed blood levels for these environmental contaminants are uncertain.

Population screening risk assessments can be made by comparing the measured biomonitoring levels to existing screening criteria such as reference dose (RfD), or tolerable daily intake (TDI). This comparison cannot be conducted directly because almost all regulatory health-based toxicity screening criteria are based on an intake level ($mg \cdot kg^{-1} \cdot d^{-1}$) or a concentration in an environmental medium (air, water, soil, etc.) which corresponds to an acceptable level of intake. However, the substantial effort already invested in developing these screening exposure guidelines can be leveraged through translation of these guidelines into BEs as a basis for interpreting biomonitoring results for specific chemicals in a health risk context (Hays et al. 2007, Hays et al. 2008).

Comparing biomonitoring data for a chemical with its BE provides a means for assessing population exposures to chemicals. BEs can assist scientists and risk managers in the prioritization of chemicals for follow-up or risk management activities (Hays et al. 2007). BEs for more than 110 chemicals, including cadmium, benzene, chloroform, arsenic, toluene, methylene chloride, triclosan, dioxins, volatile organic compounds, and others have been derived and published (Angerer et al. 2011). Several have been developed through collaborations of scientists from the U.S. EPA, CDC and Health Canada (Hays et al. 2008).

Therefore, we will interpret biomonitoring data by developing BEs for chlordane and toxaphene. In addition, we propose to develop guidance for health authorities to understand BEs as a tool to screen population level biomonitoring data. Given the confidence level of the underlying data used to develop the BEs, associated public health action plans will also be developed similar to the approach that was used for establishing the blood guidance values for methylmercury in Canada (Legrand et al. 2010).

Activities in 2015-2016

During the 2015-2016 funding year we have derived BE values for cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, toxaphene Parlars No. 26, 50, and 62. In addition, we have derived a provisional BE for oxychlordane based on a single toxicity study (note: no oral intake reference dose was available for oxychlordane, hence we conducted a separate search of studies for oxychlordane toxicity endpoints). We also compared the BE values with the biomonitoring data from the Inuit Health Survey and the CHMS, Cycle 1. A team working meeting was held at Health Canada and results were presented at the NCP annual workshop.

Capacity Building: This initial stage of the project is primarily a data analysis project and, therefore, there will be limited opportunity for training. However, in the final year of this study, we will help the regional contaminant committees to understand the process of developing the BE values and assist them to develop risk management and communication plans.

Communications: The initial BE results were presented at the NCP annual workshop in Vancouver, December 2015. Scientific articles will be submitted for publication in relevant peer-reviewed journals and communications in international meetings will be presented. We will develop a package of communication materials under the guidance of the partners in each region. The publications will be published in English and the appropriate Inuktitut language. The communication will be coordinated with the NCP Risk Communication SubCommittee and the NCP Regional Contaminant Committees.

Traditional Knowledge Integration: In the initial stage of the project, there is no direct use of traditional knowledge due to the specialized and focused nature of the study. However, in the last year of the project, community input will be critical in the development of risk management and communication plans.

Results

Tables 1 and 2 present the BE values derived for chlordane and toxaphene isomers, along with the corresponding PODs. The range of BE values is due to input of different values for the pharmacokinetic parameters of bioavailability and elimination rate constant, as supported by the scientific literature. In Table 3, the derived BE values are compared with values for other POPs from the published literature. Table 4 provides mean levels of contaminants in the Inuit Health Survey reported by Laird et al. 2013. In Table 5, levels for trans-nonachlor in the general Canadian population and for subgroups in the CHMS, Cycle 1 are provided. For other chlordane and toxaphene isomers in the CHMS, >40% of observations were below the limit of detection (LOD). Table 6 shows the percentage of the CHMS population that exceeds derived BE values for chlordane and toxaphene. The percentage of the sample exceeding BEs from the Inuit Health Survey have been analyzed but have not been presented here as we will first present and discuss these findings with Inuit partners. In addition, the provisional BE derived for oxychlordane has not been presented here as further discussions about its relevance will be discussed with risk assessors from Health Canada.

Table 1: Chlordane BE Derivation

Reference Dose (mg·kg⁻¹·d⁻¹)	Toxicity Endpoint	NOAEL (mg·kg⁻¹·d⁻¹)	LOAEL (mg·kg⁻¹·d⁻¹)	Human BE based on NOAEL (mg·kg⁻¹ lipid)			
				Cis-Chlordane	Trans-Chlordane	Cis-Nonachlor	Trans-Nonachlor
ATSDR 1994 (MRL): 0.0006	Hepatocellular hypertrophy (rats, 30 month study)	0.055	0.273	0.10-0.27	0.23-0.52	0.39-0.62	0.59-0.94
JMPR 1994 (pTDI): 0.0005	Hepatic toxicity* (rats, 32 month study)	0.05	N/A*	0.09-0.24	0.21-0.47	0.36-0.57	0.53-0.85
EPA 2009 (RfD): 0.0005	Hepatic necrosis (mice, 26 month study)	0.15	0.75	0.14-0.72	0.45-0.72	0.51-0.82	0.90-1.44
Abbreviations: ATSDR = Agency for Toxic Substances and Disease Registry; BE = biomonitoring equivalent; Css = steady state concentration; EPA = Environmental Protection Agency; JMPR = Joint FAO/WHO Meeting on Pesticide Residues; LOAEL = lowest observed adverse effect level; MRL = minimum risk level; NOAEL = no-observed adverse effect level; pTDI = provisional tolerable daily intake; RfD = reference dose (oral)							

* Unpublished study submitted to FAO/WHO – specific toxicity endpoint unclear and LOAEL not provided.

Table 2: Toxaphene BE Derivation

Reference Dose (mg·kg⁻¹·d⁻¹)	Toxicity Endpoint	NOAEL (mg·kg⁻¹·d⁻¹)	LOAEL (mg·kg⁻¹·d⁻¹)	Human BE based on NOAEL (mg·kg⁻¹ lipid)		
				Parlar No. 26	Parlar No. 50	Parlar No. 62
MATT 2012 (pTDI): 0.018 (weathered toxaphene)	Altered hepatic foci expressing placental glutathione-S-transferase in rats (indication of tumour promotion)	1.8	Not observed	2.74-38.38	6.40-19.19	6.40-15.35
Simon 2006 (RfD): 0.00002 (∑Parlars 26, 50, 62)	Altered hepatic foci expressing placental glutathione-S-transferase in rats (indication of tumour promotion)	0.0021	0.0063*	0.003-0.05	0.01-0.02	0.01-0.02
ATSDR 2014 (MRL): 0.002	Depressed humoral immunity (cynomolgus monkeys, 19 month study)	0.1	0.4	Not derived	Not derived	Not derived
HC 2007 (pTDI): 0.0002	Liver toxicity (dogs,3 month study)	0.2	2.0	Not derived	Not derived	Not derived
Swiss 2004 (TDI): 0.0001	Depressed humoral immunity (cynomolgus monkeys, 19 month study)	0.1	0.4	Not derived	Not derived	Not derived
Abbreviations: ATSDR = Agency for Toxic Substances and Disease Registry; BE = biomonitoring equivalent; Css = steady state concentration; HC = Health Canada; LOAEL = lowest observed adverse effect level; MRL = minimum risk level; NOAEL = no-observed adverse effect level; pTDI = provisional tolerable daily intake; RfD = reference dose; TDI = tolerable daily intake						

* Decreased glutathione-S-transferase observed.

Table 3: Comparison of Derived BEs with Published BE Values

Compound	BE (µg•kg⁻¹ lipid)	Endpoint	Reference
∑DDT/DDE/DDD	5 000-40 000	Hepatic/Rat pup growth	Kirman 2011
DDT	4 000-30 000	Hepatic/Rat pup growth	Kirman 2011
Toxaphene – Parlar No. 26	2 740-38 380	Expression of placental glutathione-S-transferase in hepatic foci	Current Work
Toxaphene – Parlar No. 50	6 400-19 190	Expression of placental glutathione-S-transferase in hepatic foci	Current Work
Toxaphene – Parlar No. 62	6 400-15 350	Expression of placental glutathione-S-transferase in hepatic foci	Current Work
Trans-nonachlor	530-1 440	Hepatic	Current Work
Cis-nonachlor	360-820	Hepatic	Current Work
Trans-chlordane	210-720	Hepatic	Current Work
Cis-chlordane	90-720	Hepatic	Current Work
PBDE-99	520	Neurobehavioural	Krishnan 2011
HCB	25-340	Hepatic	Aylward 2010
Abbreviations: BE = biomonitoring equivalent; DDD = dichlorodiphenyldichloroethane; DDE = dichlorodiphenyldichloroethylene; DDT = dichlorodiphenyltrichloroethane; HCB = hexachlorobenzene; PBDE-99 = pentabromodiphenylether-99			

Table 4: Persistent Organic Pollutant Levels - IHS (2007-2008)*

Contaminant	Range (µg·kg⁻¹ lipid)	Geometric Mean (µg·kg⁻¹ lipid) (95% CI)
Chlordane (∑cis-nonachlor, trans-nonachlor, oxychlordane)	1.5-6 600	150 (138, 159)
Toxaphene (∑Parlars No. 26, 50)	0.55-1510	28.7 (26.3, 30.3)
PBDEs (∑PBDE-47, 99, 100)	3.4-2130	13.4 (12.9, 14.0)
DDE and DDT	5.0-8460	311 (292, 323)
Abbreviations: CI = confidence interval; DDE = dichlorodiphenyldichloroethylene; DDT = dichlorodiphenyltrichloroethane PBDE = polybrominated diphenyl ether		

* From Laird BD et al. Body burden of metals and persistent organic pollutants among Inuit in the Canadian Arctic. Environment International 2013;59 :33-40.

Table 5: Trans-Nonachlor Levels - CHMS Cycle 1 (2007-2009)*

Population	NWeighted	Geometric Mean (μg·kg^{-1} lipid) (95% CI)
Whole	23 279 744	6 (5, 7)
Males	11 661 741	6 (5, 7)
Females	11 618003	6 (5, 7)
Women Child-Bearing Age (18-44)	5 191 239	3.4 (2.7, 4.2)
Young (18-25)	2 752 504	2.1 (1.7, 2.5)
Middle (40-55)	8 234 753	7 (6, 8)
Elderly (≥60)	4 886 233	14 (12, 16)
Abbreviations: CI = confidence interval		

* >40% of observations for cis-chlordane, trans-chlordane, cis-nonachlor, and Parlars No. 26 and 50 were below the limit of detection. Parlar No. 62 was not measured.

Table 6: Percentage of respondents in CHMS Cycle 1 (2007-2009) exceeding BEs

Contaminant	Population	Percentage Exceeding BEs
Chlordane (cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor)	Whole	0.0
	Males	0.0
	Females	0.0
	Women Child-Bearing Age (18-44)	0.0
	Young (18-25)	0.0
	Middle-Aged (40-55)	0.0
	Elderly (≥60)	0.0
Toxaphene (Parlars No. 26, 50)*	Whole	0.0
	Males	0.0
	Females	0.0
	Women Child-Bearing Age (18-44)	0.0
	Young (18-25)	0.0
	Middle-Aged (40-55)	0.0
	Elderly (≥60)	0.0
Abbreviations: BE = biomonitoring equivalent		

* Based on BE values derived from MATT 2012 pTDI.

Discussion and Conclusions

During the 2015-2016 fiscal year, we have derived BEs for cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, oxychlordane, toxaphene Parlars. No. 26, 50, and 62 based on one-compartment pharmacokinetic models. We have compared these values with the biomonitoring data from the Inuit Health Survey and the CHMS, Cycle 1 to determine the percentage of the population in exceedance of these BEs. We have also conducted subgroup analyses by sex, women of childbearing age, young adults, middle-aged, and elderly. This has provided an indication of population-level risks of contaminant exposure.

Work to be continued in 2016-2017 fiscal year

In the final year of the project, we will refine the BEs based on population-specific body fat percentage values. We will also explore whether BEs vary based on two and multi-compartmental modeling for a selected contaminant. For those contaminants that are in exceedance among the Inuit population, we will explore important dietary sources of exposure using data on contaminant levels in traditional foods in the Canadian Arctic and responses to the food frequency questionnaire of the Inuit Health Survey. Findings will be communicated with the regional health authorities and the Inuit Health Survey Steering Committee. We hope to work with the NCP and Inuit partners to develop a knowledge translation package for communities.

Expected Project Completion Date

03/2017

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References

Angerer, J., Aylward, L.L., Hays, S.M., Heinzow, B., Wilhelm, M.. 2011. Human biomonitoring assessment values: Approaches and data requirements. *Int. J. Hyg. Environ. Health.* 214: 348–360.

Aylward, L.L., Hays, S.M., Gagne, M., Nong, A., Krishnan, K. 2010. Biomonitoring equivalents for hexachlorobenzene. *Regul. Toxicol. Pharmacol.* 58(1): 25-32.

Hays, S.M., Becker, R.A., Leung, H.W., Aylward, L.L., Pyatt, D.W. 2007. Biomonitoring equivalents: A screening approach for interpreting biomonitoring results from a public health risk perspective. *Regul. Toxicol. Pharmacol.* 47: 96–109.

Hays, S.M., Aylward, L.L., Lakind, J.S., Bartels, M.J., Barton, H.A., Boogaard, P.J., et al. 2008. Guidelines for the derivation of biomonitoring equivalents: Report from the Biomonitoring Equivalents Expert Workshop. *Regul. Toxicol. Pharmacol.* 51: S4–15.

Kirman, C.R., Aylward, L.L., Hays, S.M., Krishnan, K., Nong, A. 2011. Biomonitoring equivalents for DDT/DDE. *Regul. Toxicol. Pharmacol.* 60(2): 172-180.

Krishnan, K., Adamou, T., Aylward, L.L., Hays, S.M., Kirman, C.R., Nong, A. 2011. Biomonitoring equivalents for 2,2’,4,4’,5-pentabromodiphenylether (PBDE-99). *Regul. Toxicol. Pharmacol.* 60(2): 165-171.

Laird, B.D., Goncharov, A.B., Chan, H.M. 2013. Body burden of metals and persistent organic pollutants among Inuit in the Canadian Arctic. *Environ. Int.* 59: 33-40.

Laird, B.D., Goncharov, A.B., Egeland, G.M., Chan, H.M. 2013b. Dietary advice on Inuit traditional food use needs to balance benefits and risks of mercury, selenium, and n3 fatty acids. *J. Nutr.* 143: 923–930.

Legrand, M., Feeley, M., Tikhonov, C., Schoen, D., Li-Muller, A. 2010. Methylmercury blood guidance values for Canada. *Can. J. Public Health.* 101: 28-31.

Van Oostdam, J., Donaldson, S.G., Feeley, M., Arnold, D., Ayotte, P., Bondy, G., et al. 2005. Human health implications of environmental contaminants in Arctic Canada: A review. *Sci. Total Environ.* 351-352: 165-246.

Do country food nutrients protect against mercury toxicity and cardiometabolic diseases? Integrating data from cutting-edge science and mobilizing knowledge towards Nunavimmiut health (year 2)

Les éléments nutritifs présents dans les aliments traditionnels assurent-ils une protection contre la toxicité du mercure et les maladies cardiométaboliques? Intégration des données scientifiques de pointe et mobilisation des connaissances pour la santé des Nunavimmiut (deuxième année)

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Abstract

Methylmercury (MeHg) exposure in the Inuit population of Nunavik remains one of the highest in the world. Traditional marine foods are the major source of this exposure, in addition to being rich in nutrients such as selenium (Se) and omega-3 polyunsaturated fatty acids (n-3 PUFA). Through an interdisciplinary program incorporating nutrition, epidemiology, toxicology and implementation research, we are addressing the complex issue of benefits and risks of country foods in the Inuit population of Nunavik, with a

Résumé

La population inuite du Nunavik est l'une des plus exposées au méthylmercure (MeHg) dans le monde. Les aliments traditionnels provenant des milieux marins sont la principale cause de cette exposition. Ils sont aussi riches en éléments nutritifs comme le sélénium (se) et les acides gras polyinsaturés oméga3 (AGPI n-3). Dans le cadre d'un programme multidisciplinaire intégrant nutrition, épidémiologie, toxicologie et recherche sur la mise en œuvre, nous nous penchons sur la question complexe des avantages et des risques que posent les aliments

particular focus on cardiovascular diseases and type 2 diabetes (T2D). This year, we have started exploring associations between biomarkers of MeHg exposure, Se status and n-3 PUFA status, and biomarkers of T2D-related effects (plasma levels of adiponectine, branched-chain amino acids and acylcarnitines). Following up on the identification of selenoneine as the major selenium compound present in Inuit red blood cells (RBCs) and in beluga mattaaq, we completed the determination of selenoneine in RBCs of all 2004 Nunavik Health Survey participants. Results indicate that selenoneine is a major Se species in Nunavimmiut RBCs. We also measured selenoneine in beluga mattaaq samples from Nunavik and Arviat (Nunavut) and found that selenoneine represents more than 50% of the total selenium concentration in this marine food. Selenoneine and MeHg both accumulate in RBCs, where selenoneine may enhance MeHg demethylation and therefore decrease MeHg distribution to target organs. These results will improve our capacity to develop and implement interventions that aim to promote the benefits of the traditional marine diet, while minimizing MeHg toxicity in this population.

traditionnels pour la population du Nunavik, avec une attention particulière sur les maladies cardiovasculaires et le diabète de type 2. Cette année, nous avons commencé à étudier les liens entre les biomarqueurs de l'exposition au méthylmercure, les niveaux de sélénium et les niveaux d'AGPI n3 et les biomarqueurs des effets du diabète de type 2 (niveaux d'adiponectine dans le plasma, chaînes d'acides aminés et acylcarnitines). À la suite de l'identification de la sélénonéine comme principal composant du sélénium présent dans les globules rouges des Inuits et dans le mattaaq de béluga, nous avons pu établir le niveau de sélénonéine dans les globules rouges de tous les participants de l'Enquête sur la santé au Nunavik de 2004. Les résultats montrent que la sélénonéine est un composant du sélénium très présent dans les globules rouges des Nunavimmiut. Nous avons également mesuré les niveaux de sélénonéine dans le mattaaq de béluga au Nunavik et à Arviat (Nunavut) et constaté qu'ils représentent plus de 50 % de la concentration totale de sélénium dans ces aliments issus de la mer. La sélénonéine et le méthylmercure s'accumulent tous deux dans les globules rouges, où la sélénonéine pourrait accélérer la déméthylation, ce qui réduirait l'accumulation de méthylmercure dans les organes cibles. Ces résultats nous aideront à élaborer et à mettre en œuvre des interventions axées sur les avantages des aliments traditionnels issus de l'eau tout en réduisant au minimum la toxicité du méthylmercure dans cette population.

Key messages

- Selenoneine, an organic form of selenium, represents more than 50% of selenium in beluga mattaaq samples from Nunavik and Nunavut
- Selenoneine was identified as a major Se compound in red blood cells of Nunavimmiut
- Selenoneine may enhance methylmercury demethylation and decrease its distribution to target organs

Messages clés

- La sélénonéine, un dérivé organique du sélénium, représente plus de 50 % de la concentration totale de sélénium dans les échantillons de mattaaq de béluga prélevés au Nunavik et au Nunavut.
- La sélénonéine est un dérivé du sélénium qu'on retrouve en grande quantité dans les globules rouges des Nunavimmiut.
- La sélénonéine pourrait accélérer la déméthylation, ce qui réduirait l'accumulation de méthylmercure dans les organes cibles.

- Whether or not selenoneine protects against methylmercury toxicity is currently being examined

- L'équipe se penche actuellement sur les effets de la sélénonéine sur la toxicité du méthylmercure.

Objectives

The **main objective** of this interdisciplinary project is to investigate the effects of country foods on cardiometabolic diseases in Inuit adults from Nunavik. This study consists of three sections. The **first section** focuses on contaminant/nutrient interactions and their effects on biomarkers of early metabolic changes that are predictive of T2D risk. Specific objectives of this section are:

- To measure total Se and Se-containing proteins levels in plasma samples of NHS participants (completed);
- To measure recently validated early biomarkers of T2D risk issued from metabolomics studies in the same plasma samples(completed);
- To measure concentrations of selenoneine and its metabolites in red blood cells of NHS participants (completed);
- To examine the associations between biomarkers of methylmercury (MeHg) exposure, biomarkers of Se status and early biomarkers of TD2 risk (on-going);
- To investigate links between MeHg exposure, nutrient status, early biomarkers of TD2 risk and T2D related effects using path analyses (on-going).

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

- To collect selected country foods from several Nunavik villages (completed);
- To determine the age of the animals sampled and measure total Se and Hg concentrations in the corresponding country food samples (completed);
- To measure Se and Hg species and to study the bioaccessibility and bioavailability of Se and Hg and in these same country food samples (completed);
- To study the potential of other local foods to mitigate Hg bioaccessibility of selected country foods (completed);
- To study the ability of Se and n-3 PUFA to limit the absorption of Hg (on-going);
- To evaluate the associations between Se and Hg bioaccessibility of country foods and biomarkers of exposure to Hg and Se, and the influence of other local food intake on these associations (on-going).

The **third section** consists in developing a human study on bioavailability of n-3 PUFA, Se and Hg in country. The specific objective of this section is:

- To develop a human study on bioavailability of *n*-3 PUFA, Se and Hg in country foods

The **fourth** section focuses on the integration of the data from the two above sections. Specific objectives of this section are:

- To determine whether nutrients in country foods protect against Hg toxicity and cardiometabolic diseases (on-going);

- To mobilize this integrated knowledge towards Nunavimmiut health (on-going).

Introduction

The Inuit population of Nunavik displays among the highest Se intake and blood Se status in the world since their traditional marine mammal diet is exceptionally rich in Se (Lemire et al., 2015). Se is an essential element involved in several body functions through selenoproteins expression, including regulation of oxidative stress, and immune and thyroid functions (Reeves and Hoffmann, 2009). In fish and marine mammal eating populations, high dietary Se intake may play a role in offsetting some deleterious effects of high MeHg exposure (Ayotte et al., 2011; Boucher et al., 2010; Lemire et al., 2010; Lemire et al., 2011; Valera et al., 2009). Conversely, in Europe and the United States, high plasma Se has been related to T2D, hypercholesterolemia and hypertension (Stranges et al., 2010). Contrary to most European and North American populations, Inuit present an exceptionally high intake of n-3 PUFA, a preventive factor for CVD (Dewailly et al., 2001). They can also be highly exposed to MeHg, PCB, PFOS and trans-fat, all risk factors for CVD (Chateau-Degat et al., 2010; Counil et al., 2009; Valera et al., 2009).

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

According to 2004 data from the NHS, the prevalence of T2D in the Inuit population (4.8%) was low, although dietary transition may have changed the situation over the last decade. Therefore, investigating relations between exposure to toxicants, nutrient intakes and T2D risk is difficult due to lack of statistical power. An alternative is to focus on biomarkers of early biochemical changes that are part of the pathogenic sequence leading to T2D. The development of metabolic profiling methods (metabolomics), especially liquid chromatography – mass spectrometry based techniques, has allowed the identifications of several endogenous compounds in biological fluids that constitute early biomarkers of T2D risk. Results from several recent epidemiological studies indicate that plasma levels of branched-chain amino acids (BCAA: isoleucine, leucine, valine), aromatic amino acids (tyrosine and phenylalanine), acylcarnitines (AC: C3 and C5) and 2-amionoadipic acid are associated to cardiometabolic diseases and may constitute early biomarkers of T2D (Newgard et al., 2009; Wang et al., 2011, 2013). Therefore, examining the relation between MeHg, nutrients, and these early biomarkers of TD2 risk may reveal on-going biochemical changes that are linked to future risk of the disease.

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

In addition, the chemical forms of Se and Hg ingested may also influence Se and Hg solubilisation into the GI tract, absorption, Se bioavailability for selenoprotein synthesis, and Se and Hg related-health effects (Clarkson, 2002; Rayman et al., 2008). Although some studies on Se chemical forms have been conducted in fish species and HgII-Se complexes has been identified in seabirds and marine mammals organs (Ikemoto et al., 2004; Lemes and Wang, 2009; Yamashita and Yamashita, 2010), little information is available on Se and Hg speciation in country foods. Recently, a novel seleno-containing compound, selenoneine, has been identified as the major form of organic Se in Bluefin tuna (Yamashita and Yamashita, 2010) and in blood cells of a fish-eating population (Yamashita et al., 2013). This Se-analog of ergothioneine, a powerful antioxidant molecule, could contribute to the scavenging of reactive oxygen species that are involved in the etiology of chronic diseases or MeHg toxicity. Different "methylated/non-methylated" ratios of selenoneine have been observed in human blood and urine, indicating their active metabolism and suggesting a promising metabolic role of these redox metabolites in humans (Klein et al., 2011).

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

Activities in 2015-2016

Section 1 of the project:

Data on Se speciation in plasma obtained in 2014-2015 showed that Se-containing proteins represent the major part of plasma Se content, indicating that concentrations of low-molecular weight Se compounds are likely very low in plasma. Furthermore, examination of the relationship between plasma and whole blood total Se concentrations revealed that individuals with high blood levels (i.e. > 1000 µg/L) do not exhibit similarly high plasma concentrations. This strongly suggests that a selenocompound present in country food of marine origin, likely selenoneine, is accumulating in red blood cells in Inuit highly consuming these country foods (Achouba et al., manuscript submitted for publication in May 2016). We therefore decided to focus our efforts on this compound. In July 2015, we produced 100 ml of a purified selenoneine standard at 1000 µg Se L^{-1} using the genetically modified yeast kindly provided by Dr. Yanagida (Pluskal et al., 2014). Starting from the purified selenoneine standard, we were also able to produce the methyl-selenoneine standard. The availability of both standards permitted to complete the development and validation of the analytical method for the quantification of selenoneine and methyl-selenoneine in RBCs by the end of November 2015. In February 2016, the quantification of selenoneine and methyl-selenoneine in RBCs of all NHS participants was completed and results are now available (see Table 2).

Following the completion of metabolomic analyses in 2014-2015, Cynthia Roy (Ph.D. student), examined associations between plasma concentrations of 8 amino acids and 8 acylcarnitines (targeted metabolomics), and components of the metabolic syndrome in NHS participants. A scientific publication will be submitted on these associations by the end of September 2016. Untargeted metabolomics data covering up to 671 metabolites will later be examined as they may provide additional clues the pathogenesis of diabetes among Inuit.

In April 2016, we completed the determination of plasma adiponectin concentrations in all NHS participants using an enzyme-linked immunosorbent assay (ELISA) (see Table 3). Adiponectin levels may also provide useful information regarding diabetogenesis in Inuit.

Path analyses are being used by Abdullah Al Maruf, a new postdoctoral fellow with our group, to investigate links between MeHg exposure, nutrient intake status, early biomarkers of TD2 risk and T2D related effects. An article presenting these associations is expected to be submitted by the fall of 2016.

Section 2 of the project:

In the fall of 2015, we received 5 samples of beluga from Nunavut (Arviat) provided by Dr. Gary Stern which were analyzed for total selenium, selenoneine and methyl-selenoneine along with 5 samples from Nunavik (Kangiqsualujjuaq). Results for these 10 samples are available in Table 3.

Most research investigating the bioaccessibility of metals in country foods is limited in that the extraction models assess single foods in isolation. However, in reality, foods are generally eaten within mixtures (i.e. meals). Therefore, the accuracy of bioaccessibility adjustments for exposure assessments hinges on whether the bioaccessible fractions of metals in co-consumed foods are additive or not. Should the bioaccessible fractions not be additive, the implication of this would be determined by whether bioaccessibility is less than additive or more than additive. To better understand this issue, we evaluated the effect of co-consumption on the in vitro bioaccessibility of Hg and Se in Inuit country foods collected from Nunavik, Quebec. Each binary country food mixture tested consisted of a country food with elevated Hg concentrations (e.g. ringed seal liver, beluga nikku, raw beluga meat, walrus, lake trout, eider duck egg white) and a second food that may have a mitigating effect on metal bioaccessibility (e.g. crowberries, blueberries, seaweed, sculpin eggs and tomato paste). Each of these food mixtures were digested using a previously developed in vitro model for the measurement of mercury and selenium bioaccessibility.

Results

Section 1 of the project

Selenium speciation in RBCs was carried out using ion pair liquid chromatography-inductively coupled mass spectrometry (IPLC-ICP-MS). Separation conditions were first optimised using a mixture of commercially available selenium standards to which we added the purified selenoneine standard. Figure 1 shows the complete separation of 6 selenium species; selenoneine elutes at 1.64 min.

Figure 1. Separation of a mixture of selenium standards by ion pair liquid chromatography- inductively coupled mass spectrometry.

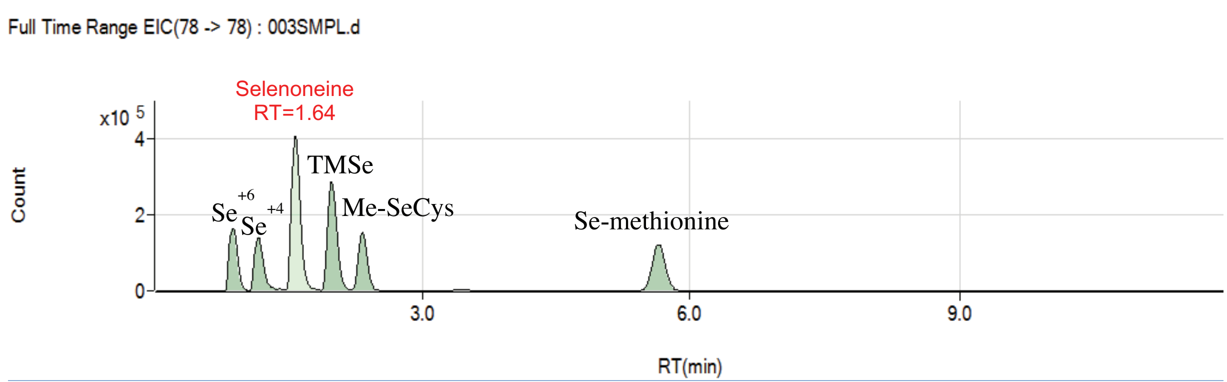


Figure 2. Chromatogram of methyl-selenoneine obtained by derivatization of the selenoneine standard using diazomethane.

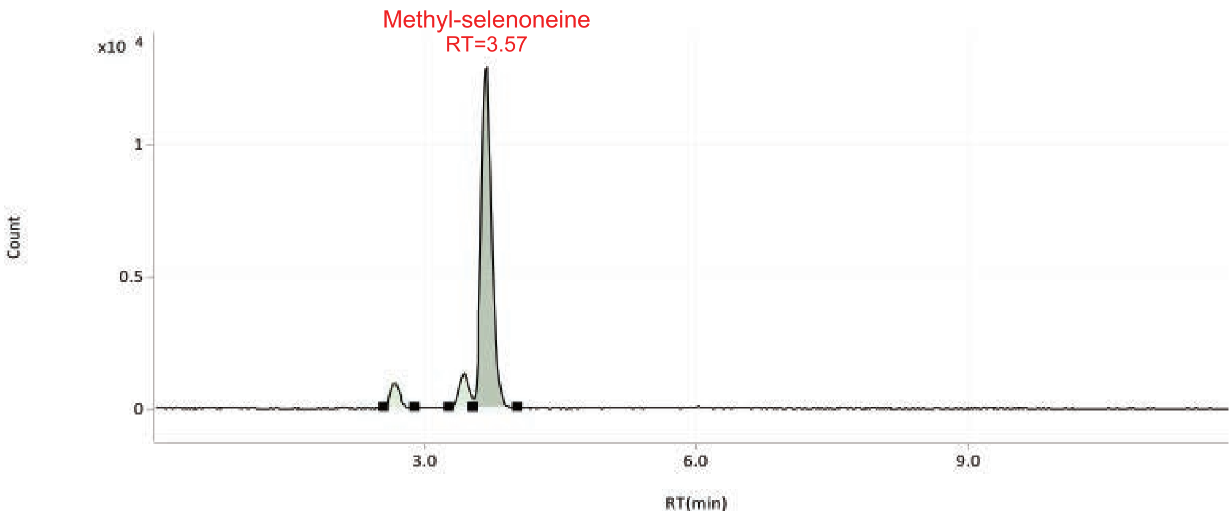


Figure 2 presents the chromatogram of methyl-selenoneine which was obtained through derivatization of the purified selenoneine standard by diazomethane. Using the optimized IPLC-ICP-MS method, methyl-selenoneine elutes at 3.5 min and its identity was confirmed by LC-QTOF (data not shown).

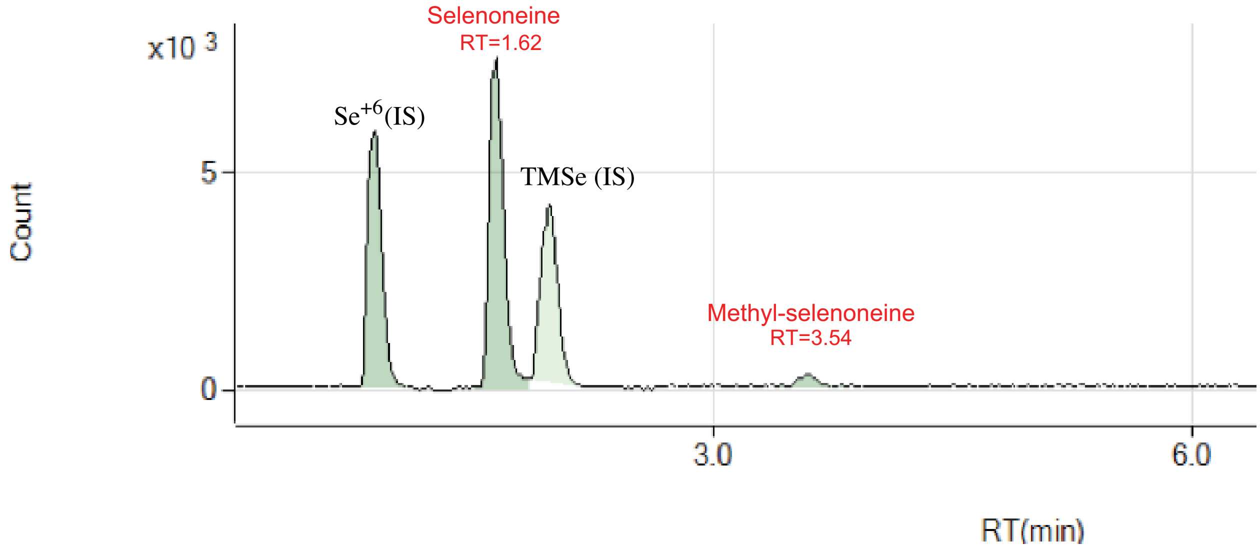
Table 1 lists the analytical performances of the developed method which combines the extraction of selenium species from RBCs and their quantification by ion pair LC-ICP-MS. The limit of detections of selenoneine and methyl-selenoneine were 2 and 3.9 µg Se L^{-1} respectively with between-day repeatability inferior to 6%.

Figure 3 shows a typical chromatogram obtained when analysing RBCs of Inuit adults for selenoneine and methyl-selenoneine. As expected, selenoneine and methyl-selenoneine eluted at 1.6 and 3.5 min, respectively. Two internal standards (IS) were used to quantify selenoneine and methyl-selenoneine using external calibration curves.

Table 1. Analytical performances of the method for selenoneine and methyl-selenoneine quantification (n=10).

Parameters	Selenoneine	Methyl-selenoneine
Limit of detection (µg Se L^{-1})	2	3.9
Limit of quantification (µg Se L^{-1})	4.1	8
Recovery (%)	88.5	88
Matrix effect (%)	104	103
Within-day CV (%)	3	2.9
Inter-day CV (%)	4.6	5.9

Figure 3. Typical chromatogram obtained when analyzing RBCs from Inuit adults by IPLC-ICPMS. Peaks corresponding to selenoneine and methyl-selenoneine are observed at RT values of 1.6 and 3.5 min, respectively.



Results for total Se, selenoneine and methyl-selenoneine analyses in RBCs of 886 Inuit who participated to NHS 2004 are presented in Table 2. The median selenoneine concentration was 130.3 µg Se L^{-1} (range = 1 to 3226.3 µg Se L^{-1}) while that of methyl-selenoneine was 6.3 µg Se L^{-1} (range = 2 to 124.3 µg Se L^{-1}). Selenoneine represented on average 33% (range = 0.25 to 92%) of total RBC Se content and 50% (range = 0.8 to 91%) of total Se in whole blood. There was a gender difference for all selenium analysis in RBCs, females had a slightly higher selenoneine percentage in RBCs than males (36% vs 28%). Preliminary analysis shows that participants with whole blood total Se below 200 ug/L were found with very low or no selenoneine in RBCs.

Table 2. Concentrations of total Se, selenoneine and methyl-selenoneine in RBCs of adults Inuit from Nunavik (NHS 2004; n=886).

	Sex	N	Min	Max	IQR	Mean	95% CI	Median
Selenoneine µg Se L^{-1}	F	488	1	2710	314	318	281 – 355	163
	M	398	1	3230	250	233	197 - 268	98.4
	All	886	1	3230	291	280	254 – 306	130
Me-Selenoneine µg Se L^{-1}	F	488	2	114	15.1	13.3	11.9 - 14.8	7.3
	M	398	2	124	10.2	10.6	9.1 - 12.1	4.9
	All	886	2	124	13.0	12.1	11.0 - 13.1	6.3
RBC Total Se µg Se L^{-1}	F	488	184	3130	402	609	567 – 652	448
	M	398	175	3890	300	502	462 – 542	351
	All	886	175	3890	356	561	532 - 591	398

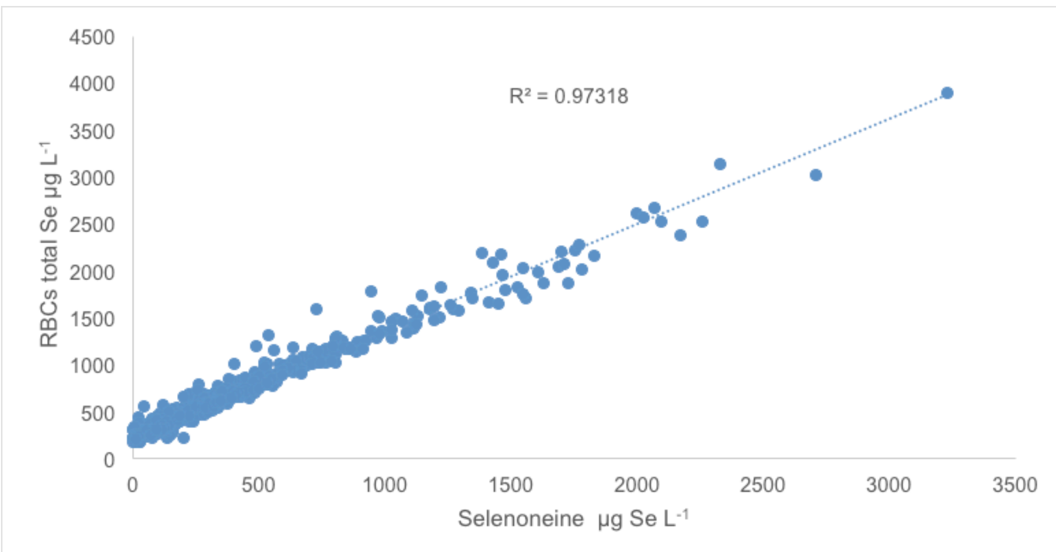
Results for adiponectin analysis in plasma of Inuit adults are presented in Table 3. Mean adiponectin concentration was 8 µg mL^{-1}, with values ranging from 0.1 to 38 µg mL^{-1}.

Figure 4 displays the relationship between total Se and selenoneine concentrations in RBCs of Inuit adults from Nunavik. A very strong correlation was observed, confirming that selenoneine is a major selenium compound accumulating in RBCs of Nunavik Inuit.

Table 3. Concentrations of adiponectin in plasma of Inuit adults from Nunavik (NHS 2004; n=859).

	Sex		N	Min	Max	IQR	Mean	95% CI	Median
Adiponectin µg mL^{-1}	F		468	0.1	31	5.3	8.2	7.8 - 8.6	7.6
	M		391	1.0	38	4.7	7.8	7.4 - 8.2	7.0
	All		859	0.1	38	5.1	8.0	7.7 - 8.3	7.3

Figure 4. Relationship between selenoneine and total Se concentrations in RBCs of Inuit adults from Nunavik (NHS 2004; n=886).



Section 2 of the project

Selenononeine content of mattaaq samples. Table 4 contains median selenoneine and total Se concentrations in 10 different beluga mattaaq samples from two different arctic locations (Kangiqsualujjuaq, Nunavik and Arviat, Nunavut; five samples from each location). Median selenoneine concentrations represented more than 50% of total median Se concentrations in beluga mattaaq samples from both locations.

Bioaccessibility of Hg and Se – co-consumption of country foods. The presence of a second, potentially mitigating food within the in vitro extraction digest occasionally affected the bioaccessibility of Hg and Se in country foods, either increasing or decreasing metal bioaccessibility. The results from this co-digest experiment and the summary of whether the results indicated metal bioaccessibility as "less than additive", "additive", or "more than additive" are summarized in Table 5. Although bioaccessible Hg concentrations in each of the food modifiers were below the limit of detection, the addition of the food modifiers in the co-digest appeared to occasionally increase the solubilization of mercury from some country foods (e.g. walrus meat/ blubber, beluga meat, ringed seal meat). For example, the addition of berries and seaweed each appeared to increase the solubilization of mercury from ringed seal meat (Table 5). Similarly, the bioaccessible fractions of beluga meat in combination with tomato paste and walrus meat/blubber together with blueberries both appeared greater more than additive. In contrast, the co-digest of sculpin eggs appeared to decrease the solubilization of Hg from ringed seal liver while tomato paste may have decreased the solubilization of Hg from lake trout. Notably, none of the food modifiers consistently lowered Hg bioaccessibility from all of the tested country foods. Of the treatments that demonstrated less than additivity in Hg bioaccessibility (e.g. Lake Trout+ Tomato Paste; Ringed Seal Meat+ Sculpin Eggs), none resulted in Se bioaccessibility less than additive. Therefore, the decreased Hg bioaccessibility noted in these treatments was not likely driven by complexation with selenium. Unexpectedly, most binary mixtures showed less than additivity in terms of Se bioaccessibility. Accordingly, more often than not, the presence of a food modifier within the in vitro extraction fluid decreased the Se bioaccessibility of country foods (Table 5). For example, seaweed co-digested with Eider duck egg whites reduced Se bioaccessibility by three-fold (seaweed).

Table 4. Selenoneine and total selenium content of beluga mattaaq samples from Nunavik and Nunavut.

Location	Selenoneine (µg Se g^{-1}) wet weight	Total Se (µg Se g^{-1}) wet weight	% Selenoneine of total Se
Nunavik	1.8 (1.2 - 7.4)*	3.5 (2.7 - 10.2)	55 (45 - 74)
Arviat, Nunavut	2.9 (0.8 - 6.4)	4.6 (4.2 - 10.7)	50 (18 - 63)

* Median (range)

Table 5. In vitro extractions of Inuit traditional foods in binary mixtures with berries, seaweed, tomato paste, and sculpin eggs for the measurement bioaccessible Hg (ppb) and Se (ppb).

Country Food[1]	Treatment[1,2]	n	Hg IVBA, ppb (Mean ± SD)	Interaction Type[3]	Se IVBA, ppb (Mean ± SD)	Interaction Type[3]
Beluga nikku	BMAD;BB	4	61.4 ± 21.7	Additive	36.7 ± 16.1	Additive
	BMAD+BB		57.5 ± 24.8		36.1 ± 9.63	
	BMAD;SW	4	62.7 ± 23.8	Additive	34.4 ± 13.8	Additive
	BMAD+SW		57.5 ± 24.8		36.1 ± 9.63	
	BMAD;TO	3	64.2 ± 36	Additive	23.2 ± 9.61	<Additive
	BMAD+TO		57.7 ± 24.8		37.6 ± 9.72	
Eider duck Egg white	EDW;BB	3	24.8 ± 7.81	Additive	14.2 ± 10.6	<Additive
	EDW+BB		22.6 ± 7.18		21.4 ± 7.2	
	EDW;SW	3	26 ± 9.6	Additive	7.05 ± 4.93	<Additive
	EDW+SW		22.6 ± 7.18		21.4 ± 7.21	
	EDW;TO	3	25.7 ± 7.5	Additive	13.2 ± 8.58	<Additive
	EDW+TO		22.8 ± 7.2		22.8 ± 7.32	
Lake Trout	LT;BB	3	58.1 ± 18.2	Additive	5.44 ± 1.37	<Additive
	LT+BB		57.1 ± 15.2		9.74 ± 2.86	
	LT;SW	3	44.9 ± 16.2	Additive	5.58 ± 2.24	<Additive
	LT+SW		57.1 ± 15.2		9.74 ± 2.87	
	LT;TO	3	34.2 ± 8.81	<Additive	9.67 ± 3.66	Additive
	LT+TO		57.4 ± 15.2		11.2 ± 3.15	
Beluga meat (raw)	BMR;BB	3	41 ± 20.9	Additive	28.6 ± 8.6	Additive
	BMR+BB		35 ± 15.9		27.2 ± 4.63	
	BMR;SW	3	35 ± 14.1	Additive	27.6 ± 4.71	Additive
	BMR+SW		35 ± 15.9		27.2 ± 4.64	
	BMR;SE	3	42.2 ± 15.5	Additive	43.6 ± 0.749	<Additive
	BMR+SE		35.3 ± 15.9		63.3 ± 9.89	
	BMR;TO	3	44.8 ± 18.4	>Additive	15.9 ± 1.52	<Additive
	BMR+TO		35.3 ± 15.9		28.7 ± 4.81	
Ringed seal liver	RSL;BB	3	78.8 ± 16.1	Additive	211 ± 28.1	>Additive
	RSL+BB		100 ± 17.2		159 ± 30.1	
	RSL;SW	3	94 ± 21.9	Additive	230 ± 30	>Additive
	RSL+SW		100 ± 17.2		159 ± 30.1	
	RSL;SE	3	67.8 ± 15.6	<Additive	167 ± 15.2	Additive
	RSL+SE		101 ± 17.2		195 ± 31.3	
	RSL;TO	3	88.5 ± 14.2	Additive	156 ± 9.06	Additive
	RSL+TO		101 ± 17.2		160 ± 30.1	

1. BMAD - Beluga nikku; BMR - Raw beluga meat; RSL - Ringed seal liver; RSM - Ringed seal muscle; EDW - Eider duck egg white; BB - Blueberries, LT - Lake trout; SW: Seaweed; SE: Sculpin eggs; TO: Tomato paste
2. Treatment codes including “;” represent co-digest binary mixtures while codes including “+” represent the sum of the bioaccessible fractions from single food extractions
3. “<Additive”: the co-digest mixture is <75% of the sum of the bioaccessible fractions of single food extractions; “Additive”: the co-digest mixture is ±25% of the sum bioaccessible fractions of single food extractions; “>Additive” ”: the co-digest mixture is >125% of the sum of the bioaccessible fractions of single food extractions.

Section 3 of the project

Increasing evidence is showing that the composition of our gut bacteria is determined by our diet and this composition will in turn affect our health. We have developed a new human study to investigate mercury absorption from country food and how the microflora will interact with mercury absorption. This will be the first study to focus on the benefits of country food on human gut health among Inuit. We plan to conduct three trials in the three Inuit regions starting with Inuvik and Iqaluit during the first year (2016-2017), and in Kuujjuaq during the second year (2017-2018). At each site, we will recruit 30 volunteer participants who will be fed country foods for 14 days. Stool, hair, blood and urine samples will be collected from each participant before and after the trial and also at 14 days after the trial. A comprehensive suite of chemical, biochemical and molecular tests will be performed on the samples. The aim of our study is to address the concern of northerners about mercury contamination of country foods and to gain more insights into how consuming country foods can interact with gut pathogens such as *H. pylori*. We will also assess the risk of parasites in country foods. A proposal was submitted to NCP for funding support of this project in January 2016.

Section 4 of the project

Results of selenoneine analysis in RBCs of Inuit NHS 2004 participants revealed elevated concentrations of this compound in red blood cells. In fact, in participants with total Se concentrations greater than 1000 µg/L, selenoneine is the major contributor to total blood Se concentration. Analyses of beluga mattaaq samples from two arctic locations indicate that this country food is rich in selenoneine and likely the major source of this selenocompound in the Inuit diet. Additional analyses in other country foods are underway to provide a complete picture of selenoneine sources in the Inuit diet. In March of 2016, in view of these remarkable and unique results, communication activities were held in Kuujjuaq and in Puvirnituq to start discussing their implications for public health in the North. Interestingly, a group of hunters that we met in Puvirnituq mentioned that the nutritional qualities of beluga mattaaq were already known by Inuit. Hunters were nevertheless appreciative of the study results as they are bringing quantitative data to support the value of a long-lasting dietary habit in this population. Preliminary results from another NCP Project (Muckle, Lemire et al) suggest that higher Se intake may mitigate MeHg neurodevelopmental and neuromotor toxic effects in children. Thanks to the present project, selenoneine analysis of the archived samples of the Nunavik Child Development Study is underway. Findings from both projects will be integrated and discussed with our Northern partners for them to eventually revise public health recommendations with respect to Hg and country foods in Nunavik.

Discussion and Conclusions

As mentioned in last year's synopsis, plasma Se concentrations documented in Inuit adults were not exceptionally elevated compared to other North American populations. In contrast, whole blood concentrations were higher than plasma concentrations, with several Inuit exhibiting total blood Se levels exceeding 1000 µg/L. We have now completed selenoneine analyses in all NHS participants and our results clearly indicate that selenoneine is a major Se species in Inuit adult blood. We also found very high levels of this compound in beluga mattaaq samples, which is likely the major dietary source of selenoneine in this population. Interestingly, both selenoneine and methylmercury accumulate in red blood cells of Inuit. Palmer and Parkin (2015) recently provided evidence that selenoneine could demethylate methylmercury. We speculate that in situ demethylation occurs, leading to a decrease in the distribution of methylmercury to target organs. We are presently designing an experimental study to test the hypothesis that selenoneine pretreatment during gestation decreases fetal brain exposure to methylmercury and in turn neurotoxicity.

In the bioaccessibility experiments none of the food mixtures tested using the in vitro extraction model appeared particularly effective at decreasing Hg bioaccessibility. In fact, the food modifiers appeared to be more effective at lowering the bioaccessibility of Se rather than Hg. Although food modifiers occasionally appeared to alter metal bioaccessibility, the effect sizes were relatively small (+10% on average for Hg; -14% on average for Se). These results support the continued derivation and use of Hg and Se bioaccessibility estimates from individual foods (i.e. rather than meals) in risk assessment. This is important because it would be exceptionally challenging to incorporate mixture-based bioaccessibility measures into exposure characterizations. Additionally, these results suggest that the prospect of decreasing Hg exposure reduction in Hg bioaccessibility mediated from specific dietary constituents appears unlikely. Furthermore, it is worth noting that alterations in bioaccessibility observed using the in vitro extraction model do not necessarily mean that bioavailability would similarly be impacted. Also, it is possible for nutrients to mitigate Hg toxicity without affecting luminal Hg bioaccessibility. Consequently, in vivo models may provide a more robust approach to evaluate nutrient-mercury interactions.

In conclusion, we found elevated concentrations of selenoneine in red blood cells of Inuit and in beluga mattaaq samples from two arctic locations. We are currently reanalysing results from NHS 2004 and the Nunavik Child Development Study (see synopsis by Muckle, Lemire et al.) to examine the possible protection afforded by selenoneine on methylmercury-induced toxicity.

Expected Project Completion Date

March 2017

Acknowledgments

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References

AMAP, 2011. AMAP Assessment 2011: Mercury in the Arctic Arctic Monitoring Assessment Program (AMAP), Olso.

Ayotte, P., et al. 2011. Relation between methylmercury exposure and plasma paraoxonase activity in inuit adults from Nunavik. *Environ. Health Perspect.* 119: 1077-1083.

Blanchet, C., Rochette, L. 2008. *Nutrition and food consumption among the Inuit of Nunavik. Nunavik Inuit Health Survey 2004 Quanuippitaa? How are we?* Quebec: Institut national de santé publique du Québec, Nunavik Regional Board of Health and Social Services Quebec, 143 pp.

Boucher, O., et al. 2010. Prenatal exposure to methylmercury and PCBs affects distinct stages of information processing: An event-related potential study with Inuit children. *Neurotoxicol.* 31: 373-384.

Chateau-Degat, M. L., et al, 2010. Effects of perfluorooctanesulfonate exposure on plasma lipid levels in the Inuit population of Nunavik (Northern Quebec). *Environ. Res.* 110: 710-717.

Clarkson, T. W. 2002. The three modern faces of mercury. *Environ. Health Perspect.* 110 Suppl 1: 11-23.

Counil, E., et al. 2009. Association between trans-fatty acids in erythrocytes and pro-atherogenic lipid profiles among Canadian Inuit of Nunavik: possible influences of sex and age. *Br J Nutr.* 102: 766-776.

Dewailly, E., et al. 2001. n-3 Fatty acids and cardiovascular disease risk factors among the Inuit of Nunavik. *Am. J. Clin. Nutr.*. 74: 464-473.

Gammelgaard, B., et al. 2012. Estimating Intestinal Absorption of Inorganic and Organic Selenium Compounds by in Vitro Flux and Biotransformation Studies in Caco-2 Cells and ICP-MS Detection. *Biol. Trace Ele. Res.* 145: 248-256.

Hwang, H. J., Shim, S. M. 2008. Impact of sodium copper chlorophyllin on mercury absorption using an in vitro digestion with human intestinal cell model. *Food Sci. Biotechnol.* 17: 564-568.

Ikemoto, T., et al. 2004. Detoxification mechanism of heavy metals in marine mammals and seabirds: interaction of selenium with mercury, silver, copper, zinc, and cadmium in liver. *Arch. Environ. Contam. Toxicol.* 47: 402-413.

Khan, M. A. K., Wang, F. Y. 2009. Mercury-selenium compounds and their toxicological significance: towards a molecular understanding of mercury-selenium antagonism. *Environ. Toxicol. Chem.* 28: 1567-1577.

Klein, M., et al. 2011. Identification in human urine and blood of a novel selenium metabolite, Se-methylselenoneine, a potential biomarker of metabolization in mammals of the naturally occurring selenoneine, by HPLC coupled to electrospray hybrid linear ion trap-orbital ion trap MS. *Metallomics.* 3: 513-20.

Laird, B. D., et al. 2009. Bioaccessibility of mercury from traditional northern country foods measured using an in vitro gastrointestinal model is independent of mercury concentration. *Sci. Tot. Environ.* 407: 6003-6008.

Lemes, M. and F.Y. Wang. 2009. Methylmercury speciation in fish muscle by HPLC-ICP-MS following enzymatic hydrolysis. *J. Anal. Atom. Spectr.* 24: 663-668.

Lemire, M., et al. 2010. Selenium and mercury in the Brazilian Amazon: opposing influences on age-related cataracts. *Environ. Health Perspect.* 118: 1584-1589.

Lemire, M., et al. 2011. Selenium from dietary sources and motor functions in the Brazilian Amazon. *Neurotoxicology.* 32: 944-953.

Lemire, M., et al. 2015. Local country food sources of methylmercury, selenium and omega-3 fatty acids Nunavik, Northern Quebec. *Sci. Tot. Environ.* 509-510: 248-259.

Newgard, C.B., et al. 2009. A branched-chain amino acid-related metabolic signature that differentiates obese and lean humans and contributes to insulin resistance. *Cell. Metab.* 9: 311-326.

Palmer, J.H., Parkin, G. 2015. Protolytic cleavage of Hg–C bonds induced by 1-Methyl-1,3-dihydro-2H-benzimidazole-2-selone: synthesis and structural characterization of mercury complexes. *J. Am. Chem. Soc.* 137: 4503–4516.

Pluskal, T., et al. 2014. Genetic and metabolomic dissection of the ergothioneine and selenoneine biosynthetic pathway in the fission yeast, S pombe, and construction of an overproduction system. *PLoS One*. 9: e97774.

Rayman, M. P., et al. 2008. Food-chain selenium and human health: spotlight on speciation. *Br. J. Nutr.* 100: 238-253.

Reeves, M. A., and P. R.Hoffmann. 2009. The human selenoproteome: recent insights into functions and regulation. *Cell. Mol. Life Sci.* 66: 2457-2478.

Steinbrenner, H., et al. 2011. High selenium intake and increased diabetes risk: experimental evidence for interplay between selenium and carbohydrate metabolism. J. *Clin. Biochem. Nutr.* 48: 40-45.

Stranges, S., et al. 2010. Selenium status and cardiometabolic health: state of the evidence. *Nutr. Metab. Cardiovasc. Dis.* 20: 754-60.

Twaroski, T. P., et al. 2001. Effects of selected polychlorinated biphenyl (PCB) congeners on hepatic glutathione, glutathione-related enzymes, and selenium status: implications for oxidative stress. *Biochem. Pharmacol.* 62: 273-281.

Valera, B., et al. 2009. Environmental Mercury Exposure and Blood Pressure Among Nunavik Inuit Adults. *Hypertension (Baltimore)*. 54: 981-986.

Wang, T.J., et al. 2011. Metabolite profiles and the risk of developing diabetes. *Nat. Med.* 17: 448-453.

Wang, T.J., et al. 2013. 2-Aminoadipic acid is a biomarker for diabetes risk. *J. Clin. Invest.* 123: 4309-4317.

Xia, Y. M., et al., 2010. Optimization of selenoprotein P and other plasma selenium biomarkers for the assessment of the selenium nutritional requirement: a placebo-controlled, double-blind study of selenomethionine supplementation in selenium-deficient Chinese subjects. *Am. J. Clin. Nutr.* 92: 525-531.

Yamashita, Y. and M. Yamashita. 2010. Identification of a novel selenium-containing compound, selenoneine, as the predominant chemical form of organic selenium in the blood of bluefin tuna. *J. Biol. Chem.* 285: 18134-18138.

Yamashita, .M, Y., et al. 2013. Identification and determination of selenoneine, 2-selenyl-N α , N α , N α -trimethyl-L-histidine, as the major organic selenium in blood cells in a fish-eating population on remote Japanese Islands. *Biol Trace Elem Res.* 156: 36-44.

Zwolak, I., and H. Zaporowska. 2012. Selenium interactions and toxicity: a review. Selenium interactions and toxicity. *Cell Biol. Toxicol.* 28: 31-46.

Is high Se intake from marine diet during pregnancy and childhood neurotoxic or mitigating the adverse effects of MeHg exposure on child development?

Un apport élevé de sélénium provenant du réseau trophique marin pendant la grossesse et l'enfance a-t-il un effet neurotoxique ou atténue-t-il les effets indésirables de l'exposition au méthylmercure sur le développement de l'enfant?

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Abstract

Prenatal exposure to methylmercury (MeHg) is associated with adverse effects on child development. The Inuit from Nunavik are one of the mosthighly exposed populations to MeHg, due to their high consumption of predatory fish and marine mammals, which can bioaccumulate high concentrations of MeHg. In school age Inuit children from Nunavik, prenatal MeHg exposure has been related to poorer visual and intellectual functions and greater risk of behavioural and attention problems. Since fish and marine mammals are also exceptionally rich in essential nutrients such as selenium (Se), the Inuit also have the highest blood Se concentrations in the world. In fish-eating

Résumé

L'exposition prénatale au méthylmercure (MeHg) est associée à des effets indésirables sur le développement de l'enfant. Les Inuits du Nunavik sont parmi les populations les plus exposées au méthylmercure en raison de leur fréquente consommation de poissons prédateurs et de mammifères marins, lesquels peuvent accumuler dans leurs organismes des concentrations élevées de ce polluant. Chez les enfants d'âge scolaire du Nunavik, l'exposition prénatale au méthylmercure est associée à des déficiences visuelles et intellectuelles ainsi qu'à une augmentation du risque de troubles du comportement ou de l'attention. Les poissons de mer et les mammifères marins sont

adult populations, there is increasing evidence suggesting that high Se intake may play a role in mitigating some of the negative effects of MeHg. High Se may exert beneficial effects on the same health outcomes affected by MeHg. In addition, Se may partially mitigate damaging pro-oxidant effects of MeHg and/or directly bind to MeHg or to inorganic Hg, reducing MeHg's availability for target proteins and organs.

The Nunavik Child Development Study (NCDS) is a mother-child cohort conducted in Nunavik over the last 20 years involving the monitoring of prenatal exposure from cord blood, and follow-up of children at 12 months of age, 5- and 11- years old. We have started to re-analyze the NCDS data in order to evaluate Se neurotoxicity and mitigating effects of Se on MeHg neurotoxicity in children at 5 and 11 years old, and to estimate dietary sources of Se intake among 11 year-old children in Nunavik. Blood selenoneine analyses in archived NCDS cord blood and 11 year-old child blood samples were added to the study design as Inuit with high blood concentrations of Se mostly had Se in the form of selenoneine, a strong anti-oxidant with potential detoxifying MeHg effects. These statistical and laboratory analyses are underway and manuscripts will be published shortly.

aussi particulièrement riches en nutriments essentiels comme le sélénium, ce qui fait que l'on enregistre chez les Inuits les concentrations sanguines de sélénium les plus élevées au monde. En ce qui concerne les populations adultes qui se nourrissent de poissons et de mammifères marins, une quantité croissante de données probantes donnent à penser qu'un apport élevé en sélénium pourrait jouer un rôle dans l'atténuation de certains des effets négatifs de l'exposition au méthylmercure. De fortes concentrations de sélénium pourraient avoir des effets bénéfiques sur la santé des personnes exposées au méthylmercure. En outre, il est possible que le sélénium atténue une partie des effets pro-oxydants du méthylmercure ou se lie directement à ce polluant ou au mercure inorganique, réduisant ainsi la quantité de méthylmercure se retrouvant dans les protéines et les organes.

L'étude NCDS (Nunavik Child Development Study) vise une cohorte de mères et d'enfants et a été réalisé au Nunavik au cours des 20 dernières années afin de surveiller l'exposition prénatale à partir du sang ombilical et d'assurer un suivi lorsque les enfants ont 12 mois, 5 ans et 11 ans. Nous avons lancé une nouvelle analyse des données de la NCDS afin de mieux comprendre la neurotoxicité du sélénium et les effets de cet élément sur la neurotoxicité du méthylmercure chez les enfants de 5 ans et de 11 ans, et de déterminer les sources alimentaires de l'apport en sélénium chez les enfants de 11 ans au Nunavik. Des analyses de la sélénonéine présente dans le sang ombilical et dans les échantillons de sang des enfants de 11 ans ont été ajoutées au plan de l'étude, car les Inuits ayant de fortes concentrations sanguines de sélénium présentaient essentiellement de forts taux de sélénonéine, un puissant antioxydant qui pourrait atténuer les effets toxiques du méthylmercure. Les analyses statistiques et les analyses de laboratoire sont en cours. Les résultats préliminaires seront publiés sous peu.

Key messages

- This study aimed to re-analyse the Nunavik Child Development Study (NCDS) data in order to evaluate Se neurotoxicity and Se effects on MeHg neurotoxicity in children at 5 and 11 years old
- This study estimated dietary sources of Se intake among 11 year-old children in Nunavik
- Blood selenoneine analysis in archived NCDS blood samples were added to the study design and are underway
- All study results will be available, presented to the Nunavik population and published in fall 2016 – winter 2017

Messages clés

- L'étude consiste à faire une nouvelle analyse des données de l'étude NCDS (Nunavik Child Development Study) afin de déterminer la neurotoxicité du sélénium et ses effets sur la neurotoxicité du méthylmercure chez les enfants de 5 et 11 ans.
- L'étude ciblait les sources de sélénium dans l'alimentation des enfants de 11 ans qui vivent au Nunavik.
- L'analyse des taux de sélénonéine dans les échantillons sanguins de l'étude NCDS a été ajoutée au plan de l'étude et est en cours.
- Tous les résultats des études seront présentés aux résidants du Nunavik et publiés à l'automne 2016 ou à l'hiver 2017.

Objectives

The objectives of the proposal were to re-analyse NCDS data in order to:

1. Study the association between prenatal and current Se status (5- and 11-yr blood) and neurobehavioral outcomes (cognitive, behavioral, visual, motor) in children at 5 and 11 years of age, and establish (if any) the threshold of Se neurotoxicity among children with high Se status;
2. Study how prenatal MeHg neurodevelopmental toxicity (cognitive, behavioral, visual, motor) in children at 5 and 11 years of age is mitigated by prenatal and current Se status;
3. Estimate dietary sources of Se intake among 11-year old children.

Introduction

Se is an essential element, and more than 25 different selenoproteins have been identified in humans. Several are known to be involved in antioxidant defense, regulation of redox status, and immune, inflammatory, and thyroid functions (Reeves and Hoffmann 2009). Recently, a novel small Se-molecule, selenoneine, has been identified as one of the major organic form of Se found in blood cells of a Japanese fish-eating population (Yamashita et al. 2013). This Se-analog to ergothioneine, a powerful antioxidant, could also contribute to the scavenging of reactive oxygen species involved in chronic diseases etiology and/or to counteract MeHg toxicity.

Both Se deficiency and excess may lead to neurologic disorders. Low Se status in the elderly has been associated with reduced coordination, motor speed and muscle strength, and accelerated cognitive decline (Akbaraly et al. 2007; Beck et al. 2007; Berr 2000; Gao et al. 2007; Lauretani et al. 2007; Shahar et al. 2010).

Conversely, in the 1970-80's, hair and nail loss, skin lesions, garlic breath, and gastro-intestinal disorders have been linked to excessive Se exposure (blood Se above 1000 µg/L) among Chinese adults using mineral coal naturally rich in Se for cooking, soil amending and heating purposes. In a particularly heavily affected Chinese village, where blood Se levels ranged from 1300 to 7500 µg/L, polyneuropathy and paraesthesia (sensory and motor losses) were also reported (Poirier 1994; Yang et al. 1983). In this context, excessive Se intake was from multiple sources (food, water and/or air) with a high proportion of inorganic Se (water and air) (Liu et al. 2007). To our knowledge, no studies have documented the effects of high prenatal or childhood Se status on neurobehavioral development.

In 2004, the median blood Se status in Inuit adults of Nunavik was 261 µg/L (range: 126-3553 µg/L). Exceptionally high Se status is also reported among Inuit adults from Greenland, Nunavut, Nunatsiavut and Inuvialuit Settlement Region (Hansen et al. 2004; Laird et al. 2013). In the NCDS cohorts, Se status was likewise high and presented a very large range, but decreased among children at 11 years of age (see Table 1).

In Nunavik, marine foods such as beluga mattaaq (skin and blubber), marine mammal organs, walrus meat and fish eggs are exceptional sources of Se, containing on average between 1.0 and 7.0 µg/g; these levels are much higher than those found in commercial foods, which usually never exceed 0.8 µg/g (Lemire et al. 2015; Rayman 2012). In Nunavik, beluga mattaaq was found to be marine food most highly contributing to Se intake among Inuit adults and during pregnancy (in the first NCDS cohort) (Lemire et al. 2015; Muckle et al. 2001a). However, no study has documented dietary sources of Se during Inuit childhood.

In the 1990's, National Institute of Environmental Health Sciences (NIEHS) funded two prospective, longitudinal studies on lower level prenatal MeHg exposure: one in the Faroe Islands in the North Atlantic (Grandjean et al. 1997b), and the other in the Seychelles Islands in the Indian Ocean (Davidson et al. 1998). The primary source of MeHg exposure in the Faroes was pilot whale meat, while the primary source in the Seychelles was marine fish. Although levels of MeHg exposure were similar in the two cohorts, they yielded contradictory findings. The Faroes study found significant associations between prenatal MeHg exposure and poorer cognitive and fine motor function in childhood and adolescence (Debes et al. 2006b; Grandjean et al. 1997b), but the Seychelles study did not (Davidson et al. 1998; Myers et al. 2003). In the NCDS cohorts, we have reported several adverse neurodevelopmental outcomes at levels of MeHg exposure similar to the Faroes and Seychelles studies (summarized in *Results – Obj. 2).*

One explanation for these contradictory findings is that high long-chain polyunsaturated fatty acids (PUFA) intake during pregnancy and childhood may act as a confounder on the associations between MeHg and adverse neurodevelopmental outcomes (Rice et al, 2008; Karagas et al., 2012). A second explanation is the high Se status found in marine mammal eating-populations, and to lower extent in fish-eating populations, although most evidence for now are primarily among adult populations (Ayotte et al, 2011; Fillion et al, 2013; Lemire et al, 2010; Lemire et al 2011; Valera et al, 2009). First, like PUFA, Se may act as a negative confounder on the associations between MeHg and toxic outcomes. Moreover, Se may partially mitigate deleterious pro-oxidant effects of MeHg and/or directly bind to MeHg or to inorganic Hg following *in situ* demethylation, reducing its availability for target proteins and organs (Khan and Wang, 2009).

In the Faroe Islands, Se status is lower than Nunavik (mean cord blood Se: 103 ± 14 µg/L) since they consumed pilot whale meat but not necessarily the skin. Adjustments with cord blood Se neither obscure nor modified the adverse association between cord blood Hg and neurobehavioral deficits in neonates (Steuerwald et al. 2000) nor in children at 7 years old (Choi et al. 2008). Cord blood Se associations with the outcomes as an independent variable was never reported. To our knowledge, none of the Seychelles cohort studies measured prenatal or postnatal Se status.

For the present work, our aim was to re-analyse NCDS data in order to evaluate Se neurotoxicity and mitigating effects of Se on MeHg neurotoxicity in children at 5 and 11 years old, and to estimate dietary sources of Se intake among 11 year-old children in Nunavik.

Activities in 2015-2016

Data and samples analyses

– **Data analyses**
NCDS data re-analyses are being conducted by an experienced data analyst, Dr Olivier Boucher, which has worked with this dataset since several years. Objective 2 was addressed first, followed by the Objective 1, for which analyses are still on-going. Data analyses for the Objective 3 are also underway.

– **Blood samples re-analyses**
Ayotte, Lemire et al. (see Ayotte et al, 2015-2016 NCP research synopsis) recently showed exceptionally high selenoneine concentrations in red blood cells of Inuit adults (in Qanuippitaa 2004 archived samples). The percentage of selenoneine over total Se significantly increased with total Se concentration in whole blood. In addition, high selenoneine concentrations were found in beluga mattaaq, the primary source of dietary Se among Inuit adults. These data also highlight that Inuit adults with total blood Se below 200µg/L had no detectable concentrations of selenoneine in their blood, suggesting that those that don't often consume marine foods, and particularly beluga mattaaq, get a mild Se intake from other food sources (vegetal, terrestrial animal, freshwater fish) which contain other form of Se than selenoneine.

Therefore, blood selenoneine analyses in archived NCDS blood samples were added to the present study objectives in order to confirm these findings in the NCDS cohort (cord blood (n=100) and 11 years-old children's blood (n=100, of which 86 are paired cord blood - child blood samples)).

Communications

– **NNHC – February 2016**
Findings from the objective 2 (see Result's section) were carefully presented to NNHC members last February. These findings were presented just after Ayotte et al. findings on selenoneine (see Ayotte et al, 2015-2016 NCP research synopsis). Several questions and comments were raised, since these new and positive findings on marine country foods properties may have a significant impact on actual dietary recommendations on MeHg dietary sources and overall country food promotion activities. Conversely, at that time, objective 1 analyses were not fully completed. Therefore, it was collectively decided to primarily focus our communication activities in Nunavik in March 2016 (Kuujjuaq and Puvirnituq) on our most recent findings on selenoneine in Inuit adults' blood and beluga mattaaq. We aim to present our latest study findings at the next NNHC meeting in June 2016. In the coming months, a communication plan for the presentation of final study results to the Nunavik population will be developed with our Nunavik partners.

– **ArcticNet – December 10th, 2015, Vancouver – Community Health and Well Being 1st session**
Gina Muckle, Mélanie Lemire, Dave Saint-Amour, Pierre Ayotte, Olivier Boucher
« Is high Se intake from marine diet during pregnancy and childhood mitigating the adverse effects of MeHg exposure on neurobehavioral development at school age? »

– **Association francophone pour le savoir-ACFAS– May 10th, 2016 (9am-5pm) - Colloque 103 - Neuropsychotoxicologie environnementale : un mariage interdisciplinaire heureux**
Mélanie Lemire (invited speaker), Gina Muckle, Dave Saint-Amour, Pierre Ayotte, Olivier Boucher.« *Est-ce que le sélénium de l'alimentation marine chez les Inuits atténue les effets néfastes de l'exposition au méthylmercure sur le développement de l'enfant?* »

- G. Muckle (invited speaker). *« Contaminants environnementaux et développement de l'enfant inuit : 20 années de collaboration interdisciplinaire »*.
- **Manuscripts in preparation**
  Two manuscripts presenting the objective 2 and the objective 1 findings separately are envisioned. The first manuscript (for Objective 2) is already in preparation. The selenoneine data will be included into this first manuscript, while objective 3 findings will also probably be included into the supplementary material section of this manuscript.

Traditional Knowledge Integration

Pure traditional knowledge was not integrated to the NCDS research protocol and methods but working so closely with many Inuit women for long periods of time during data collection allowed to initiate discussions on many issues and deepened our understanding of socio-familial factors related to child development.

Results

- **Objective 1 – Mitigating effect of Se on MeHg neurotoxicity**

We have previously shown that prenatal MeHg exposure is associated with adverse effects on cognitive function (Jacobson et al., 2015), attention in the classroom (Boucher et al., 2012), and visual function – as assessed with visual evoked potentials –in school-aged Inuit children (Éthier et al., 2012), whereas postnatal MeHg exposure is associated with impaired fine motor function (Boucher et al., in preparation). It has been hypothesized that Se may protect against or mitigate these MeHg effects. We intended to determine the impact of Se levels on the adverse effects associated with MeHg exposure on cognitive function (WISC-IV), attention in the classroom (CBCL), visual function (contrast sensitivity visual evoked potentials; VEPs) and fine motor function (Finger Tapping Test) by using two different statistical approaches. In a first set of analyses (conventional approach), hierarchical linear regression analyses were conducted to examine the effect of adding Se to the statistical model, on the association between mercury and each child outcome, after controlling for a set of mandatory covariates. Then, the interaction between mercury and Se was tested statistically at the last step of the regression model. In the vast majority of cases, adding Se to the regression resulted in a slight increase in the association between mercury and child outcomes. There was a significant MeHg x Se interaction effect on visual function, as assessed with the amplitude of the N75 VEP potential, indicating stronger mercury effects with lower Se levels ($p = 0.03$). In a second set of statistical analyses (stratified approach), linear regression models for the relation of mercury to child outcomes were conducted separately for each tertile of Se concentrations. Among children within the first tertile of cord blood Se concentrations, cord blood mercury was adversely associated with lower Full Scale IQ and Perceptual Reasoning Index, $p < 0.05$), and smaller amplitude of the N75 VEP component ($p < 0.05$). Among children within the first tertile of blood Se concentrations at the time of testing, blood mercury concentrations were associated with poorer fine motor function ($p < 0.05$). However, no significant association between cord and child blood mercury concentrations and child outcomes among children was found for the second or third tertiles of Se concentrations.

These results suggest that higher blood Se concentrations protect against the neurotoxic effects of MeHg during the prenatal and postnatal periods.

- **Objective 2 – Se and neurobehavioral outcomes**

We examined the potential neurotoxic effects of prenatal and postnatal Se exposure by exploring the associations between Se concentrations and a comprehensive neurodevelopmental assessment composed of cognitive function testing (WISC-IV), teacher ratings of child's behavior in classroom (CBCL), visuo-motor integration (Stanford-Binet Copy subtest), verbal learning (CVLT-II for children), fine motor function (Finger Tapping Test and Santa-Ana Form Board test), and visual function (contrast sensitivity VEPs). Linear regression analyses were conducted to examine the relation between cord and child Se concentrations and each child outcome after controlling for potential confounders. There was no significant association between Se concentrations in cord blood and any neurodevelopmental measure (all *p*s > 0.05). Conversely, Se concentrations in the child's blood at testing were negatively associated with externalizing problems as reported by the classroom teacher ($p < 0.05$). Supplemental analyses of covariance (ANCOVAs) were conducted to test for differences between children with higher Se levels and those with lower levels (median split) after statistical control for confounders. Children with higher Se levels in cord blood have significantly higher Processing Speed Index on the WISC-IV ($p < 0.05$) than children with cord blood Se lower levels. Furthermore, children with higher Se levels at time of testing had significantly lower externalizing problems according to their classroom teacher, in comparison to children with lower levels.

For now, these results suggest that blood Se levels in Inuit children from Nunavik are not associated with adverse neurotoxic effects. Statistical analyses are still on-going.

- **Objective 3 – Dietary sources of Se among 11 year-old children**

These analyses are still in progress. Preliminary analysis show that the correlation between child blood Se at 11 years old with marine mammal consumption is stronger (Spearman $\rho = 0.45$, $p < 0.01$) than for fish, molluscs, seaweeds, caribou, wildfowl and wild berry consumption (Spearman $\rho < 0.26$). As previously reported by our team among Inuit adult population (Lemire et al, 2015), blood Se concentrations in cord blood and at 11 years old are significantly higher in the Hudson Strait villages (see Table 1), were most of marine mammal hunting and consumption take place in Nunavik.

Discussion and Conclusions

This study aimed at re-analysing Nunavik Child Development Study (NCDS) data in order to evaluate Se neurotoxicity and Se mitigating effects on MeHg neurotoxicity in children at 5 and 11 years old, and to estimate dietary sources of Se intake among 11 year-old children in Nunavik. Data analyses are almost completed. Blood selenoneine analysis in archived NCDS blood samples were added to the study design and are underway. Study results will be presented to the Nunavik population in the next months and later published (Fall 2016 - Winter 2017).

Table 1: Cord and 11 years-old child Se blood concentrations by Nunavik regions

Nunavik regions	Cord blood Se (µg/L)					Child blood Se at 11 years old (µg/L)			
	n	Mean ± SD	Median	Range		n	Mean ± SD	Median	Range
Eastern Hudson Bay	155	310 ± 149	261	156 – 1105		163	193 ± 49	182	73 ± 458
Hudson Strait	37	480 ± 269	414	112 – 1579		38	289 ± 181	233	71 – 948
Ungava Bay	70	307 ± 123	268	152 – 687		83	174 ± 71	166	68 – 490

Expected Project Completion Date

Data analysis and blood samples re-analysis for selenoneine concentrations will be completed by June 2016. Overall study findings will be presented to the Nunavik population in fall 2016, while manuscripts will be published by December 2016 – March 2017.

Project website

A short project summary will be described here: melanielemire.weebly.com (to be published in June 2016).

References

Akbaraly N.T., I. Hininger-Favier, I. Carrière, J. Arnaud, V. Gourlet V, A.M. Roussel, et al. 2007. Plasma selenium over time and cognitive decline in the elderly. *Epidemiol.* 18:52-58.

Ayotte P., a. Carrier, N. Ouellet, V. Boiteau, B. Abdous, E.A. Sidi et al. 2011. Relation between methylmercury exposure and plasma paraoxonase activity in inuit adults from Nunavik. *Environ. Health Perspect.* 119:1077-1083.

Beck J., L. Ferrucci L, K. Sun K, J. Walston J, L.P. Fried, R. Varadhan, et al. 2007. Low serum selenium concentrations are associated with poor grip strength among older women living in the community. B*ioFactors* 29:37-44.

Berr C. 2000. Cognitive impairment and oxidative stress in the elderly: Results of epidemiological studies. *BioFactors* 13:205-209.

Boucher O, Jacobson SW, Plusquellec P, Dewailly E, Ayotte P, Forget-Dubois N, et al. 2012. Prenatal methylmercury and postnatal lead exposure: Risk factors for attention deficit hyperactivity disorder among inuit children in arctic Quebec. *Environ. Health Perspect.* 120:1456-1461.

Boucher O., G. Muckle, P. Ayotte, E. Dewailly, S.W. Jacobson, J.L. Jacobson. Altered Fine Motor Function in Children Exposed to PCBs, methylmercury, and lead. *In preparation*

Choi A.L., E. Budtz-Jørgensen, P.J. Jørgensen, U. Steuerwald, F. Debes, P. Weihe, et al. 2008. Selenium as a potential protective factor against mercury developmental neurotoxicity. *Environ. Res.* 107:45-52.

Davidson P.W., G. J. Myers , C. Cox, C. Axtell, C. Shamlaye, J. Sloane-Reeves et al. 1998. Effects of prenatal and postnatal methylmercury exposure from fish consumption on neurodevelopment: Outcomes at 66 months of age in the Seychelles child development study. *Jama.* 280:701-707.

Debes F., E. Budtz-Jorgensen, P. Weihe, R.F. White, P. Grandjean. 2006b. Impact of prenatal methylmercury exposure on neurobehavioral function at age 14 years. *Neurotoxicol. Teratol.* 28:536-547.

Ethier A.A., G. Muckle, C. Bastien, E. Dewailly, P. Ayotte, C. Arfken, et al. 2012. Effects of environmental contaminant exposure on visual brain development: A prospective electrophysiological study in school-aged children. *Neurotoxicol.* 33:1075-1085.

Fillion M., M. Lemire, A. Philibert, B. Frenette , H.A. Weiler, J.R. Deguire, et al. 2013. Toxic risks and nutritional benefits of traditional diet on near visual contrast sensitivity and color vision in the brazilian amazon. *Neurotoxicol.* 37:173-181.

Gao S., Y. Jin, K.S. Hall, C. Liang, F.W. Unverzagt , R Ji, et al. 2007. Selenium level and cognitive function in rural elderly chinese. *Am J Epidemiol.* 165:955-965.

Grandjean P., P. Weihe, R.F. White, F. Debes, S. Araki, K. Yokoyama, et al. 1997a. Cognitive deficits in 7-year-old children with prenatal exposure to methylmercury. *Neurotoxicol. Teratol.* 19:417-428.

Grandjean P., P. Weihe, R.F. White, F. Debes, S. Araki, K. Yokoyama, et al. 1997b. Cognitive deficit in 7-year-old children with prenatal exposure to methylmercury. Neurotoxicol Teratol 19:417-428.

Hansen J.C., B. Deutch, H.S. Pedersen. 2004. Selenium status in Greenland Inuit. *Sci. Total Environ.* 331:207-214.

Jacobson J.L., G. Muckle G, P. Ayotte P, É. Dewailly, S.W. Jacobson. 2015. Relation of Prenatal

Methylmercury Exposure from Environmental Sources to Childhood IQ. *Environ. Health Perspect.* 123(8):827-33.

Karagas M.R., A.L. Choi , E. Oken, M. Horvat, R. Schoeny, E. Kamai, et al. 2012. Evidence on the human health effects of low-level methylmercury exposure. *Environ Health Perspect.* 120:799-806.

Khan M.A.K., Wang F. 2009. Mercury-selenium compounds and their toxicological significance: Toward a molecular understanding of the mercury-selenium antagonism. *Environ. Toxicol. Chem.* 28:1567-1577.

Laird B.D., A.B. Goncharov, G.M. Egeland, H.M. Chan. 2013. Dietary advice on inuit traditional food use needs to balance benefits and risks of mercury, selenium, and n3 fatty acids. *J. Nutr.* 143:923-930.

Lauretani F, Semba RD, Bandinelli S, Ray AL, Guralnik JM, Ferrucci L. 2007. Association of low plasma selenium concentrations with poor muscle strength in older community-dwelling adults: The Inchianti study. American Journal of Clinical Nutrition 86:347-352.

Lemire M., M. Fillion, B. Frenette A. Mayer, A. Philibert, C.J.S. Passos, et al. 2010. Selenium and mercury in the Brazilian Amazon: Opposing influences on age-related cataracts. *Environ. Health Perspect.* 118:1584-1589.

Lemire M., M. Fillion, B. Frenette, C.J. Passos, J.R. Guimaraes, F. Jr. Barbosa, et al. 2011. Selenium from dietary sources and motor functions in the brazilian amazon. *Neurotoxicol.* 32:944-953.

Lemire M., M. Kwan, E.A. Laouan-Sidi, G. Muckle, C. Pirkle, P. Ayotte, et al. 2015. Local country food sources of methylmercury, selenium and omega-3 fatty acids nunavik, northern quebec. *Sci. Total Environ.* 509-510:248-59.

Liu GJ, Zheng LG, Duzgoren-Aydin NS, Gao LF, Liu JH, Peng ZC. 2007. Health effects of arsenic, fluorine, and selenium from indoor burning of chinese coal. In: Reviews of Environmental Contamination and Toxicology, Vol. 189, 89-106.

Muckle G., P. Ayotte, E. Dewailly, S.W. Jacobson, J.L. Jacobson. 2001a. Determinants of polychlorinated biphenyls and methylmercury exposure in inuit women of childbearing age. *Environ. Health Perspect.* 109:957-963.

Myers G.J., P.W. Davidson, C. Cox, C.F. Shamlaye, D. Palumbo, E. Cernichiari, et al. 2003. Prenatal methylmercury exposure from ocean fish consumption in the seychelles child development study. *Lancet.* 361:1686-1692.

Poirier K.A.. ed. 1994. Summary of the derivation of the reference dose for selenium. Washington D.C.: ILSI Press.

Rayman M.P. 2012. Selenium and human health. *Lancet.* 379:1256-1268.

Reeves M.A., P.R. Hoffmann. 2009. The human selenoproteome: Recent insights into functions and regulation. *Cellular and Molecular Life Sciences*. 66:2457-2478.

Rice D.C. 2008. Overview of modifiers of methylmercury neurotoxicity: Chemicals, nutrients, and the social environment. *NeuroToxicol*. 29:761-766.

Shahar A., K.V. Patel, R.D. Semba, S. Bandinelli, D.R. Shahar, L. Ferrucci, et al. 2010. Plasma selenium is positively related to performance in neurological tasks assessing coordination and motor speed. *Movement Disorders*. 25:1909-1915.

Steuerwald U., P. Weihe, P.J. Jorgensen, K. Bjerve, J. Brock, B. Heinzow et al. 2000. Maternal seafood diet, methylmercury exposure, and neonatal neurologic function. *J. Pediatr.* 136:599-605.

Valera B., É. Dewailly, P. Poirier. 2009. Environmental mercury exposure and blood pressure among Nunavik Inuit adults. *Hypertension*. 54:981-986.

Yamashita M., Y. Yamashita, T. Ando, J. Wakamiya, S. Akiba. 2013. Identification and determination of selenoneine, 2-selenyl-n alpha , n alpha , n alpha -trimethyl-l-histidine, as the major organic selenium in blood cells in a fish-eating population on remote japanese islands. *Biol. Trace Elem. Res.* 156:36-44.

Yang G., S. Wang, R. Zhou, S. Sun. 1983. Endemic selenium intoxication of humans in china. American *J. Clin. Nutr.* 37:872-881.

Tukisinirlungniq: Understandings of the risks and benefits of consuming beluga in Arviat, NU

Tukisinirlungniq : comprendre les risques et les avantages liés à la consommation du béluga à Arviat (Nunavut)

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Abstract

The goal of this project is to enhance understanding of the factors influencing food choices in Inuit communities and the potential role that concern over contaminants, and the legacy of past health advice or advisories may play in the consumption of country food items. Inuit communities are commonly faced with food security challenges and therefore require information about the viability and feasibility of consuming different culturally acceptable food options. This project uses a mental models approach to explore the current perceptions and misperceptions regarding the safety of beluga whales as a country food item in Arviat, NU and Repulse Bay, NU. In both communities, community members sampled locally harvested

Résumé

Ce projet de recherche vise à accroître notre compréhension des facteurs qui influent sur les choix alimentaires dans les collectivités inuites ainsi que de l'importance que peuvent avoir les préoccupations relatives aux contaminants et, au fil du temps, les consignes et les avis sanitaires, sur la consommation des aliments traditionnels. Les collectivités inuites vivent couramment une insécurité alimentaire. Elles ont donc besoin de renseignements sur la faisabilité et la viabilité de consommer différents aliments culturellement acceptables. Ce projet met de l'avant une approche fondée sur des modèles mentaux pour étudier les perceptions actuelles et les erreurs de perception quant à la salubrité du béluga comme aliment traditionnel dans les collectivités

whales and researchers generated up to date information about contaminants (mercury-Hg) and nutrients (selenium-Se) from the area. In addition, researchers have started to create updated health messages on the consumption of beluga for the community of Arviat and determine the most preferred and effective risk communication methods for this region. Messaging about country foods will be developed in consideration of current perceptions and misperceptions of the safety (health benefits and risks) of consuming beluga as a country food item, current levels of Hg and Se in these food items and current diet behavior and levels of exposure to contaminants in the region. This project has value to other similar cases across the North where the legacy of past contaminant advisories is currently unknown or where uncertainty exists regarding the impacts of contaminant perception on current diet behavior.

d'Arviat et de Repulse Bay, au Nunavut. Dans les deux collectivités, des membres ont recueilli des échantillons de baleines chassées localement et les chercheurs ont produit des données à jour sur les contaminants, comme le mercure (Hg), et les nutriments, comme le sélénium (Se), dans la région. De plus, les chercheurs ont commencé à rédiger des messages, à l'intention de la collectivité d'Arviat, s'appuyant sur des données à jour concernant les effets de la consommation du béluga sur la santé et s'emploient à déterminer la méthode la plus efficace pour communiquer les risques connexes dans cette région. Ces messages tiendront compte des perceptions et des idées fausses ayant cours actuellement sur l'innocuité du béluga comme aliment traditionnel (bienfaits et risques pour la santé), les concentrations actuelles de mercure et de sélénium dans le béluga, ainsi que les comportements alimentaires actuels et les niveaux d'exposition aux contaminants dans la région. Ce projet présente un intérêt pour d'autres cas similaires dans le Nord, où les répercussions des consignes sanitaires antérieures au sujet des contaminants demeurent inconnues ou dans lesquels plane une incertitude quant aux effets des perceptions relatives aux contaminants sur les comportements alimentaires actuels.

Key messages

- The goal of this research is to assess factors influencing local decisions regarding the consumption of beluga in Arviat and Repulse Bay
- Mental model interviews have been completed in Arviat and Repulse Bay to better understand perceptions of contaminants as well as the risks and benefits of consuming beluga among residents in Arviat and Repulse Bay. Confirmatory surveys have been completed in Arviat
- MeHg, THg and Se were measured from locally sampled beluga in the two communities (including maaqtaq, muscle, liver and dried nikku)

Messages clés

- Cette recherche a pour objet d'évaluer les facteurs influant sur les décisions prises localement quant à la consommation de béluga à Arviat et à Repulse Bay.
- Des entrevues sur les modèles mentaux ont été réalisées à Arviat et à Repulse Bay afin de mieux comprendre les perceptions des contaminants ainsi que les risques et avantages associés à la consommation de béluga chez les résidants d'Arviat et de Repulse Bay. Un sondage a été mené à Arviat afin de confirmer les données recueillies.
- Les concentrations de méthylmercure, de mercure total et de sélénium ont été mesurées dans des échantillons de bélugas recueillis dans les deux collectivités (maattaq, muscles, foie et nikku).

- Communication messages are being developed and delivered based on Arviat residents' perceptions of beluga consumption and the analysis of nutrients and contaminants in beluga samples
- Results from the MeHg, THg and Se analysis of locally sampled beluga will be delivered to community partners in Repulse Bay

- Les chercheurs élaborent et envoient des messages en fonction des perceptions des résidants d'Arviat quant à la consommation de béluga et sur l'analyse des nutriments et des contaminants trouvés dans les échantillons de béluga.
- Les résultats des analyses sur les concentrations de méthylmercure, de mercure total et de sélénium dans les échantillons de bélugas locaux seront communiqués aux partenaires communautaires à Repulse Bay.

Objectives

Short term

Using the case of beluga whale consumption in Arviat, NU and Repulse Bay, NU this project will:

1. Gain a better understanding of factors influencing local decisions regarding the consumption of beluga whale in Arviat, NU and Repulse Bay, NU;
2. Help explain differences in perceptions and perspectives of food safety (i.e. contaminants) between Inuit residents and scientists that may be influencing the gap between science-based health messaging and Inuit diet behavior;
3. Update existing Hg and Se data on beluga tissues in Arviat, NU and Repulse Bay, NU;
4. Based on an enhanced understanding of risk perception and other factors influencing food choice developed in i. and ii., as well as current exposure levels of Hg from country food consumption, identify and develop updated population specific health messages and materials on the consumption of common country food items in Arviat, NU;
5. Pre-test, deliver and evaluate impacts of updated health messages regarding the consumption of a common country food item (beluga) on risk perception and diet behavior in Arviat, NU;
6. Develop a framework that communicators and health authorities can use to examine risk perceptions (both accurate and misrepresentations of a risk) and develop focused health messages.

Long term

1. To enhance community and local health authority capacity in understanding diet behavior and undertaking risk communications research;
2. To enhance capacity among front line workers and communicators in the region through risk communication training and the development of new health messages and materials;
3. To provide updated information to Inuit to support informed decision making regarding the risks and benefits of consumption of specific country foods while addressing current perceptions and perspectives;
4. To support the local assessment and understanding of these issues at the

intersection of wildlife and human health in other Nunavut communities and elsewhere.

Introduction

Nunavut reports the highest level of household food insecurity among an Indigenous population outside the developing world (Egeland et al., 2010). Currently, the Inuit diet is comprised of both elements from the local environment and food transported long distances to the North and purchased from local stores. With increasing climate change and variability, reports of challenges to household food security are not uncommon in Nunavut and other Arctic regions. It is for this reason that communities require the most current information regarding availability, accessibility and quality (including safety) of local food resources to help address food security challenges now and in the future.

While beluga whales represent a source of mercury (Hg) exposure for Inuit through consumption in the traditional diet, they also provide benefits for Inuit health through the provision of critical elements such as selenium (Se) and protein. Small-scale commercial harvests for belugas were conducted at Arviat and Whale Cove, NU in the early 1960s. Seal meat was also processed for commercial sale by the fish plant at Daly Bay and later Rankin Inlet between 1964 and 1970. Product demand declined steadily and in 1970 when mercury levels of 0.5 ppm (wet wt.) were found in the whale and seal meat, commercial harvesting was halted (Stewart and Lockhart, 2004). According to local Elders in Arviat, historically Inuit in the community hunted beluga whales along the west coast of Hudson Bay and consumed the maaqtaq and meat in a variety of different forms (fresh, dried). However, since the early 1970s it appears that beluga meat is no longer consumed in this community. Examination of the factors influencing the lack of consumption of beluga whale meat in Arviat, NU provides the opportunity to explore a number of critical questions facing environmental health risk managers and communicators in the Arctic today (Donaldson et al., 2009), including, but not limited to:

- What are the critical factors influencing Inuit diet behavior - is contaminant concern, as a result of a past health message, causing a lack of beluga meat consumption and negative perceptions surrounding this country food item?
- If current behavior is associated with a past health advisory, why/how has this advice/advisory had such a lasting impact? What can we learn from this case in regards to the implementation of effective health advisories in the future?
- What message should health communicators provide Inuit in Arviat regarding the consumption of beluga considering the results of current analysis on contaminants in the area (as proposed in this study)?
- If we understand what is influencing diet behavior and risk perceptions related to beluga meat in this community, can we design and deliver health messages to address misperceptions and positively influence consumption behavior (if deemed acceptable to health authorities) in the future?
- Should beluga meat be considered a culturally acceptable and viable country food option (i.e. quality) for some residents in Arviat, NU in the context of adaptation to climate change and impacts on food security?

This project is using a multidisciplinary and action oriented approach to investigate the case of beluga meat consumption in the community of Arviat, Nunavut. It began with an exploration of current Inuit perceptions and understandings of the health and safety of beluga consumption in this community and how these understandings differ from or correspond to current health and scientific knowledge. These aspects were assessed through a mental models approach, employing in-depth interviews and a community survey, to better understand risk perceptions and behavior. In cooperation with local trainees, researchers gathered samples to update the data on Hg and Se in tissues from beluga in the area. Local community and research team members have analyzed this data and in the near future will consider the generated contaminants information and local perceptions to develop, implement and evaluate updated messaging on the consumption of beluga meat as a country food item in the community. The results of this study will generate a new understanding relevant to other cases in the Arctic related to food choice behavior, risk perceptions, and environmental health risk communication.

Activities in 2015-2016

Whale Sampling: Tissues from Arviat beluga were analyzed for Se speciation. 15 kits were sent to and received by the Repulse Bay Hunters and Trappers Organization. Unfortunately, only tissues from two animals (liver, muscle and muktuk) were collected and sent to the University of Manitoba for analysis. We will try to arrange another collection in the summer of 2016 using the remaining kits.

Community Survey: During 2014-2015 mental model interviews and surveys were completed in Arviat, NU. Interviews were transcribed and reviewed. Preliminary analysis has been completed to determine the prevalence of understandings of beluga consumption safety. We have been finalizing analysis and mental model mapping in 2016-17 to develop a presentation to the project team and partners. Two research assistants were also trained in mental model interviews in Repulse Bay, NU. Mental model interviews were completed and transcribed in Repulse Bay.

Analysis of Existing IHS Dataset: A process for accessing the IHS dataset for additional analysis has been clarified and we are following that process to identify key contributors of Hg exposure among the population in Arviat, NU.

Risk Communication Meeting: After the analysis of the existing IHS dataset, beluga analysis and perceptions of consuming beluga has been completed, we will convene the risk communication meeting to discuss findings to date. The team will propose messages about beluga consumption that will be provided to the community partners, GN Health and the Arviat Public Health team for review and comment.

Capacity Building

Since the inception of this project, we have been engaging local researchers through the Arviat Wellness Centre. The Wellness Centre staff and team director work with local health representatives to engage with community members, including youth, to build local capacity. We are currently planning a risk communication workshop with local staff and team members to provide training opportunities in health risk communication.

Communications

The next step of the project involves release of messages related to beluga consumption in the community of Arviat. During early stages of this research, we have used local radio, community postings in common locations (e.g. stores, Wellness Centre, Health Centre) and word of mouth to provide information about the project and opportunities to be involved in the research. We will continue to follow the advice of our community based project team leaders and members to guide our ongoing and future communication strategies.

Messages specifically related to beluga consumption will be designed based on the results of the beluga sampling, community survey and analysis of the IHS database. Feedback and input of the research team members and project partners will be sought at the risk communication meeting and prior to message delivery.

Traditional Knowledge Integration

Traditional Knowledge Integration has been a regular part of our research design and administration. The Arviat Wellness Centre led the effort in traditional knowledge integration and has established protocols for doing so (see original proposal). As the local leaders for the project, Arviat Wellness Center employees/

members have been ensuring knowledge integration is an important part of project planning and interview administration. They will be continuing to lead the efforts in this manner as we complete the final stages of research, analysis and message delivery.

Results

We are now in the process of analyzing the existing Inuit Health Survey dataset to identify key contributors of Hg exposure among the population. Beluga samples have been collected and analyzed by Dr. Gary Stern, with plans for additional analysis of Repulse Bay whales. Results to date show that the dried muscle MMHg levels are 2 to 3 times higher than the wet weight values and above the 0.5 ug/g Health Canada guidelines (for fish) as was found in the whales samples from Arviat last year. Plans are being made to discuss results of the beluga analysis and the perceptions of the risks and benefits of consuming beluga in Arviat. We will be completing reports and factsheets in spring/ early summer 2016. Once GN Health and the Arviat Public Health team have approved these documents, research results will be delivered to the relevant groups.

Discussion and Conclusions

Survey and interview data has been collected and interviews have been transcribed. Beluga samples have been collected and analyzed by Dr. Gary Stern. Additional sampling of beluga in Repulse Bay is planned for 2016. The final results from the interviews and questionnaires, and data analysis of Hg and Se concentrations in various beluga preparations, as well as current Hg exposure levels as presented in the Nunavut IHS, will be used to determine what knowledge gaps need to be filled, what misperceptions need to be addressed and what health advice should be given to target audiences within the population regarding the consumption of beluga in Arviat, NU. Team members and partners from the research team will gather at a central location to review data from the various project components (cultural context, mental models research, beluga tissue analysis, diet/ exposure behaviour and contaminant review) and recommend messaging for development and dissemination.

Communication messages and materials will be disseminated in the community using commonly used local pathways (identified by the Arviat team members). The effectiveness of the communications will be tested through a second survey to examine if the messages reached the target population. Questions will measure any potential changes in perception and behavior re: the consumption of beluga whale (meat (dried, fresh), maaqtaq). Additional questions will focus on how risk communications can be improved. This will provide information on why (or why not) some communication strategies are successful (or not successful).

After the risk communication materials and messages have been released, a second set of mental model interviews will be completed with the original population interviewed (people originally interviewed in the 2014 mental model interviews). The same research process and question design will be used in the second set of mental model interviews. This will allow us to compare the two sets of mental models (i.e. one before hearing/seeing the messages and one after hearing/seeing the messages). This will allow us to examine if the mental models have been modified and determine the success of the message delivery. If there were still knowledge gaps, we could use these mental model interviews to understand how we could further improve message design and delivery. The addition of this final step will allow us to evaluate the communication process and the use of mental models in risk perception and communication research in the North.

Expected Project Completion Date:

March 2017

Project website (if applicable):

Not applicable

References

Egeland, G.M., Pacey, A., Cao, Z. and Sobol, I., 2010. Food insecurity among Inuit preschoolers: Nunavut Inuit child health survey, 2007–2008. *Canadian Medical Association Journal*, 182(3): 243-248.

Furgal, C.M., Powell, S., and Myers, H. 2005. Digesting the Message about Contaminants in the Canadian North: Review and Recommendations for Future Research and Action. *Arctic,* 58(2): 103-114.

Donaldson, S., Loring, E., Hartnett, E and Arnold, D. 2009. Chapter 7, Risk-benefit characterization and communication, In Van Oostdam, J., Donaldson, S.G., Feeley, M., C. Tikhonov (eds.), *Human Health: Canadian Arctic Contaminants and Assessment Report III*. Ottawa: Indian and Northern Affairs Canada, Ottawa, pp.109-137.

Morgan, G.M., Fischhoff, B., Bostrom, A., Atman, C.J., 2002. Risk Communication: A Mental Models Approach. Cambridge University Press, Cambridge.

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

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

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Abstract

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

Résumé

Dans les régions industrialisées ou éloignées, l'alimentation influe fortement sur l'exposition humaine aux polluants organiques persistants. Les aliments que nous mangeons et l'origine de ces aliments sont les principaux déterminants de la charge corporelle et des risques associés à l'exposition chronique à de tels composés. Il est bien connu que la contamination aux polluants organiques persistants varie d'un aliment à l'autre. En raison de ces écarts dans les niveaux de contaminants, l'alimentation peut influencer l'exposition aux contaminants. Nous avons étudié l'effet des transitions alimentaires sur l'exposition humaine aux polluants organiques persistants à l'aide de scénarios d'ajustements provisoires (p. ex. si une femme enceinte exclut temporairement de son alimentation

gradually shift from a traditional diet of locally hunted animals to a diet that includes more imported food (IF). We have developed a series of computer simulation-based food chain bioaccumulation models that quantify how much such dietary changes can affect exposure to contaminants. Applications range from exploring general population-wide transitions away from Northern traditional food (TF) to investigating individuals temporarily adjusting their diet during child-bearing age. Our main findings from this past year are that (1) the quality of the data on dietary compositional trends currently challenges the ability to determine the impact of long-term dietary transitions on human POP exposure in Canada's North (2) short-term dietary transitions may considerably affect intakes of POPs and essential nutrients in sensitive Arctic populations, and (3) traditional food preparation methods can significantly alter POP levels in these unique food items.

les aliments réputés les plus contaminés) et de changements plus graduels et permanents (p. ex. des collectivités remplacent graduellement leur alimentation traditionnelle à base de viande d'animaux chassés localement par une alimentation comprenant davantage d'aliments importés). Nous avons mis au point une série de modèles de simulation informatique qui permettent de déterminer, quantitativement, dans quelle mesure de tels changements peuvent influer sur l'exposition aux contaminants. Les applications vont de l'étude du délaissement graduel des aliments traditionnels du Nord par l'ensemble d'une population à l'examen d'ajustements temporaires individuels du régime alimentaire durant l'âge de procréation. L'année dernière, nos conclusions principales ont été que 1) la capacité à déterminer les effets des transitions alimentaires à long terme dans le Nord canadien sur les tendances observées quant à l'exposition humaine aux polluants organiques persistants varie grandement selon la qualité des données sur les tendances dans la composition alimentaire; 2) les transitions alimentaires à court terme peuvent exercer une influence appréciable sur l'apport en polluants organiques persistants et en nutriments essentiels chez les populations arctiques sensibles, et 3) les méthodes traditionnelles de préparation des aliments peuvent modifier considérablement les concentrations de polluants organiques persistants dans ces produits alimentaires particuliers.

Key Messages

- Arctic dietary dilemma derives from balancing nutritional benefits of, and contaminant intakes from, traditional food derived from marine mammals (MMs)
- Temporarily reducing MM consumption is ineffective in lowering PCB exposure, and reduces intakes of selenium and other nutrients
- Whether it's advisable to increase MM consumption during childbearing age for nutritional enhancement depends on baseline consumption

Messages clés

- Le dilemme alimentaire dans l'Arctique découle de la conciliation entre les avantages nutritionnels et l'apport en contaminants provenant des aliments traditionnels issus des mammifères marins.
- La réduction temporaire de la consommation d'aliments issus des mammifères marins ne réduit pas l'exposition aux BPC et diminue l'apport en sélénium et autres nutriments;
- La pertinence de diminuer de la consommation d'aliments issus des mammifères marins durant l'âge de

- Certain beluga blubber TF preparation processes (ageing, roasting) consistently and significantly altered levels of particular nutrients and contaminants: polyunsaturated fatty acids (PUFAs), selenium (Se), mercury (Hg), and ionogenic POPs
- Preparation processes may also introduce environmental contaminants to beluga blubber TFs not present in raw tissues [polycyclic aromatic hydrocarbons (PAHs)]
- Based on contaminant and nutrient changes due to preparation, aged inner blubber (uqsuq) represents the beluga blubber TF for which PUFA consumption can be maximized, while environmental contaminant intake is minimized (Hg, ionogenic POPs). However, ageing uqsuq also noticeably depleted Se

procréation dépend de la consommation de référence.

- De manière générale, certains processus traditionnels de préparation de la graisse de béluga (vieillissement, rôtissage) réduisent la teneur en certains nutriments et contaminants : acides gras polyinsaturés, sélénium, mercure et polluants organiques persistants ionogènes.
- Les processus traditionnels de préparation de la graisse de béluga peuvent aussi introduire des contaminants environnementaux qui ne sont pas présents dans les tissus (hydrocarbures aromatiques polycycliques).
- Tout dépendant des changements touchant les contaminants et les nutriments, la graisse interne vieillie (uqsuq) constitue l'aliment traditionnel issu de la graisse de béluga pour lequel la consommation d'acides gras polyinsaturés peut être maximisée tout en réduisant l'apport en contaminants environnementaux (mercure et polluants organiques persistants ionogènes). Toutefois, la teneur en sélénium est considérablement réduite dans l'uqsuq.

Objectives

Long-term

1. To maximize the value of existing Northern human biomonitoring data by using them in continued model evaluation.
2. To build capacity for assessing human exposures in Northern communities to new and emerging chemicals of concern.

Short-term

1. Further utilize previously sampled beluga blubber TFs to determine whether differences in environmental contaminant levels also results in significant variability from in vitro toxicity bioassays (Jin et al. 2013; 2015).
2. To develop a novel physiologically-based pharmacokinetic (PBPK) model capable of describing mammalian tissue distribution of mercury following prescribed dietary intake.

Introduction

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

In addition to these long-term population-wide dietary transitions among Northerners, POP exposures may also be impacted by short-term dietary transitions, such as food advisory compliance by women during pregnancy and nursing, or transient modifications to food preparation methods. As individuals are particularly susceptible to the neurocognitive effects of POPs during pre- and postnatal development (Stewart et al. 2008; Walkowiak et al. 2001), regulatory bodies often publish guidelines to promote safe maternal preparation practices, and intake levels of certain foods, mainly fish (Turyk et al. 2012). The majority of current POP dietary consumption advisories are for temperate populations, such as those in the Great Lakes region (Bhavsar et al. 2011), while, to our knowledge, no POP-based advisories have been published specifically for indigenous Arctic residents consuming a traditional diet. One reason for this being that sources of local food, the amounts consumed, their preparation methods, and levels of contaminants are extremely variable throughout the Arctic (Donaldson et al. 2010). Additionally, traditional food serves as a cultural and spiritual cornerstone of community health in many indigenous groups. In fact, authors agree that consumption of traditional foods should continue to be recommended, and intakes monitored only for sensitive populations (children and pregnant women) (Donaldson et al. 2010).

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

Activities in 2015-2016

One of the main activities in the past project year was exploring the potential of short-term TF replacement scenarios to impact not only POP exposures, but intakes of essential nutrients as well. For this purpose, we updated our ACC-Human Arctic model to include estimates of nutrient intake rates for relevant TF species. For example, we estimated whether expectant, pregnant, or nursing indigenous Arctic mothers that exceed global guidelines for polychlorinated biphenyl (PCB) and Hg exposure would drop below these thresholds by temporarily replacing significant PCB and Hg TF sources (ex. MM blubber) with less contaminated foods. And further, we estimated how these dietary changes might impact intakes of essential nutrients from a TF diet, particularly given the increased importance of certain vitamins and minerals during these reproductive phases. Using TF nutrient level data from the Health Canada Canadian Nutrient File (http://webprod3.hc-sc.gc.ca/cnf-fce/index-eng.jsp) our model quantified daily intake rates of several minerals (calcium, iron, magnesium, sodium, etc.), vitamins (A, C, D, E), and polyunsaturated fatty acids (PUFAs) from TF diets. We have performed calculations using these implemented updates to assess the above questions using hypothetical TF replacement scenarios for indigenous Arctic women of childbearing age based on TF intake rates from the Inuit Health Survey in 2007-2008 (Laird *et al.*, 2013).

A third major project activity was experimental analysis of beluga TF samples to assess food preparation impacts on POP and nutrient contents in these food items. Beluga blubber samples were collected during the 2014 summer hunting season in Tuktoyaktuk, Northwest Territories by team member Matthew Binnington with the assistance of the local Hunters and Trappers Committee. We have analyzed the collected samples to determine their levels of PCBs, organochlorine pesticides (OCPs), PAHs, polybrominated diphenyl ethers (PBDEs), perfluorinated chemicals (PFCs), Hg, as well as nutrients Se and PUFAs.

Communications

The results from these three major activities have been disseminated through a variety of means during this past year. Specifically, findings from our ACC-Human Arctic model expansion activities were presented at a meeting of the Society of Environmental Toxicology and Chemistry (Binnington et al. 2015a) and our TF substitution project was also presented at this meeting (Binnington et al. 2015b), as well as the 2015 NCP meeting in Vancouver (Wania et al. 2015). Additionally, our TF preparation work was presented at the 2016 Beluga Summit (Binnington et al. 2016a). Our TF substitution project was recently accepted for publication in the journal *Environment International* (Binnington et al. 2016b), as was our previous work describing attempts to reproduce indigenous Arctic PCB exposures measured in biomonitoring via ACC-Human Arctic (Binnington et al. 2016c).

The project team also held communication meetings with our Northern partners on three separate occasions during the previous project year. In July 2015, Frank Wania, Matthew Binnington, and Meredith Curren hosted an in-person meeting/conference call in Ottawa to discuss ongoing project results, the appropriateness of planned traditional food additions to our model framework, as well as any information on existing and potential traditional food substitution scenarios. Also, in December 2015 additional informal meetings were conducted with Northern partners during the NCP meeting, while further discussion was facilitated by the 2016 Beluga Summit in Inuvik, NT.

Capacity Building

Our 2014 field study conducted in Tuktoyaktuk by Matthew Binnington to examine the impact of traditional food preparation practices on nutrient intake and POP exposure provided unique capacity building opportunities, such as visiting local elders to explain the significance of our work and our interest in assisting with issues related to local food safety and security. We also frequently participated in local activities (ex. Aboriginal Day and Canada Day festivities), volunteered, and presented our findings, as well as answered questions during this field study. We will continue to do those capacity building activities during all stages of the project, including future results reporting. We also presented findings for this project in-person at the 2016 Beluga Summit (Binnington et al. 2016a), receiving feedback from local indigenous stakeholders on the suitability of our methodology and relevance of our findings.

Traditional Knowledge Integration

Traditional Knowledge (TK) was incorporated during project activities over the past year through advising our Northern project partners on existing or potential traditional food substitution scenarios, as well as input from our Northern project partners on the appropriateness of planned traditional food additions to our model framework. Furthermore inclusion of TK was critical in conducting our TF preparation field campaign investigating the impacts of traditional food preparation on nutrient intake and POP exposure. TK was also valuable in designing realistic dietary replacement scenarios for applying our transient dietary transition approach to Northern communities.

Results and Discussion

For our first major project, we performed a series of model calculations exploring POP and nutrient intake changes resulting from short-term TF replacement. Our interest was in determining whether members of populations sensitive to POP-related toxicity (expectant, pregnant, and nursing mothers) experiencing PCB and Hg blood concentrations above global advisory thresholds could drop below this threshold by replacing certain TF items with others temporarily. The thresholds we identified were: 0.5 µg and 1.0 µg ΣPCB g lipid^{-1} (German Federal Environment Agency - Umweltbundesamt - UBA), 0.7 µg ΣPCB g lipid^{-1} (French Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement, et du travail – ANSES), and the Health Canada toxicological Hg toxicological reference value of 0.23 µg methylmercury kg^{-1} d^{-1}. Results indicate that replacing marine mammal (ringed seal, beluga whale, and narwhal) blubber with meat from these species, and/or with food from Arctic char, caribou, Canada goose, or a combination of all these food items is ineffective in lowering total PCB exposure even when employed throughout childbearing age (18-45 y), but can substantially contribute to reducing Hg intakes (Figure 1). However, these TF replacement scenarios also appreciably affected estimates of certain nutrient intakes; particularly iron, selenium, vitamin D, and the essential polyunsaturated fatty acids alpha-linoleic acid and eicosapentaenoic acid (EPA). In some cases, marine mammal blubber replacement caused maternal intake estimates of selenium and EPA to drop below Health Canada recommended dietary allowances (RDAs) for pregnant and nursing mothers.

We also estimated how alternative TF substitution scenarios, such as replacement of caribou due to availability issues, or increases to MM consumption during childbearing age might also impact intake rates of PCBs, Hg, and essential nutrients. The potential for these three collective strategies to result or not result in guideline exceedance for environmental contaminants and nutrients was most impacted by baseline levels of TF consumption. For example, increased MM TF consumption by women of childbearing age characterized by low baseline intakes of these food items can improve nutrient adequacy without causing excessive environmental pollutant exposures. All told, these calculations reaffirm the mixed effects from MM TF consumption by indigenous Arctic women of childbearing age. The benefits of their high nutrient yields are somewhat offset by their traditionally high concentrations of environmental contaminants. Our calculations primarily suggest that specific consideration of baseline MM TF intake rates, with potential replacement by fish TF products, can help ensure adequate nutrient intakes during reproduction while minimizing environmental pollutant exposures.

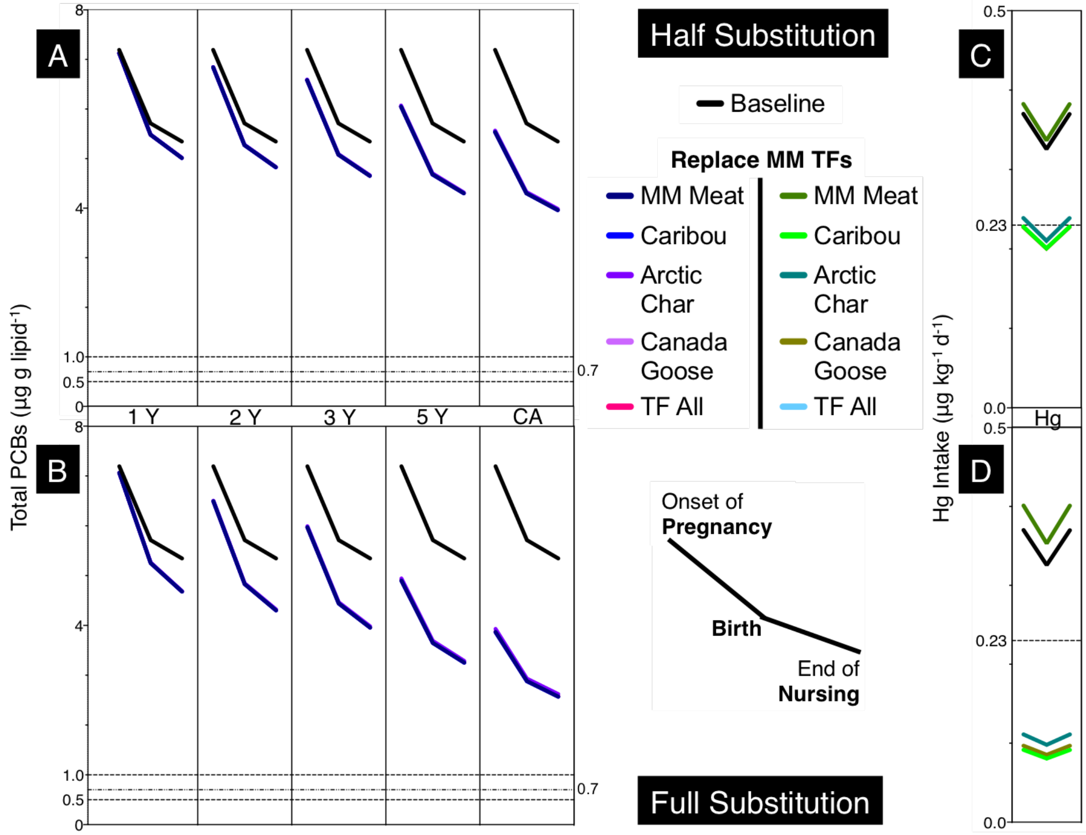


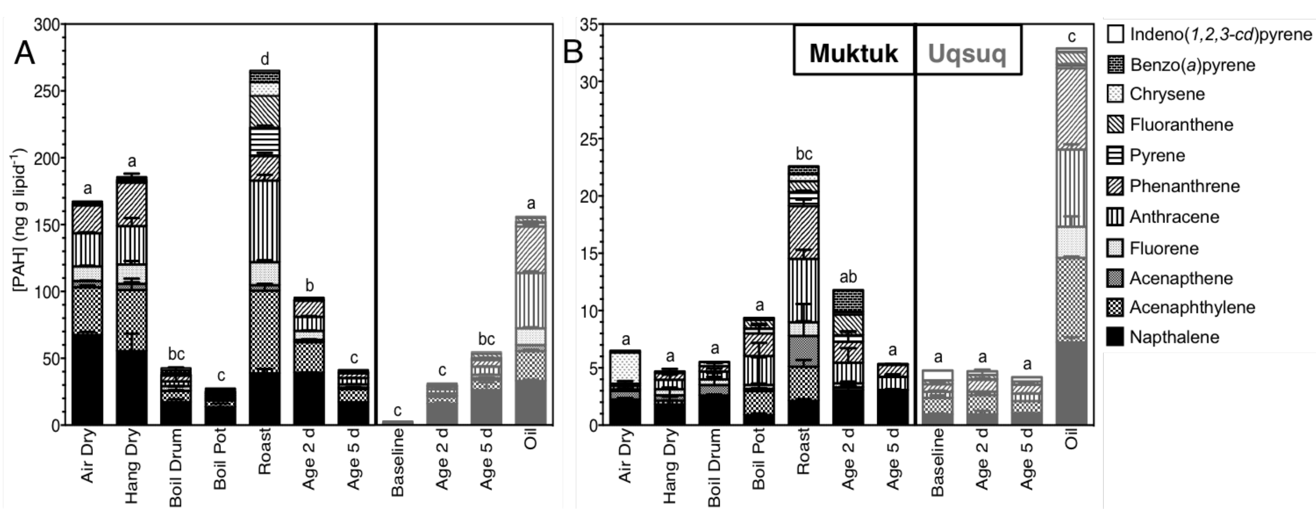
Figure 1. The impact of MM TF substitution on moderate baseline mothers' simulated PCB and Hg exposures. Depicted are the effects of half (A) or full (B) MM TF substitution on PCB exposure, and the effect of half (C) or full (D) MM TF substitution on Hg daily intakes. For PCBs, first-time mothers at the age of 25 replaced MM TFs for the durations listed along the central x-axis, which refer to either the length of time prior to birth and nursing at which substitution began (1, 2, 3, or 5 y), or the total childbearing age (CA) period. Hg intake values were averaged by age, while TF substitution duration exerted no effect since intakes were estimated as per-day rates. The two lines link estimated PCB and Hg exposures at the onset of pregnancy, birth, and the end of nursing. The additional y-axis labels 0.5, 0.7, and 1.0 µg g lipid^{-1} (PCBs), and 0.23 µg kg^{-1} d^{-1} (Hg) denote PCB and Hg exposure advisory thresholds for UBA, ANSES, and HC. Note that not all substitution scenarios are visible due to overlapping PCB and Hg exposure values.

For our second project, we conducted a series of experiments to investigate the impact of beluga blubber TF preparation on the levels of nutrients and environmental contaminants in these food items. Our results suggest that beluga blubber preparation can have a significant effect on the concentrations of certain compounds, depending mainly on the process utilized and the chemical properties of the examined substance. Ageing uqsuq was the method primarily responsible for many blubber preparation process impacts we detected, due to the distinctive phase separation between solid fat and liquid oil observed following sufficient fermentation time. Uqsuq oil contained a higher total lipid proportion and PUFA content, and its phase separation selectively depleted hydrophilic compounds that do not preferentially partition into lipid-rich phases. Thus uqsuq oil was found to contain near-detection limit levels of Se, Hg, and ionogenic PFCs. However, uqsuq ageing did not consistently enrich hydrophobic POP concentrations in uqsuq oil as we anticipated. Though uqsuq oil occasionally exhibited significantly greater levels of OCPs, PBDEs, and PCBs, the degree of this effect was lower than anticipated. Ultimately, our findings support previous food preparation investigations that have identified variable impacts of preparation depending on the types of food and substances examined, as well as measurements often characterized by inconsistency in preparation impacts.

Interestingly, our analysis of PAH variability following beluga blubber preparation indicated that preparation methods may also introduce environmental contaminant concentrations to TFs, rather than simply modulate levels already contained therein. As beluga blubber preparation is regularly conducted within or adjacent to indigenous Arctic smokehouses, and liberally uses woodfires to boil water used in the cooking process, PAHs derived from organic material combustion were readily introduced into blubber products. We found that certain methods, such as directly roasting muktuk over an open flame or drying/ageing muktuk in the area surrounding a functional smokehouse, were sufficient to elevate PAH concentrations significantly above levels measured in alternatively prepared blubber TFs (Figure 2). This suggests that adjustments to beluga blubber TF preparation methods can not only potentially reduce environmental contaminant levels but also prevent their incorporation.

Collectively these results provide some guidance on our goal to potentially provide beluga blubber TF consumption advice to maximize nutrient intakes while minimizing contaminant exposure. Based on the inconsistency of uqsuq ageing in enriching hydrophobic POP concentrations within uqsuq oil, and the corresponding depletion of certain environmental contaminants from this phase through the same process, it would seem that uqsuq oil is the most ideal product for consumption, particularly since n-3 PUFA levels are also maximized in this product. Though this product was correspondingly low in Se as well, this intake loss can be mitigated by consumption of beluga skin included in alternative muktuk products, with boiled food items representing the likely best choice. Additionally, as discussed above, preparation of beluga TFs physically removed from the environment surrounding an in-use smokehouse can mitigate PAH exposure. All told, we determined that variable beluga blubber TF preparation techniques can differentiate nutrient and pollutant concentrations in these food items, and that aged uqsuq oil is likely the best option for individuals wishing to maximize nutrient content while minimizing pollutant exposure.

Figure 2. The impact of beluga blubber preparation on PAH levels. Lipid-adjusted concentrations of PAHs are depicted for the two belugas in A) and B), respectively. Duplicate measurements were performed for each beluga whale-preparation step combination. Statistical comparisons of ΣPAH levels were performed via one-way ANOVA with Tukey's post-hoc correction for multiple comparisons; only preparation steps that do not share *any* common letters exhibited significantly different ΣPAH concentrations ($p \leq 0.05$).



Conclusions

During the 2015-2016 project year we have made several significant advancements. Firstly, we determined the impact of hypothetical short-term TF replacement scenarios on POP and nutrient intakes in indigenous Arctic mothers, suggesting that the impacts of substitution on PCB, Hg, and nutrient intakes are highly dependent on baseline intake levels of various important source TFs. Secondly, we determined that distinct preparation methods for beluga blubber food items can distinguish environmental contaminant and nutrient levels in these TFs. Further, based on the observance of decreased concentrations of certain pollutants (Hg, PFCs), and enhancement of nutrients such as PUFAs, aged uqsuq oil represents a suitable beluga blubber TF choice for populations most sensitive to intakes of these compounds.

Expected Project Completion Date:

August 2016

References

Bhavsar S.P., Awad E., Mahon C.G., Petro S. 2011. Great Lakes fish consumption advisories: is mercury a concern? *Ecotoxicol.* 20:1588–1598.

Binnington M.J., Quinn C.L., Curren M.S., Armitage J.M., Arnot J.A., Chan H.M., Wania F. 2015a. Challenges in modeling indigenous Arctic human POP exposure. Platform presentation at the 36th Annual Meeting of SETAC North America, Salt Lake City UT. Nov. 1-5, 2015.

Binnington MJ, Curren MS, Chan HM, Wania F. 2015b. Balancing the benefits and costs of traditional food substitution by indigenous women of childbearing age: POP, Hg, and nutrient impacts. Poster presentation at the 36th Annual Meeting of SETAC North America, Salt Lake City UT. Nov. 1-5, 2015.

Binnington M.J., Lei Y.D., Pokiak L., Pokiak J., Ostertag S.K., Loseto L.L., Chan H.M., Yeung L.W.Y., Wania F. 2016a. Measuring changes to nutrient and persistent organic pollutant levels in beluga traditional foods from food preparation. Platform presentation at the Beluga Summit, Inuvik NT. Feb. 22-25, 2016.

Binnington M.J., Curren M.S., Quinn C.L., Armitage J.M., Arnot J.A., Chan H.M., Wania, F. 2016b. Mechanistic polychlorinated biphenyl exposure modeling of mothers in the Canadian Arctic: the challenge of reliably establishing dietary composition. *Environ Int.* 92-93: 256-268.

Binnington M.J., Curren M.S., Chan H.M., Wania F. 2016c. Balancing the benefits and costs of traditional food substitution by indigenous Arctic women of childbearing age: impacts on persistent organic pollutant, mercury and nutrient intakes. *Environ Int.* Accepted

Deutch B., Dyerberg J., Pedersen H.S., Aschlund E., Hansen J.C. 2007. Traditional and modern Greenlandic food - Dietary composition, nutrients and contaminants. *Sci Total Environ.* 384:106–119.

Donaldson S.G., Van Oostdam J., Tikhonov C., Feeley M., Armstrong B., Ayotte P., et al. 2010. Environmental contaminants and human health in the Canadian Arctic. *Sci Total Environ.* 408:5165–5234.

Hoekstra P.F., O'Hara T.M., Backus S.M., Hanns C., Muir D.C.G. 2005. Concentrations of persistent organochlorine contaminants in bowhead whale tissues and other biota from northern Alaska: implications for human exposure from a subsistence diet. *Environ Res.* 98:329–340.

Jin L., Gaus C., van Mourik L., Escher B.I. 2013. Applicability of passive sampling of bioanalytical screening of bioaccumulative chemicals in marine wildlife. *Environ Sci Technol.* 47: 7982-7988.

Jin L, Escher BI, Limpus CJ, Gaus C. 2015. Coupling passive sampling with *in vitro* bioassays and chemical analysis to understand combined effects of bioaccumulative chemicals in blood of marine turtles. *Chemosphere*. 138: 292-299.

Kuhnlein H., Receveur O., Soueida R., Egeland G. 2004. Arctic Indigenous Peoples experience the nutrition transition with changing dietary patterns and obesity. *J Nutr*. 134: 1447–1453.

Laird B.D., Goncharov A.B., Egeland G.M., Chan, H.M. 2013. Dietary advice on Inuit traditional food use needs to balance benefits and risks of mercury, selenium, and n3 fatty acids. *J Nutr*. 143: 923-930.

O'Hara T.M., Hoekstra P.F., Hanns C., Backus S.M., Muir D.C.G. 2005. Concentrations of selected persistent organochlorine contaminants in store-bought foods from northern Alaska. *Int J of Circumpolar Health*. 64: 303–313.

Stewart P.W., Lonky E., Reihman J., Pagano J., Gump B.B., Darvill T. 2008. The relationship between prenatal PCB exposure and intelligence (IQ) in 9-year-old children. *Environ Health Persp*. 116:1416.

Turyk M.E., Bhavsar S.P., Bowerman W., Boysen E., Clark M., Diamond M.L., et al. 2012. Risks and benefits of consumption of great lakes fish. *Environ Health Persp*. 120:11–18.

Walkowiak J., Wiener J.A., Fastabend A., Heinzow B., Krämer U., Schmidt E., et al. 2001. Environmental exposure to polychlorinated biphenyls and quality of the home environment: effects on psychodevelopment in early childhood. Lancet 358:1602–1607.

Wania F. et al. Balancing the benefits and costs of traditional food substitution. Presentation at the Northern Contaminants Program Results Workshop, Vancouver, BC, Dec. 7-8, 2015.

Genetic polymorphisms to improve interpretation of contaminant exposure and risk in Inuit

Polymorphismes génétiques pour améliorer l'interprétation de données sur l'exposition aux contaminants et les risques liés aux contaminants chez les Inuits

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Abstract

The project's goal is to better understand how Inuit 'process' contaminants. The ultimate goal is to arm public health decision makers with knowledge to help identify the most susceptible subpopulations and make informed and objective risk assessments. The central hypothesis was that analysis of polymorphisms in environmentally-responsive genes that help the body 'process' toxicants will increase understanding and utility of exposure biomarkers of mercury, PCBs, and other persistent organic pollutants. Over the past two funding years, previously collected samples were studied from some members of the Inuvialuit community (N=288 participants) who

Résumé

Le projet a pour but de mieux comprendre comment les Inuits sont touchés par les contaminants. Son objectif ultime est de fournir aux décideurs en santé publique les connaissances qui les aideront à déterminer les sous-populations les plus vulnérables et à effectuer des évaluations des risques éclairées et objectives. L'hypothèse principale était que l'analyse des polymorphismes génétiques présents dans des gènes en interaction avec l'environnement qui aident l'organisme à « traiter » les substances toxiques augmenterait la compréhension et l'utilité des biomarqueurs de l'exposition au mercure, aux BPC et à d'autres polluants organiques

participated in the 2007-2008 International Polar Year Inuit Health Survey. Blood contaminants (Hg, Cd, Pb, Se, DDE, PCB-153) and fatty acids (DHA, EPA) levels were related to genetic polymorphisms, while considering pertinent covariates. Several polymorphisms emerged to be influential, indicating that environmentally-responsive genes can influence contaminant and nutrient biomarker levels. A similar gene-environment study is now being carried out with participants from Nunavik (N=669 participants) as part of the 2004 Qanuippitaa Survey.

persistants. Au cours des deux dernières années de financement, nous avons étudié des échantillons préalablement recueillis auprès de quelques membres de la collectivité des Inuvialuits (N= 288) ayant participé à l'Enquête sur la santé des Inuits menée lors de l'Année polaire internationale, en 2007-2008. Les niveaux de contaminants sanguins (mercure, cadmium, plomb, sélénium, DDE, BPC-153) et d'acides gras (ADH/AEP) étaient associés aux polymorphismes génétiques, et ce, considérant les variables pertinentes. Plusieurs polymorphismes semblaient avoir des influences, montrant ainsi que les gènes qui réagissent à l'environnement peuvent avoir une influence sur les niveaux des biomarqueurs associés aux contaminants et aux nutriments. Une étude semblable sur les interactions gènes-environnement est en cours au Nunavik (N=669 participants) à la suite de l'enquête Qanuippitaa de 2004.

Key messages

- 146 genetic polymorphisms were characterized from some members of the Inuvialuit community
- These polymorphisms hail from biological pathways associated with the transport and metabolism of contaminants and cardiovascular health
- Composition of many of the genetic polymorphisms were different when compared against other populations (such as Caucasians and Asians)
- Some genes are associated with changes in blood levels of mercury, cadmium, lead, and other contaminants
- Next steps include repeating the gene-environment study with previously collected samples and information from the 2004 Qanuippitaa Survey in Nunavik

Messages clés

- Quelque 146 polymorphismes génétiques ont été caractérisés chez des membres de la collectivité inuvialuite.
- Ces polymorphismes découlent de processus biologiques associés au transport et à la métabolisation des contaminants et à la santé cardiovasculaire.
- La composition de nombreux de ces polymorphismes génétiques différait de celle notée dans d'autres populations (p. ex. Caucasiens et Asiatiques).
- Certains gènes sont associés à des modifications des concentrations sanguines de mercure, de cadmium, de plomb et d'autres contaminants.
- Une des prochaines étapes consiste à répéter l'étude sur les interactions gènes-environnement avec les échantillons et les données issus de l'enquête Qanuippitaa réalisée en 2004 au Nunavik.

Objectives

- **Long-term objective** of our research program is to better understand how Inuit processes contaminants so that dietary exposure assessments and linkages to adverse health outcomes can be improved

- **Short-term goal** is to test the hypothesis that analysis of genetic polymorphisms (focus on environmentally-responsive genes within key biological pathways) will increase understanding and utility of exposure biomarkers of mercury, PCBs, and other persistent organic pollutants as well as fatty acid (DHA, EPA). In other words, inter-individual variation in key toxicokinetic genes will influence dietary exposure (survey) -biomarker (blood contaminants, fatty acids) relationships.

Introduction

A critical feature of decision-making and risk assessment is to relate biomonitoring data (i.e., blood biomarker values) to health guideline values. However, guideline values are derived to protect the entire population and thus may over- or under-protect particular segments of the population and thus lead to erroneous decisions. We illustrate this here using mercury as an example. Risk assessors assume a constant and linear relationship between dietary methylmercury exposure and body burden (i.e., hair mercury levels). In a re-analyses of several epidemiological studies, we documented that such an approach yields highly variable outcomes (Canuel et al., 2006). For example, we re-analyzed a 1992 dataset from Nunavut and found that predicted hair mercury values (18.1 ppm) in Inuit were nearly 5-times higher than the measured value of 3.8ppm. In this paper we concluded that "the relation between between methylmercury oral dose and body burden… may vary among certain ethnic groups" and "metabolic excretion rates might vary according to ethnicity", however very little is known about these topics.

Risk assessments attempt to account for variability by utilizing default uncertainty factors (Basu et al., 2014). Uncertainty factors increase the margin of safety in an effort to protect sensitive subgroups, but in doing so they may still prove to be insufficient or perhaps even over-protective. As we embark upon next-generation risk assessment (Zeise et al., 2013), there is a need to harness emerging ecogenetic approaches (e.g., genetic polymorphisms) to help increase understanding of true biological variation across and within individuals and ethnic groups so that uncertainty factors are refined and risk assessments improved. From the 2009 AMAP Human Health Assessment, "too little is known about the genetics of [Arctic] populations to elucidate the implications of contaminant-genetic interactions on health. Because the genetic background of the Inuit differs compared with Caucasians these genetic differences must … become a part of the future studies on Arctic populations because the genotype may be fundamental to the effects of exposure to environmental contaminants".

Activities in 2015-2016

This was the second year of the project, and thus a majority of the time was spent to: A) finalize the dataset collected from the first year of the project (i.e., information and samples collected in the Inuvialuit Settlement Region (ISR) during the IHS); and B) collect and process biospecimens to conduct the second gene-environment study with the 2004 Qanuippitaa Survey. As such the larger research project focuses on two geographically separated Inuit communities for which we have detailed cross-sectional epidemiological data: the Inuvialuit community (Chan, 2012; Laird et al., 2013b) from the 2007-2008 International Polar Year Inuit Health Survey, and from Nunavik (Dewailly et al., 2007) as part of the 2004 Qanuippitaa Survey. By studying samples collected from both studies, we will have a robust sample size of approximately 1,000 participants which would enable us to explore gene-environment interactions with greater confidence. The aim of the project's third year will be to thus amalgamate the datasets and finalize the reports.

In the 2014/2015-year (year #1), we focused on the samples collected in the Inuvialuit Settlement Region (ISR) during the IHS. Already isolated genomic samples were obtained by Dr. Hegele's group at Western University, and shipped to Genome Quebec in early 2015. Of the 288 samples sent to Genome Quebec, 285 were deemed technically acceptable for further study. A total of 360 genetic polymorphisms were initially selected for study. Out of which, 146 yielded useful data and they hail from biological pathways associated with, for example, the transport and metabolism of contaminants and cardiovascular health. The analysis of genetic polymorphism was completed in late March (2015) and has since been cleaned with results reported upon below. The data was matched with the existing IHS database for blood contaminant concentrations and other life-style and diet information. The merged database has undergone statistical analyses by Dr. Parajuli (postdoctoral fellow, McGill University) and Dr. David Hi (postdoctoral fellow, University of Ottawa).

In the 2015/2016-year (year #2), we focused on the samples collected in Nunavik as part of the 2004 Qanuippitaa Survey. Already isolated genomic samples were obtained by Dr. Hegele's group at Western University, and shipped to Genome Quebec in early 2016. In total, 664 samples were sent to Genome Quebec. A total of 140 genetic polymorphisms were initially selected for study out of which 106 yielded useful data (i.e., they were technically adequate, frequencies were above 5%). The analysis of genetic polymorphism was completed in late March (2016) and has since been cleaned with preliminary results reported upon below. The data is now being matched with the existing Nunavik database for blood contaminant concentrations and other life-style and diet information. The merged database will undergo statistical analyses by Dr. Parajuli (postdoctoral fellow, McGill University) in a manner similar to that of the ISR work.

Results

Inuvialuit Settlement Region (ISR) Study

Characteristics of ISR study participants have been outlined elsewhere (Chan et al., 2012). In brief, the ISR study population largely consisted of females (66.2%) that were middle-aged though the age distribution was wide (mean ± SD 44.7±16.0, range 18-90 years). Total biomarker concentrations were measured in blood samples, and the levels of bHg, bCd, bSe, bPb, DDE, PCB 153, DHA and EPA levels are presented in other reports (Chan et al., 2012). From the sub-sample we worked with here, geometric means (SD) for the aforementioned biomarkers were 4.64 (9.31) µg/L for bHg, 1.31 (1.72) µg/L for bCd, 304.36 (32.18) for bSe, 32.18 (33.36) µg/L for bPb, 1.98 µg/L for DDE, 0.57 µg/L for blood PCB 153, 0.60 % / total fatty acid (TFA) for DHA and 0.61 % / TFA for EPA.

Table 1 summarizes the results of ANOVA tests comparing the mean bHg, bCd, and bPb levels among SNP genotypes. Among the 146 single nucleotide polymorphisms (SNPs) studied, 26 SNPs indicated significant differences ($p<0.05$) by genotype for at least one metal (bHg, or bCd or bPb) biomarker; 11 SNPs for Hg, 7 SNPs for bCd and 9 SNPs for bPb levels. In some cases, carrying the minor allele was associated with higher bHg levels (e.g., higher bHg levels among minor homozygotes for *IL-4R* SNPs – rs1805010, *SELP* - rs6131, *CYP1B1*- rs180040, *CYP1A2*- rs762551 and *CBS*-rs1051319). In other instances, the minor allele carriers had lower bHg levels (e.g., lower bHg among variant genotypes for rs5748469 in *TXNRD2*, rs693 and rs1367117 in *APOB*, rs1332018 in *GSTM3*). Similar association was observed for bCd and bPb levels. After Bonferroni correction ($p<0.0003$; note to reduce the risk of chance findings due to multiple comparisons (146 tests per biomarker), a Bonferroni correction approach was adopted in which we considered p-values<0.0003 as statistically significant), two SNPs (rs1056836 in *CYP1B1* and rs1042838 in *PGR*) remained statistically significant with bCd levels. Heterozygotes and minor homozygotes had 121.1% and 316.3% higher bCd levels on average compared to wild genotype for rs1056836 in *CYP1B1* and a similar pattern was observed for rs1042838 in *PGR* too.

Table 2 summarizes the results of ANOVA tests comparing the DDE and PCB 153 stratified by SNP genotype for 11 SNPs (9 SNP for DDE and 6 SNPs for PCB 153) that showed significant differences (ANOVA p<0.05 or Tukey comparison with p<0.05). In some cases, carrying at least one copy of the minor allele was associated with higher POPs levels (e.g., higher DDE or PCB 153 levels among heterozygotes and minor homozygotes for *PGR* SNPs – rs1042838). In other instances, the minor allele may be protective as carriers had lower POPs levels (e.g., lower DDE and PCB 153 among variant genotypes for rs693 in *APOB* and rs5748469 in *TXNRD2*). After Bonferroni correction (p<0.0003), one SNP (rs1042838 in *PGR*) remained statistically significant. Heterozygotes had 31.1% lower DDE levels while minor homozygote had 286.9% higher DDE levels on average compared to major homozygotes, and a similar pattern was observed in PCB 153 levels (ANOVA p=0.013).

We also used ANOVA tests to compare the mean red blood cells (RBCs) omega-3 fatty acids (DHA and EPA) levels among SNP genotypes. Among 146 SNPs studied, 39 SNPs indicated significant differences (p<0.05) by genotype for at least omega-3 fatty acids (DHE or EPA) biomarker; 30 SNPs for DHA, 21 SNPs for EPA levels. In some cases, carrying at least one copy of the minor allele was associated with higher omega-3 fatty acids levels (e.g., higher DHA or EPA levels among heterozygotes and minor homozygotes for *LDLR* SNP – rs2738464 and *GSTO1* SNP-rs4925). In other instances, the minor allele was associated with lower omega-3 fatty acids levels (e.g., lower DHA and EPA among variant genotypes for *CYP1B1* SNP-rs180040, *FMO* SNPs- rs8050136, and rs9939609, and *BCL11A* SNP-rs4671393). After Bonferroni correction (p<0.0003), 3 SNP for DHA (rs4671393 in *BCL11A*, rs11644094 in *MT4*, and rs180040 in *CYP1B1*) and one SNP for EPA (rs180040 in *CYP1B1*) remained statistically

Table 1. Association between genetic polymorphisms and toxic metal (Hg, Cd and Pb) levels in blood. Significantly different values (p<0.05) are shown in shade (shade darkness increase with increases in significance level). Only genes with significant ANOVA tests are shown here

Pathway/ Category	Gene symbol	SNPs	n	MAF	Blood Hg (μg/L)			Blood Cd (μg/L)			Blood Pb (μg/L)		
					Geometric mean ±Arithmetic SD								
					[1]Major	[2]Heterozy	[3]Minor	[1]Major	[2]Heterozy	[3]Minor	[1]Major	[2]Heterozy	[3]Minor
Folate Pathway	*CBS*	rs1051319	249	0.111	4.29±8.88	6.09±8.74	13.06±27.35	1.25±1.69	1.51±1.85	3.53±0.85[4]			
	MTRR	rs1801394	247	0.271							32.74±31.33	29.11±32.83	45.96±45.71
	MTRR	rs3776467	246	0.164							30.12±32.16	37.52±36.52	45.27±35.80
Glutathione	*GSTM3*	rs1332018	245	0.120	4.62±9.20	5.37±10.22	1.23±4.12						
Inflammation	*IL-4R*	rs1805010	244	0.301	5.30±9.13	3.78±10.01	7.02±7.15						
	SELP	rs6131	245	0.162	5.18±9.74	3.37±8.39	6.67±10.06						
	THBD	rs1042579	247	0.351				1.51±1.80	1.07±1.50	1.61±1.93			
Lipid Metabolism	*FMO*	rs1144193	237	0.453	3.48±8.52	5.17±8.97	5.50±9.56						
	APOB	rs1367117	245	0.209	4.84±9.36	4.94±9.80	1.72±4.26						
	APOB	rs693	234	0.254	4.83±9.32	5.00±9.80	2.08±3.79						
	APOB	rs1801702	241	0.119				1.24±1.72	1.63±1.69	3.05±1.77[4]			
Oxidative Stress	*TXNRD2*	rs5748469	244	0.192	5.20±10.11	3.95±7.92	2.08±2.52						
	TXNRD2	rs1139793	243	0.233							35.88±35.21	26.88±29.00	27.92±28.23
Selenoprotein	*SEPHS2*	rs1133238	249	0.149	4.16±7.82	6.29±12.44	5.44±7.73						
	SEPP1	rs7579	239	0.250				1.30±1.71	1.19±1.74	2.63±1.65[4]			
Xenobiotic Metabolism	*CYP1B1*	rs180040	247	0.080	4.89±9.43	2.88±7.43	9.16±14.58						
	CYP1A2	rs762551	243	0.284	5.13±9.21	3.62±8.80	6.51±11.87						
	CYP1B1	rs1056836	247	0.099				1.23±1.79	1.49±1.38	3.89±0.92[4]			
	CYP2C19	rs4244285	247	0.134							30.81±33.58	39.06±32.92	18.32±25.61
Transporter	*SLC7A5/LAT1*	rs33916661	248	0.252				1.36±1.75	1.19±1.59	3.03±2.22[4]			
	SLC15A2	rs2257212	243	0.409							31.94±36.01	28.71±28.96	39.32±28.58
	SLC15A2	rs2293616	228	0.407							32.50±37.18	29.82±32.60	41.58±29.08
	ABCB1	rs3213619	248	0.052							30.94±32.79	44.40±35.02	NA
	ABCB1	rs3842	239	0.133							32.46±32.46	28.95±26.93	61.90±64.72
Metal Responsive	*PGR*	rs1042838	245	0.121				1.22±1.77	1.58±1.59	3.26±0.84[4]			
	ALAD	rs1805313	247	0.256							34.07±37.86	31.28±26.66	21.91±18.34

[1]Major: major homozygotes, [2]Heterozy: heterozygote, [3]Minor: minor homozygote, [4]Welch test, MAF: Minor allele frequency, Hg: mercury, Cd: cadmium, Pb: lead SD: Standard deviation, n: number of participants, SNP: single nucleotide polymorphism. Significant p values after Bonferroni Correction are shaded with darkest grey color (p<0.0003). Details of significance level in ANOVA, TUKEY post hoc test and T test are provided in Supplementary Table 1a for Hg, 1b for Cd, 1c for Pb.

Shading Key ANOVA: p<0.05 | p<0.01 | p<0.0003

Table 2. Association between genetic polymorphisms and persistent organic pollutants (POPs) (i.e., pp DDE and PCB 153) biomarker levels blood. Significantly different values (p<0.05) are shown in shade (shade darkness increases with increase in significance level). Only genes with significant ANOVA or t tests are shown here

Pathway/ Category	Gene symbol	SNPs	n	MAF	Blood DDE µg/L Geometric mean ± arithmetic SD			ANOVA p	Tukey post hoc test p	T test p (SD)	Blood PCB 153 µg/L Geometric mean +SD			ANOVA p	Tukey post hoc test p	T test p (SD)
					[1]Maj_ Homo	[2]Heterozy	[3]Min_ Homo				[1]Maj_ Homo	[2]Heterozy	[3]Min_ Homo			
Folate Pathway	*CBS*	rs1051319	248	0.111	1.90±5.46	2.07±4.73	13.10±4.99*	0.046	0.04 (1 vs 3)		0.55±3.23	0.55±1.78	3.24±1.84	NS		
Glutathione	*GSTA2*	rs2180314	225	0.126	2.01±4.31	1.51±4.86	5.17±9.94	0.04[4]			0.59±2.81	0.38±2.74	1.31±3.55	NS		
Lipid Metabolism	*APOB*	rs693	233	0.254	2.11±5.85	2.15±5.22	0.92±4.90	0.03	1 vs 3 (p=0.030); 2 vs 3 (p=0.03)		0.62±2.58	0.55±2.53	0.25±1.83	0.047	1 vs 3; p=0.04	
Oxidative Stress	*TXNRD2*	rs5748469	243	0.192	1.95±5.35	2.24±5.63	0.51±4.42	0.01	1 vs 3 (p=0.01); 2 vs 3 (p=0.009)		0.60±3.33	0.57±2.50	0.14±1.55	0.046	1 vs 3; p=0.03 2 vs 3; p=0.05	
Selenoprotein	*SEPHS2*	rs1133238	248	0.149	1.75±4.28	2.71±7.63	3.19±4.86	NS		1 vs (2+3)=2.75 (7.44); p=0.02	0.49±2.12	0.81±4.62	0.96±3.44	NS		1 vs (2+3)=0.82 (4.51)]; p=0.03
Transporter	*SLCO1B1*	rs4149056	246	0.177	2.25±5.83	1.54±4.43	0.93±1.61	0.04		0.02	0.65±3.49	0.43±1.50	0.28±1.98	NS		1 vs (2+3)= [0.42 (1.53)]; p=0.04
Xenobiotic Metabolism	*CYP1B1*	rs180040	246	0.080	2.10±5.61	1.23±3.87	3.12±5.76	NS			0.62±3.21	0.30±0.93	0.78±2.97	0.043	1 vs 2; p=0.04	1 vs (2+3)= [0.33 (1.32)]; (p=0.03)
Metal Responsive	*PON2*	rs7493	247	0.245	2.34±6.14	1.49±4.32	2.20±3.31	0.04	1 vs 2 (p=0.03)		0.70±3.01	0.38±1.30	0.80±7.26	0.009	1 vs 2; p= 0.009	
	CYP1A2	rs762551	242	0.284	2.22±4.54	1.49±4.88	3.70±9.76	NS			0.62±1.98	0.43±3.75	1.10±4.41	0.024	2 vs 3; p= 0.03	
	PON1	rs854560	248	0.103	2.03±5.45	1.91±5.47	0.83±0.41	0.009[4]			0.59±3.03	0.50±3.04	0.23±0.22	NS	4 ma	1 vs (2+3)= [0.47 (2.93)]; NS
	PGR	rs1042838	244	0.121	2.06±4.80	1.42±4.64	5.91±2.05	0.00002[4]			0.61±3.17	0.36±1.51	2.21±2.07	0.013	2 vs 3; p= 0.03	1 vs (2+3)= [0.42 (1.62)]; NS

[1]Major: major homozygotes, [2]Heterozy: heterozygote, [3]Minor: minor homozygote, [4]Welch test p, MAF: Minor allele frequency, Hg: mercury, Cd: cadmium, Pb: lead, SD: Standard deviation, n: number of participants, SNP: single nucleotide polymorphism. Significant p values after Bonferroni Correction are shaded with darkest grey color (p<0.0003). For SNPs with ≤6 individuals in the minor homozygote category, heterozygotes and minor homozygotes were combined (for 1 vs 2+3) and calculated GMs are shown here with t test p value. Natural log transformation was conducted for PCB 153 to achieve normality. Hence, mean and SD for PCB 153 is geometric.

p<0.05	p<0.01	p<0.0003

significant. Individual carrying at least one copy of the minor allele for (*BCL11A* SNP-rs4671393) had 56.58% lower DHA levels on average compared to major homozygotes, and a similar pattern (69% low) was observed in DHA levels in *CYP1B1* SNP-rs180040. In contrast, heterozygotes (of *MT4* SNP- rs11644094) had 10% higher DHA levels while minor homozygote had 194.55% higher DHA levels on average compared to major homozygotes. Individual carrying at least one copy of the minor allele (of *CYP1B1* SNP-rs180040) had 46.27% lower EPA levels on average compared to wild type.

SNP main effects and interactions with the major source of methylmercury (Hg intake from fish; bHg models) were added to the base model. In general, the inclusion of SNPs into the base models improved the model r^2. In the best cases, the r2 increased from 0.374 to 0.401 for bHg. Below we provide further details for each of the biomarkers.

In the bHg model adjusting for Hg intake from fish, age, and hemoglobin, 16 SNPs had significant main effects and/or interactions with fish Hg (Figure 1 for key examples). Out of 9 significant main effects, variant alleles of 2 SNPs were associated with lower bHg concentrations, while variant alleles from the remaining 7 SNPs were associated with higher bHg. Among these, rs1051319 in *CBS* and rs1801394 in *MTRR* were significant at p<0.01 level with each variant allele associated with a 0.19 and 0.13 natural log-unit increase in bHg. All of these 9 SNPs lost significance after Bonferroni correction. Ten SNPs had significant interaction terms including eight that were negative, though none of these were significant following Bonferroni correction.

Figure 1a-d depicts the correlation between blood Hg levels and estimated Hg intake from fish stratified by genotypes [rs2270836 in *MT1M* and rs1041983 in *NAT*, rs1801394 in *MTRR*, and rs8177412 in *GPX3*, with greatest p value and enough individual for 3 genotypes] (without adjustment for age and Hb).

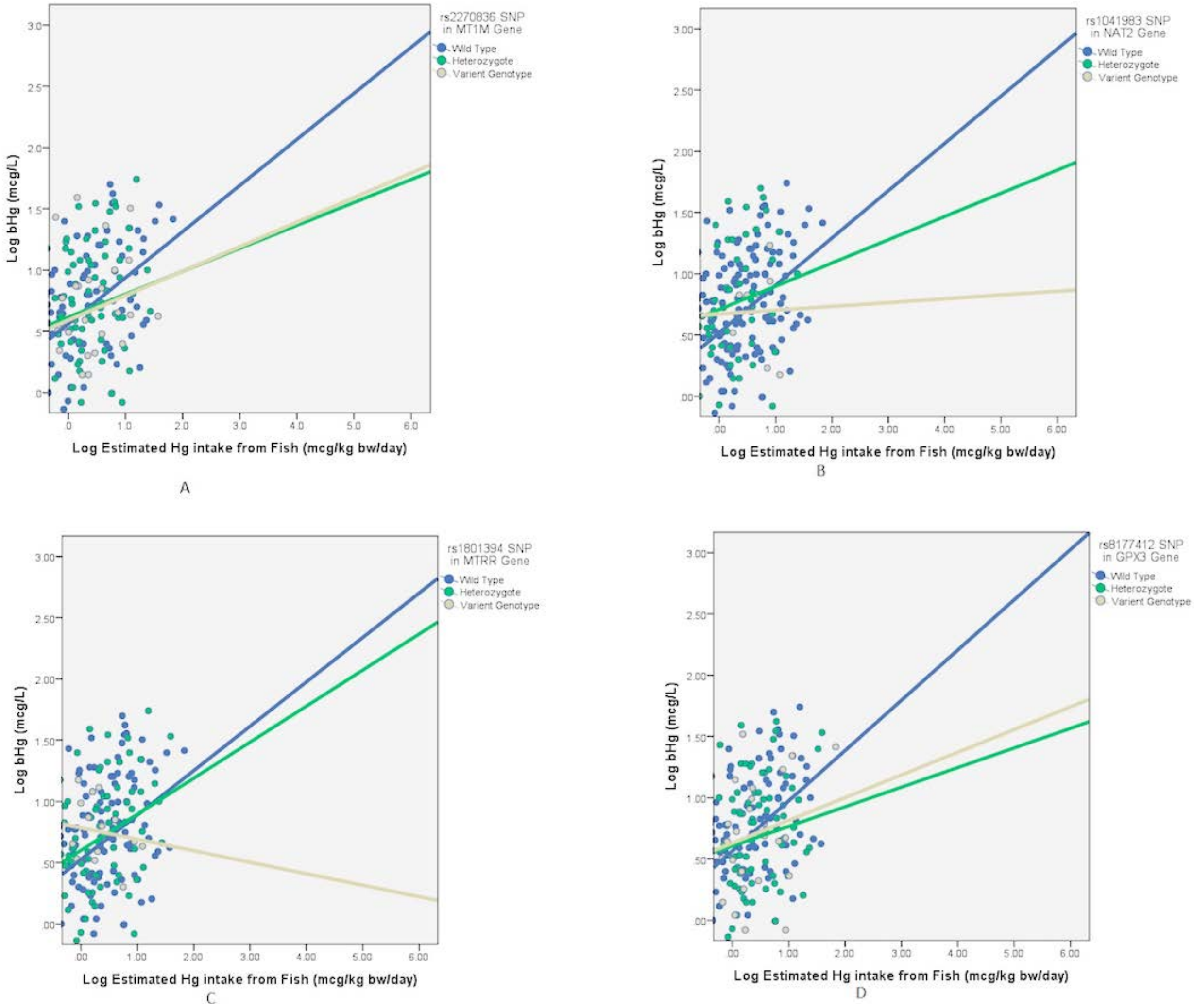

Fig 1 a-d. Correlations between blood Hg and estimated Hg Intake from fish consumption differ by genotype. Relationships between log-transformed bHg or and log-transformed Hg intake from fish consumption stratified by genotype at 4 SNPs significantly associated with the Hg biomarker level at a significance level of <0.001 are depicted (A–D). The lines show the bivariate correlation and do not adjust for other factors included in the models.

Nunavik Study (2004 Qanuippitaa Survey)

A total of 140 genetic polymorphisms were initially selected for study out of which 106 yielded useful data (i.e., they were technically adequate, frequencies were above 5%). The analysis of genetic polymorphism was completed in late March (2016) and has since been cleaned with preliminary results reported upon below. The data is now being matched with the existing Nunavik database for blood contaminant concentrations and other life-style and diet information. The merged database will undergo statistical analyses by Dr. Parajuli (postdoctoral fellow, McGill University) in a manner similar to that of the ISR work.

Discussion and Conclusions

The analysis of the ISR data (Year 1, 2014/2015) of the overall study re-affirms our stated objective that there are genetic differences between Inuit and other populations in terms of the composition of genes that handle contaminants, and that some of these may be significantly associated with altered biomarker levels. In the ISR study, we observe significant associations between SNPs and metal (Hg, Cd), POPs (DDE) and omega 3 fatty acids (DHA and EPA) biomarker levels as well as modification of exposure source-biomarker relationships by SNPs. Our study adds to the growing body of literature on genetic factors influencing susceptibility to metal accumulation and toxicity (Basu et al., 2014). We addressed our hypotheses in a unique population with elevated and differing levels of contaminants and nutritional burdens than the general Canadian population. For example, the ISR population had nearly seven times higher bHg, four times higher bCd, and three times higher bPb than that of Canadian adults enrolled in the Canadian Health Measures Survey (Health Canada 2010), yet despite these striking differences we tend to utilize all encompassing guidelines for all Canadian sub-populations. In the coming year (2016/2017) we will continue to analyze the new results from the Nunavik dataset to characterize the influence of genetic polymorphisms on other contaminants, as well as contaminant and health measure associations, and also aim to increase the overall sample size. When the two studies are combined, the overall sample size will approach 1,000 and thus result a very robust epidemiological dataset that can be used to ask important questions concerning gene-contaminant interactions, with the hope that this will lead to improved risk assessments and decisions that are better tailored to Inuit.

Expected Project Completion Date

We have started to share findings from ISR with key community leaders. We expect to complete the Nunavik data analysis by the end of 2016 and will report the results to the Nunavik Nutritional and Health Committee in early 2017. We will continue to pursue actions that may enable us to combine the datasets. The overall project that would consist of a thorough epidemiological gene-environment study involving the Inuvialuit and Nunavik cohorts is expected to take three years and finish by March 2017.

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Reference List

Basu, N., Goodrich, J., Head, J. 2014. Ecogenetics of mercury: From genetic polymorphisms and epigenetics to risk assessment and decision-making. *Environ. Toxicol. Chem.* 33: 1248-1258.

Canuel R., de Grosbois S.B., Atikesse L., Lucotte M., Arp P., Ritchie C., Mergler D., Chan H.M., Amyot M., Anderson R. 2006. New evidence on variations of human body burden of MeHg from fish consumption. *Environ. Health Perspect.* 114: 302-306.

Chan, H.M.et al. 2012. *Inuit Health Survey 2007-2008: Contaminant assessment in the Inuvialuit Settlement Region.*

Dewailly, E., Dellaire, R., Pereg, D., Ayotte, P., Fontaine, J., Dery, S. 2007. *Exposure to environmental contaminants in Nunavik: Persistent organic pollutants and new contaminants of concern.* Québec: Institut National de santé publique de Québec, 28 pp.

Laird B.D., Goncharov A.B., Chan H.M. 2013. Body burden of metals and persistent organic pollutants among Inuit in the Canadian Arctic. *Env. Int.* 59C:33-40.

Zeise L., Bois F.Y., Chiu W.A., Hattis D., Rusyn, I., Guyton K.Z. 2013. Addressing human variability in next-generation human health risk assessments of environmental chemicals. *Environ. Health Perspect.* 121:23-31.

Contaminant biomonitoring in the Northwest Territories: Investigating the links between contaminant exposure, nutritional status, and country food use

Biosurveillance des contaminants dans les Territoires du NordOuest : étude des liens qui existent entre l'exposition aux contaminants, l'état nutritionnel et les aliments traditionnels

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Abstract

In this first year (of a 3-year project), we implemented biomonitoring research in one Northwest Territories community and consulted with seven additional communities, between November 2015 and February 2016. Building upon prior consultations in 2014-2015, our research team traveled to the first participating community (Jean Marie River First Nation, NT) for data and sample collection. With the assistance of a local research coordinator and nurse, we collected blood, urine, and/or hair samples from 22 participants. Participants also completed a questionnaire and two dietary surveys (24-hr Recall, Food Frequency Questionnaire). Additionally, our team traveled to and consulted with two Sahtú communities

Résumé

Au cours de la première année de ce projet de trois ans, nous avons lancé une recherche en biosurveillance dans une collectivité des Territoires du NordOuest en plus d'en consulter sept autres de novembre 2015 à février 2016. Faisant fond sur des consultations menées en 20142015, notre équipe de recherche s'est rendue dans la première collectivité participante (Première Nation de Jean Marie River, dans les Territoires du NordOuest) afin de recueillir des données et des échantillons. Avec l'assistance d'un coordonnateur de recherche local et d'une infirmière, nous avons recueilli des échantillons de sang, d'urine ou de cheveux auprès de 22 participants. Ces derniers ont aussi rempli un questionnaire et deux sondages sur

(Deline and Tulita) and five Dehcho communities (Hay River First Nation, Hay River Metis, West Point First Nation, Kakisa, Trout Lake, Fort Simpson) regarding the expansion of the project and their potential participation in 2016-2017. Data analysis of the Year 1 results (metals in blood/urine; POPs in blood; mercury in hair; dietary surveys) is currently underway. In collaboration with regional, territorial, and federal partners, results will be returned to Year 1 participating communities in fall 2016.

leur alimentation (relevé de 24 h et fréquence de consommation). De plus, notre équipe s'est rendue dans deux collectivités du Sahtu (Déline et Tulita) ainsi que dans cinq collectivités du Dehcho (Première Nation de Hay River, Métis de Hay River, Première Nation de West Point, Kakisa, Trout Lake et Fort Simpson) pour les consulter quant à l'élargissement du projet et à une possible participation en 2016-2017. L'analyse des données recueillies lors de la première année (métaux dans le sang et dans l'urine, polluants organiques persistants dans le sang, mercure dans les cheveux, questionnaires sur l'alimentation) est en cours. Les partenaires régionaux, territoriaux et fédéraux communiqueront les résultats aux collectivités ayant participé à la première année du projet à l'automne 2016.

Key messages

- 22 participants from Jean Marie River First Nation, NT provided hair, blood, and/or urine samples for contaminant analyses
- Year 1 samples are currently being analyzed for mercury (hair), metals and metalloids (hair, blood, urine), and POPs (blood)
- Year 1 results will be returned to participating communities in fall 2016
- Consultations with leaders and community members were held in Deline, Tulita, Trout Lake, Hay River, Kakisa, and Fort Simpson to discuss their potential participation in the biomonitoring project in 2016-2017

Messages clés

En tout, 22 participants de la Première Nation de Jean Marie River, dans les Territoires du Nord-Ouest, ont fourni des échantillons de cheveux, de sang ou d'urine à des fins d'analyse des contaminants.

Des analyses visant à détecter du mercure (cheveux), des métaux et des métalloïdes (cheveux, sang et urine) et des polluants organiques persistants (sang) sont en cours pour les échantillons recueillis au cours de la première année du projet.

Les résultats obtenus durant la première année seront communiqués aux collectivités participantes à l'automne 2016.

Des consultations ont eu lieu avec les dirigeants et les membres des collectivités de Déline, de Tulita, de Trout Lake, de Hay River, de Kakisa et de Fort Simpson afin de discuter de leur participation au projet de biosurveillance pour 2016-2017.

Objectives

The short term objectives for this research project were to:

1. Develop a results dissemination strategy with the Dehcho Health and Social Services Authority and the Department of Health and Social Services of the territorial government;
2. Evaluate country food usage patterns, contaminant exposure profiles, and nutritional biomarkers in up to three participating communities of the Dehcho Region;
3. Consult with additional communities regarding the expansion of the project in subsequent years.

The long term objectives of this research project are to:

1. Return results to the individuals and communities who took part in Year 1;
2. Implement the biomonitoring study in up to ten additional, previously-consulted Dehcho and Sahtú communities in 2016-2018;
3. Create a public health screening tool that can be used to characterize those most at risk of facing elevated contaminant exposures in the Dehcho Region;
4. Assess participants' risk perceptions and evaluate public health messages in order to improve risk communication strategies related to toxicological concerns in the Northwest Territories.

The realization of these short- and long-term objectives will assist in the development of public health communication strategies that will promote country food reliance in ways that maximize nutrient status while limiting contaminant exposure in the Northwest Territories. The realization of these objectives complements ongoing community-based environmental contaminant monitoring research underway in the Northwest Territories.

Introduction

Country food consumption is integral to the health, wellness, and food security of the Aboriginal communities within the Dehcho and Sahtú Regions of the Northwest Territories. Further, the consumption of such country foods has been associated with lower risk factors for cardiovascular disease and diabetes. However, these food items can also pose potential chronic health risks via exposure to contaminants such as mercury (Hg) and cadmium (Cd). Elevated Hg concentrations in some fish species in some lakes in the Dehcho and Sahtú Regions (Northwest Territories) have resulted in a series of food consumption advisories that suggested people limit their consumption of walleye, northern pike, and lake trout from specific lakes in the regions. Additionally, elevated Cd levels have been recorded in the organs (e.g. kidneys, livers) of moose from some parts of the Dehcho region. However, the true extent of exposure for residents of the Dehcho and Sahtú Regions to these contaminants and others is not well characterized. The extrapolation of human contaminant exposures from levels in foods is hindered by uncertainty in food consumption patterns as well as toxicokinetic variability between individuals. The direct measurement of contaminant levels in human tissues and fluids, termed biomonitoring, is often regarded as the gold standard for human exposure assessment because it implicitly accounts for dietary patterns and inter-individual toxicokinetic differences.

Therefore, a contaminant biomonitoring study has been undertaken within the Northwest Territories in order to investigate the current levels of contaminant exposure among Dehcho and Sahtú First Nations. This work incorporates a risk-benefit approach to promote the use of country foods in order to improve nutrition and food security while lessening contaminant exposure among Dehcho and Sahtú First Nations communities.

Activities in 2015-2016

NCP funding in 2015-2016 was used to work on two components of this contaminant biomonitoring research project in the Dehcho and Sahtú Region, NT.

Component 1: Partnership Development and Consultation. These activities included participation in the 2015 Sahtú Cross Cultural Camp, engagement with the Sahtú Environmental Research and Monitoring Forum, and community consultation visits with several Decho and Sahtú communities. In December 2015 community consultations were held with the communities of Deline and Tulita, and in January 2016, community consultations were held with the communities of Fort Simpson, Hay River, Trout Lake, and Kakisa. During these visits, through a series of public forums and leadership meetings, Dr. Brian Laird and Dr. Mylene Ratelle discussed the project with community leaders, nurses, educators, elders, and other interested community members. In these meetings, we heard a range of concerns regarding environmental contaminants which included concerns about mercury, uranium, lead, disinfection by-products from water chlorination, arsenic, asbestos, indoor air, endocrine disruptors, and POPs. Additionally, community members stressed the importance of promptly returning results in plain language. Given the importance of the dissemination of the results to all involved, additional experts in risk communication and evaluation were added to the project team in order to better complete those tasks (Kelly Skinner, Chris Furgal, Shannon Majowicz, Amanda Boyd). The integration of human biomonitoring research with information regarding environmental and wildlife health was also requested during these consultations. At the conclusion of these meetings, community leaders as well as the public indicated a strong interest in participating in the research in 2016-2017.

Component 2: Dietary survey development. A Food Frequency Questionnaire (FFQ) for use with the biomonitoring project was developed in consultation with local knowledge experts to ensure its relevance to Dehcho and Sahtú communities. With this FFQ we will gather information on the types of country foods consumed by participants, how often those foods are consumed, what parts of the foods are consumed, and how the foods are prepared. We looked to these local experts to provide feedback on the completeness, cultural relevance, and comprehensibility of the dietary survey.

Component 3: Biomonitoring Implementation. In preparation for the biomonitoring project implementation, we received ethics clearance from the University of Waterloo Research Ethics Committee as well as the Stanton Territorial Health Authority. Furthermore, we sought and obtained the necessary research license from the Aurora Research Institute. In Year 1, we implemented the biomonitoring sample and data collection in a single pilot community (Jean Marie River First Nation). Throughout this process, we dialogued with Chief Gladys Norwegian (Jean Marie River First Nation) for the preparation and completion of a Community Research Agreement (CRA) that clarifies the responsibilities and expectations of the research team and each participating community. Additionally, the agreement defined the scope of the work, expected benefits and outcomes, principles of informed consent, as well as the data management plan. Chief Norwegian provided critical advice for several aspects of the CRA, including translation of documents, sampling dates, local research coordinator training, and the design of a protocol for the destruction of hair samples in a culturally appropriate manner. A local research coordinator was hired from Jean Marie River, NT, to support the recruitment of participants for the collection of blood, urine, and hair samples and for the completion of the two dietary surveys. Samples have been sent to collaborative analytical laboratories and the data will be received in the next few months. After the data has been analysed, results will be returned to the participating communities and individuals before publication. Each study participant that provided a hair, urine, and/or blood sample will receive by mail a confidential, plain-language letter detailing their contaminant exposure levels. Individuals with exposure levels that exceed biomonitoring guidelines will receive follow-up on the steps they can take to lower their levels. A Scientific Advisory Committee will be formed to guide the knowledge translation of the community-level results via: a) the creation of plain-language community reports and b) hosting public forums in each participating community. These community-level reports would only include aggregate data and could not be used to identify the results of any one individual.

Capacity Building. NCP funds were used to hire a local research coordinator in Jean Marie River, NT, and will be used to hire a local research coordinator in each of the future participating communities. These coordinators assist with the implementation of the project by overseeing participant recruitment and assisting participants with completing the surveys. For the recruitment stage, the research coordinators' work includes: contacting potential participants, explaining the objectives of the study, and obtaining informed consent. During the data collection stage, the coordinators' work includes: collecting samples of hair for chemical analysis, preparing samples for storage/shipment, and assisting participants in the completion of the electronic dietary surveys. Each coordinator receives training on participant recruitment, hair sampling, urine sampling, and implementation of the dietary surveys. Further capacity building opportunities being explored in subsequent years of the project include: the hiring of community-based, social-media savvy young people in order to maintain lines of communication between the research team and participants, and training of local research assistants on a field-portable mercury analyzer to enable community-based, participatory sample collection and data analysis for mercury monitoring.

Communications. We provided our contacts within the DHSSA, Dehcho AAROM, SRRB, SHSSA, and other organizations with bi-monthly phone/email updates of the research progress. Additionally, we regularly participate in the Sahtú Environmental Research and Monitoring Forum, providing additional opportunities to liaise with other researchers, local organization members and community leaders. Additionally, we created a plain language progress report of the dietary survey results and factsheets describing the risk-benefit balance of contaminants and nutrients in country foods in the Dehcho and Sahtú Regions. Work is underway on the design of communication materials (reports, letters) to be returned to the individuals and communities that took part in the study. Additionally, social media accounts (Facebook and twitter) were created for the project to be used in addition to typical communication strategies to help us make sure community members are aware of when we arrive to do the research, when we come back to return results, and maintain contact with participants in between sample collection and the return of results. During the research trip for community consultations and implementation of the biomonitoring study, Drs. Laird and Ratelle also gave interviews to local media including the Deh Cho Drum, CBC Radio, and My Yellowknife Now/100.1 Moose FM.

Traditional Knowledge Integration. The project will rely upon local and traditional knowledge communicated through the community consultations completed in 2014-2016 to guide the project's return of results and knowledge translation. Local perspectives provided by residents of the Dehcho and Sahtú Regions within community consultations have helped ensure that the mission and design of this research addresses the priorities and concerns of Aboriginal people within the Northwest Territories. Additionally, the project has incorporated the knowledge of local experts in the development of the dietary surveys. This local knowledge has been crucial in ensuring that the dietary survey uses the names for foods that will be recognized by members of the participating communities. Other important types of local knowledge that we have included within the dietary questionnaire include: seasonality of food availability and consumption, and preparation methods. Furthermore, we are exploring the ways by which traditional knowledge can be incorporated into the results dissemination at both the individual and community level.

Results

Results from the pilot dietary survey (the Food Frequency Questionnaire that was adapted for the region) were returned to participating communities in December 2015-2016. The pilot dietary survey was completed by participants (n=20) at the Sahtú Cross Cultural Camp and to participants from the Dehcho communities of Jean Marie River and Kakisa (n=14). The most frequently consumed country foods in the Sahtú (Table 1) and Dehcho (Table 2) are summarized below. In both regions, the most commonly consumed fish, wild game, and birds were whitefish, moose meat, and Canada goose, respectively. On average, these most frequently consumed country foods were eaten between 1.3 and 1.7 times per week among Sahtú participants and between 1.7 and 2.9 times per week among Dehcho participants.

The outcome of the community consultations was that leaders and community members from Kakisa, Deline, Hay River First Nation, Hay River Metis, Trout Lake, West Point, Tulita, and Fort Simpson confirmed a desire to see a biomonitoring study take place in the Dehcho and Sahtú Regions in order to address community concerns regarding current contaminant exposures. They also indicated a desire for environmental scientists and public health researchers to coordinate their efforts in order to obtain a more holistic picture of the movement, interactions, and impacts of contaminants in the Dehcho and Sahtú Regions.

Table 1: Top Five Consumed Foods per Food Type (Fish, Land Mammals, Birds, Plants) among 20 adult participants of the Sahtú Cross Cultural Camp in July 2015

Type of Food	Food	Percent Consuming (%)	Frequency (Day/Week) Mean (SD)
Fish	Whitefish Meat (Cooked)	90	1.3 (1.1)
	Whitefish Meat (Smoked)	80	1.5 (1.6)
	Lake Trout Meat (Cooked)	75	1.0 (0.9)
	Lake Trout Meat (Smoked)	50	1.3 (1.5)
	Coney Meat (Cooked)	45	1.1 (1.2)
Land Mammals	Moose Meat (Cooked)	90	1.7 (1.4)
	Moose Meat (Smoked)	85	1.0 (0.9)
	Moose Ribs	75	1.1 (0.9)
	Barrenland Caribou Meat (Cooked)	65	1.7 (1.7)
	Barrenland Caribou Meat (Smoked)	65	1.7 (1.7)
Birds	Canada Goose Meat Cooked	80	1.3 (1.2)
	Canada Goose Meat Smoked	55	1.1 (1.1)
	Ptarmigan Meat Cooked	50	1.0 (0.5)
	Scoter Meat Cooked	40	0.8 (0.5)
	Snow Goose Meat Cooked	35	1.1 (1.3)
	Snow Goose Meat Smoked	35	1.1 (1.3)
Plants	Low Grey Blueberries	30	1.0 (0.5)
	Wild Raspberries	10	1.0 (0.7)
	Wild Strawberries	10	0.5 (0)
	High Blueberries	5	0.5 (-)
	Green Gooseberries	5	1.5 (-)

Table 2: Top 5 Consumed Foods per Food Type (Fish, Land Mammals, Birds, Plants) among Jean Marie River and Kakisa participants (n=14) in April 2015

Type of Food	Food	Percent Consuming (%)	Frequency (Day/Week) Mean (SD)
Fish	Whitefish Meat (Cooked)	93	1.8 (1.5)
	Whitefish Meat (Smoked)	79	1.3 (1.1)
	Northern Pike Meat (Cooked)	64	1.4 (1.1)
	Whitefish Eggs	50	1.4 (1.2)
	Lake Trout Meat (Cooked)	43	1.7 (1.2)
Land Mammals	Moose Meat (Cooked)	86	2.9 (1.9)
	Moose Ribs	86	1.8 (1.2)
	Moose Bone Marrow	86	1.4 (1.1)
	Moose Tongue	86	1.0 (0.4)
	Moose Meat (Smoked)	79	2.5 (0.8)
Birds	Canada Goose Meat (Cooked)	79	1.7 (1.0)
	Mallard Meat (Cooked)	79	0.9 (0.5)
	Canada Goose Meat (Smoked)	64	1.8 (1.1)
	Mallard Meat (Smoked)	64	1.3 (1.2)
	Ptarmigan Meat (Cooked)	50	0.9 (0.5)
Plants	Wild Strawberries	57	1.2 (1.2)
	Low Grey Blueberries	50	1.8 (1.6)
	Wild Raspberries	43	1.0 (0.3)
	Bog Cranberries	29	1.4 (2.1)
	Saskatoon Berries	29	0.5 (0)

A Community Research Agreement was created in consultation with Chief Gladys Norwegian for the community of Jean Marie River. Participants were recruited for the biomonitoring sample collection, held in Jean Marie River, NT in January 2016, to provide biological samples and to complete two dietary surveys. Almost 40% of the community population consented to participate. The research team spent 4 days in the community of Jean Marie River to implement the biomonitoring project. With the assistance of a local research coordinator, a total of 46 samples (urine, blood and hair) were collected from 22 First Nation participants. Chemical analyses are still ongoing. Once the analyses are completed, results will be returned to each Year 1 participant in fall 2016.

Discussion and Conclusions

This 2015-2016 NCP research lays the groundwork for the implementation of the biomonitoring project planned to begin in the Dehcho and Sahtú Regions of the Northwest Territories in 2016-2018. This biomonitoring project will inform the development of regionally-specific communication tools that promote the consumption of country foods in a way that improves food security and nutrition within Mackenzie Valley Dene and Métis communities while lowering exposure to environmental contaminants. Furthermore, the biomonitoring research will provide the information needed to create a screening tool to help identify those who are most at risk of contaminant exposure. This screening tool, which has been labeled as a critical outcome by the policy leaders on our research team, will enable contaminant risk messaging and follow-up interventions at the individual and population level to be targeted to those most at risk. The dietary survey developed and evaluated through this research will provide critical information for the identification of the most significant sources of exposure for the contaminants studied in the biomonitoring project.

Expected Project Completion Date:

March 31, 2018

Project Website

Facebook: https://www.facebook.com/BiomonitoringNT/

Twitter: @NTBiomonitoring

Acknowledgments

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References

Berti, P.R., et al. 1998. Dietary exposure to chemical contaminants from traditional food among adult Dene/Metis in the western Northwest Territories, Canada. Environ. Res. 76(2): 131-142.

Nakano, T., et al. 2005. Food use of Dene/Metis and Yukon children. International Journal of Circumpolar Health. 64(2): 137-146.

Kuhnlein, H.V., et al. 2004. Arctic indigenous peoples experience the nutrition transition with changing dietary patterns and obesity. J. of Nutr. 124: 1447-1453.

Kuhnlein, H.V. and O. Receveur. 2007. Local cultural animal food contributes high levels of nutrients for arctic Canadian Indigenous adults and children. J. Nutr. 137(4): 1110-1114.

Dewailly, E., et al. 2002. Cardiovascular disease risk factors and n-3 fatty acid status in the adult population of James Bay Cree. Am. J. Clin. Nutr. 76(1): 85-92.

Receveur, O., M. Boulay, and H.V. Kuhnlein. 1997. Decreasing traditional food use affects diet quality for adult Dene/Metis in 16 communities of the Canadian Northwest Territories. J of Nutr. 127(11): 2179-2186.

Kuhnlein, H.V. and H.M. Chan. 2000. Environment and contaminants in traditional food systems of northern indigenous peoples. An. Rev. of Nutr. 20: 595-626.

DHSS. Mercury levels in fish. 2012. Available from: http://www.hss.gov.nt.ca/health/environmental-health/mercury-levels-fish.

DHSS. (2009, February 10). Limit consumption of moose organs from the southern Mackenzie Mountains in the DehCho, due to high cadmium levels. Available from: http://www.hss.gov.nt.ca/advisory/limit-consumption-moose-organs-southern-mackenzie-mountains-DehCho-due-high-cadmium-levels.

Sexton, K., L.L. Needham, and J.L. Pirkle. 2004. Human biomonitoring of environmental chemicals. *Am. Sci.* 92(1): 38-45.

A Pilot Investigation of the Links Between Contaminant Exposure, Nutritional Status, and Country Food Use in the Sahtú Region

Projet pilote d'enquête sur les liens entre l'exposition aux contaminants, l'état nutritionnel et d'utilisation d'aliments prélevés dans la nature dans la région de Sahtú

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Abstract

Strengthening and maintaining partnerships in the Sahtú Region was a key undertaking for the pilot phase of this project. These activities included participation in the 2015 Sahtú Cross Cultural Camp, engagement with the Sahtú Environmental Research and Monitoring Forum, and community consultation visits in Délı̨nę and Tulit'a, NT. During these visits, through a series of public and one-on-one meetings, Brian Laird and Mylène Ratelle discussed the project with community leaders, nurses, educators, elders, and other interested community members. During these meetings, we heard a range of concerns regarding

Résumé

Le renforcement et le maintien de partenariats dans la région du Sahtú ont été la principale entreprise de ce projet pilote. Ces activités comprenaient la participation au camp interculturel du Sahtú de 2015, la contribution au forum de recherche et de surveillance de l'environnement du Sahtú ainsi que des visites de consultation des collectivités à Délı̨nę et Tulit'a (Nunavut). Au cours de ces visites, au moyen d'une série de réunions individuelles et publiques, Brian Laird et Mylène Ratelle ont discuté du projet avec des dirigeants communautaires, des infirmières, des éducateurs, des Aînés et d'autres membres intéressés de la collectivité. Pendant ces réunions,

environmental contaminants, including mercury, uranium, lead, disinfection by-products from water chlorination, arsenic, asbestos, indoor air, endocrine disruptors, and POPs. Additionally, community members strongly expressed the importance of returning results promptly and in plain language. Given the importance of the dissemination of the results to all involved, it was concluded that additional experts in risk communication and evaluation should be added to the project team in order to better complete those tasks. The integration of human biomonitoring research with information regarding environmental and wildlife health was also requested. At the conclusion of these meetings, community leaders as well as the public in both Délı̨nę and Tulít'a indicated a strong interest in participating in the research.

nous avons entendu un éventail de préoccupations concernant les contaminants environnementaux, notamment le mercure, l'uranium, le plomb, les sous-produits de désinfection provenant de la chloration de l'eau, l'arsenic, l'amiante, l'air intérieur, les perturbateurs endocriniens et les polluants organiques persistants. De plus, les membres de la collectivité ont fortement exprimé l'importance d'obtenir des résultats rapidement et dans un langage clair. Étant donné l'importance de la diffusion des résultats à toutes les personnes concernées, on a conclu que des experts supplémentaires en communication et en évaluation des risques doivent être ajoutés à l'équipe du projet afin de mieux effectuer ces tâches. L'intégration de la recherche de biosurveillance humaine aux renseignements concernant la santé de l'environnement et de la faune a également été demandée. À la fin de ces réunions, des dirigeants communautaires, ainsi que le public de Délı̨nę et de Tulít'a, ont manifesté un intérêt marqué à participer à la recherche.

Key messages

- Délı̨nę and Tulít'a community members have a range of concerns regarding environmental contaminants, including mercury, uranium, lead, disinfection by-products from water chlorination, arsenic, asbestos, indoor air, endocrine disruptors, and POPs.
- The importance of returning results promptly and in plain language was strongly expressed.
- Given the importance of the dissemination of the results to all involved, additional experts in risk communication and evaluation should be added to the project team in order to better complete those tasks.
- The integration of human biomonitoring research with information regarding environmental and wildlife health was requested.
- Community leaders as well as the public in both Délı̨nę and Tulít'a indicated a strong interest in participating in the research.

Messages clés

- Les membres des collectivités de Délı̨nę et de Tulít'a ont un éventail de préoccupations concernant les contaminants environnementaux, notamment le mercure, l'uranium, le plomb, les sous-produits de désinfection provenant de la chloration de l'eau, l'arsenic, l'amiante, l'air intérieur, les perturbateurs endocriniens et les polluants organiques persistants.
- Ils ont clairement exprimé qu'il était important d'obtenir des résultats dans les plus brefs délais et en langage clair.
- Étant donné l'importance de la diffusion des résultats à toutes les personnes concernées, des experts supplémentaires en communication et en évaluation des risques doivent être ajoutés à l'équipe du projet afin de mieux effectuer ces tâches.
- L'intégration de la recherche de biosurveillance humaine aux renseignements concernant la santé de l'environnement et de la faune a été demandée.

- Les dirigeants communautaires, ainsi que le public de Déline et de Tulít'a, ont manifesté un intérêt marqué à participer à la recherche.

Objectives

Short Term

1. Adapt existing dietary surveys for the Sahtú;
2. Validate the dietary survey with representatives of all five Sahtú communities at the annual Cross Cultural Camp to be held in July 2015
3. Convene a focus group at the July 2015 Cross Cultural Camp to assess the repeatability of the dietary survey through a test-retest approach.

Long Term

1. Execute a cross-sectional biomonitoring study that evaluates MeHg exposure and nutritional biomarkers among study participants in the Sahtú;
2. Create a public health screening tool that can be used to characterize those most at risk of facing elevated MeHg exposures in the Sahtú Region;
3. Develop public health communication strategies that promote country food reliance in order to maximize nutrient status while minimizing MeHg exposure in the Sahtú Region.

Introduction

Country food consumption among First Nations is associated with improved nutrition, food security, and lower rates of chronic diseases (e.g., cardiovascular disease, diabetes); however, these food items can also pose potential chronic health risks via exposure to contaminants such as mercury. Elevated mercury concentrations in some fish species in some lakes in the Sahtú Region (Northwest Territories) have resulted in a series of food consumption advisories that suggested people limit or stop their consumption of predatory fish such as walleye, northern pike, inconnu, and lake trout from specific lakes in the region.

A pilot study focusing on a dietary survey was conducted within the Sahtú Region to investigate the links between contaminants in the environment, community risk perception, nutritional status, and country food use. The work builds on, and is coordinated with, an ongoing contaminant biomonitoring study in the Dehcho. This pilot phase involved a community-based study to develop and evaluate a dietary questionnaire to be implemented as part of a future Sahtú biomonitoring project. This provided local training opportunities in the development of a community-based research program, and included a focus group of representatives of all five Sahtú communities. A risk-benefit approach was incorporated to promote the use of country foods in order to improve nutrition and food security while lessening mercury exposure among Sahtú communities.

Since 2007, there have been 12 consumption advisories issued in the NWT due to mercury levels in the muscle of predatory fish measuring above Health Canada recommendations for commercial fish. Although increased mercury levels in predatory fish in the NWT is not a new issue, the public concern over contaminants in general has been steadily increasing [1]. In the Sahtú Region, community concern about the potential negative impacts of mercury contamination in fish, public health advisories for local lakes (e.g., Ste. Therese and Kelly lakes) [2], and associated human health risks remains a priority.

The five Sahtú communities are still heavily reliant on country foods, especially wild-harvested fish such as walleye (Sander vitreus), northern pike (Esox lucius), lake trout (Salvelinus namaycaush), and lake whitefish (Coregonus clupeaformis). These are integral to the health, wellness, and food security of the Aboriginal communities within the Sahtú Region[3-6]. Further, the consumption of such country foods has been associated with lower risk factors for cardiovascular disease and diabetes [7-9]. However, global mercury (Hg) emissions have resulted in elevated methylmercury (MeHg) concentrations in several of the long-lived predatory fish species (e.g., lake trout, walleye and northern pike) in some lakes in the region. Prolonged dietary exposure to MeHg has the potential to cause permanent adverse effects to the neurological, immune, and cardiovascular systems; the developing fetus and children are particularly vulnerable to the hazards of MeHg [10]. As such, global Hg emissions have jeopardized the safety of these cultural linchpins and dietary staples and potentially undermined the food security of Sahtú residents.

Activities in 2015-2016

Principal Investigator Brian Laird and postdoctoral student Mylène Ratelle completed several scoping and research design activities during 2015-2016:

- Identified primary contacts in the Sahtú Region and Government of the NWT.
- Review of relevant literature, including previous contaminants research in the Sahtú Region.
- Presentations and attendance at teleconference meetings of the Sahtú Environmental Research and Monitoring (ERM) Forum, including representatives of the five Sahtú ʔehdzo Got'ı̨nę (Renewable Resources Councils), the Sahtú Secretariat Inc, and Sahtú Renewable Resources Board, as follows:
  - January 15: overview of the human biomonitoring project
  - June 4: planning meeting to discuss activities at the Cross-Cultural Research (CCR) Camp
  - October 26: a summary of CCR Camp results and an overview of plans for community visits.
  - December 11: summary of outcomes of community visits in Tulı́t'a and Délı̨nę.
  - Mylène Ratelle attended additional monthly teleconferences of the Forum to gain a good understanding of the broader research context.
- Attended the CCR Camp at Sans Sault Rapids on the Mackenzie River on July 4-10, attended by 38 participants, including 26 community representatives and 12 facilitators and researchers.
  - Laird and Ratelle conducted a workshop on the project on June 5, and solicited input on people's questions and concerns. Oher topics related to potential research design that were discussed include: monitoring of a range of contaminants including lead, selenium, PCBs and other chemicals; potential benefits and challenges of including children in the study; and how best to include traditional knowledge and elders. It was suggested that a Sahtú representative should be sent each year to attend the Northern Contaminants Program conference.
  - Focus groups and interviews were conducted with camp participants, including an electronic Food Frequency Survey. electronic dietary survey using QuickTapSurvey. Participants identified the types of traditional foods they consumed over the past year, the frequency by which those foods were consumed, where the foods had been harvested, and how the foods were prepared.
  - After participants completed the survey, a facilitated focus group discussion was convened. During this focus group, we asked for input on their satisfaction with the survey. These focus groups provided valuable information pertaining to

local food names, common preparation methods, as well as additional foods that should be included.

- September 4: A teleconference of the Great Bear Lake contaminants and food security research cluster, convened by the secretariat of the Sahtú ERM Forum.
- Visits by Laird and Ratelle to Déline on December 1-2, and Tulít'a on December 3-4 to introduce the project and seek feedback in its design.
  - Déline: Met with Chief Leonard Kenny, Walter Bayha at the Land Corporation, the ʔehdzo Got'ıne with Ed Reeves and a number of community members in a public meeting (12 men attended). Mylène was also able to do a radio interview and meet with staff at the health centre.
  - Tulít'a: Met with Chief Frank Andrew for several hours over a few meetings. It was a more challenging time in Tulít'a because there was a conflicting meeting and open-house but over-all people welcomed the project. In Tulít'a, lead exposure was voiced as a concern. There has been some advisories there around eating liver from predatory fish.
- Developed NCP Phase 2 funding proposal based on Phase 1 outcomes.
- December 7-8: Presented about the project at the Northern Contaminants Program results workshop in Vancouver. There is a lot of interest in the project because of the collaborative approach being used. Community involvement has been strong in informing the project even before the project begins. This started in the summer at the CCR camp.

Capacity Building

- Activities built awareness of human biomonitoring and facilitated development of community research questions.

Communications

- Communications was a primary objective of this phase, including discussions with other researchers and institutional stakeholders as well as communities through the following:
  - Sahtú ERM Forum
  - 26 community participants at the CCR Camp
  - Community leaders and the public, Déline and Tulít'a
  - Participants in the annual NCP workshop
  - Promoted Facebook post

Traditional Knowledge Integration

- Local perspectives provided by residents of the Dehcho and Sahtu Regions within community consultations have helped ensure that the mission and design of this research addresses the priorities and concerns of Aboriginal people within the Northwest Terrotories.
- Additionally, the project has incorporated the knowledge of local experts for the development of the dietary surveys. This local knowledge will be crucial in ensuring that the dietary survey uses the species names that recognized by members of the participating communities.
- Other important types of local knowledge that we have tried to include within the dietary questionnaire include: seasonality of food availability and consumption, and preparation methods.

Results

Findings and results to date of the above activities (see guide below for formatting tips regarding tables and figures).

- Established partnership with Déline ʔehdzo Got'ıne, and began partnership discussions with Tulít'a ʔehdzo Got'ıne.

- Three research authorizations obtained:
  - Ethics approval from the University of Waterloo
  - Aurora Research Institute license
  - Stanton Hospital permit
- Consolidated research partnership between Sahtú Renewable Resources Board and University of Waterloo.
- Developed an NCP funding proposal for Phase 2 research with Délı̨nę, continuation of Phase 1 consultations with Tulít'a, and initiation of Phase 1 consultations with Fort Good Hope, Norman Wells and possibly Colville Lake.
- Délı̨nę consultation results: People in the public meeting had constructive comments and questions and emphasized that uranium exposure was a big concern.
- Tulít'a consultation results: Lead exposure was voiced as a concern. There have been some advisories there around eating liver from predatory fish.
- Other commonly expressed concerns:
  - Including store food in the study because people want to know what contaminants are in those foods compared with country foods.
  - Coordination and linkages among various contaminants research activities.
- Clarification on the roles of health centres: the team can take hair and urine samples but because blood samples are being taken, the research team will need help from the health centres because a licensed nurse has to take the blood samples.

Discussion and Conclusions

This year was Phase 1 of a multi-year program. The project was successful with respect to the following objectives:

- Building community and stakeholder awareness and understanding of the program among representatives of five communities.
- Identifying community research questions and developing an understanding of Sahtú and community-specific approaches for research.
- Providing a preliminary scoping of community diet.
- Building a formal partnership with the Sahtú Renewable Resources Board and Délı̨nę ʔehdzo Got'ı̨ne.
- Initiating partnership-building with the Tulít'a ʔehdzo Got'ı̨ne.
- Completing a Sahtú-specific literature review.
- Contributing to the Sahtú ERM Forum's regional Environmental Research and Monitoring and review of research licensing referrals policy Strategy (in progress).
- Note that a "slow and steady" approach to community engagement is required given the sensitivity of this kind of research and the need to ensure that partnerships are robust and built on a strong foundation of trust. Notwithstanding shared interest in the research related to health implications of eating country foods, different communities may have differing levels of research capacity and confidence, and thus may require differing levels of engagement. Délı̨nę, which had already experienced related kinds of research through the Canada-Délı̨nę Uranium Table process investigating human health and environmental impacts of Port Radium, was confident to engage in this project. However, Tulít'a has requested additional discussions before moving forward.

Expected Project Completion Date:

Completion of the Sahtú project to be confirmed based on consultations with Tulít'a, Norman Wells, Fort Good Hope and Colville Lake. Preliminary scoping indicates a possible completion date of March 31, 2020, including a results communication phase.

Community Based Monitoring and Research

Surveillance communautaire et recherche

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

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

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Abstract

Dehcho community members are concerned about levels of mercury in food fishes such as Northern Pike, Walleye, and Lake Whitefish. In some traditional fishing lakes, mercury levels are high enough to have led to consumption advisories. Fishers, community members, regulators, monitors, and scientists want to understand why fish mercury levels are relatively low in some lakes but higher in others, and why fish mercury levels are increasing in some lakes but stable in others.

Résumé

Les membres de la collectivité du Dehcho s'inquiètent des concentrations de mercure chez des poissons de consommation tels que le grand brochet, le doré jaune et le grand corégone. Dans quelques lacs dans lesquels la pêche traditionnelle est pratiquée, les concentrations de mercure sont suffisamment élevées pour avoir mené à la diffusion d'avis aux consommateurs. Les pêcheurs, les membres de la collectivité, les organismes de réglementation, les organismes de surveillance et les scientifiques

By understanding the dominant drivers of mercury in fish in the Dehcho, we can more accurately predict how climate change and resource development may affect it.

From 2013-2015, 8 Dehcho lakes were sampled for fish, benthic invertebrates, zooplankton, and sediment. We determined fish mercury levels, as well as fish age, size, trophic level, and food source. We also determined mercury levels in invertebrates and water. Water chemistry samples were analyzed for a suite of variables. Interim results (data from 2015 for zooplankton, sediment, invertebrates not yet available) indicate that Lake Whitefish are in general safe to eat in all lakes, whereas Northern Pike and Walleye exceed consumption guidelines in some lakes. Lake Whitefish, Northern Pike, and Walleye were captured in enough lakes to enable analysis of predictor variables. Results indicate that future monitoring and predictions of fish mercury levels should consider general lake chemistry parameters, including concentrations of major catios, dissolved organic carbon, and chlorophyll-a. Results are also informing discussions regarding mercury mitigation strategies, such as fish-downs, in lakes with the highest mercury concentrations (McGill and Sanguez).

veulent comprendre les raisons pour lesquelles les concentrations de mercure chez le poisson sont relativement faibles dans certains lacs, mais élevées dans d'autres, et les raisons pour lesquelles les concentrations de mercure chez le poisson augmentent dans certains lacs, mais sont stables dans d'autres. Si nous comprenons les principaux déterminants de la présence de mercure chez le poisson dans le Dehcho, nous pourrons prévoir plus exactement les façons dont les changements climatiques et la mise en valeur des ressources peuvent l'influencer.

De 2013 à 2015, des prélèvements d'échantillons de poissons, d'invertébrés benthiques, de zooplancton et de sédiments ont été effectués dans huit lacs du Dehcho. Nous avons déterminé les concentrations de mercure chez le poisson, ainsi que l'âge, la taille, le niveau trophique et la source d'alimentation des poissons, de même que les concentrations de mercure chez les invertébrés et dans l'eau. Des échantillons d'eau prélevés pour en effectuer l'analyse chimique ont été examinés afin de déterminer un ensemble de variables. Les résultats intérimaires (les données de 2015 pour le zooplancton, les sédiments et les invertébrés ne sont pas encore disponibles) indiquent que le grand corégone de tous les lacs peut en général être consommé sans danger, alors que le grand brochet et le doré jaune dépassent les lignes directrices sur la consommation dans quelques lacs. Le grand corégone, le grand brochet et le doré jaune ont été pris dans un nombre suffisant de lacs pour que les variables prédictives puissent être analysées. Les résultats indiquent que la surveillance et les prévisions des concentrations de mercure chez le poisson devraient tenir compte des paramètres généraux de la chimie lacustre, y compris des concentrations importantes de cations, de carbone organique dissous et de chlorophylle-a. Les résultats éclairent également les discussions sur les stratégies d'atténuation du mercure, comme la réduction de la biomasse de poissons, dans les lacs dans lesquels les concentrations de mercure sont les plus fortes (McGill et Sanguez).

Key messages

- In general, mercury levels in Lake Whitefish are below subsistence consumption and commercial sale guidelines (some exceptions)
- Of the eight lakes studied, Kakisa, Trout, and Mustard have the lowest fish mercury levels, and Sanguez and McGill have the highest fish mercury levels
- Size –standardized mercury levels in Lake Whitefish (at 450 mm fork length) are best predicted by dissolved organic carbon concentrations
- Size-standardized mercury levels in Northern Pike (at 650 mm fork length) are best predicted by age-at-size and lake chloride concentrations
- Size-standardized mercury levels in Walleye (at 450 mm fork length) are best predicted by lake chlorophyll-a concentrations

Messages clés

- En général, les concentrations de mercure chez le grand corégone sont inférieures à celles des lignes directrices pour la consommation de subsistance et la vente commerciale (avec quelques exceptions).
- Sur les huit lacs étudiés, les lacs Kakisa, Trout et Mustard enregistrent les concentrations de mercure chez le poisson les plus faibles et les lacs Sanguez et McGill les plus élevées.
- Les concentrations de mercure normalisées selon la taille chez le grand corégone (de 450 mm de longueur à la fourche) sont prévues avec la meilleure précision d'après les concentrations de carbone organique dissous.
- Les concentrations de mercure normalisées selon la taille chez le grand brochet (de 650 mm de longueur à la fourche) sont prévues avec la meilleure précision d'après l'âge à la taille et les concentrations de chlorure du lac.
- Les concentrations de mercure chez le doré jaune (de 450 mm de longueur à la fourche) sont prévues avec la meilleure précision d'après les concentrations de chlorophylle-a dans le lac.

Objectives

The proposal submitted included several objectives relating to community capacity-building and youth education. The review committee indicated that funds were only available for laboratory analyses and travel. Thus, the project was re-scoped to one primary objective:

- To continue mercury testing in commonly-consumed fish from select water bodies, as determined by a 3 year sampling plan (Year 3 of 3) and project that was also supported by CIMP and Health Canada.

Introduction

Mercury (Hg) biomagnifies and bioaccumulates in aquatic food webs, and Hg levels in fish respond to many ecological and physicochemical variables (e.g., see AMAP 2011, Wiener 2003). We know that Hg levels in some traditional food fish species in the Dehcho region can be high (e.g., Lockhart et al. 2005), and that these levels continue to increase in some lakes (e.g., Evans et al. 2010). What we don't know is why some lakes have high and/or increasing fish Hg levels whereas other lakes have relatively low and/or stable fish mercury levels. This makes it difficult to predict how fish Hg levels will respond to continuing environmental change, and to evaluate mitigation options for lakes with high mercury concentrations in fish. In this three -year project, we aimed to update data on mercury levels in commonly consumed fish species from eight lakes in the Dehcho region, NT (Ekali, Sanguez, Trout, McGill, Gargan, Tathlina, Kakisa, Mustard). Analyses focused on Lake Whitefish (*Coregonus clupeaformis*), Northern Pike (*Esox lucius*), and Walleye (*Sander vitreus*). By enhancing our ability to predict Hg levels, this research will allow a better understanding of why fish Hg levels differ among lakes, and how fish Hg levels will be affected by future environmental change. Results will contribute to the development of targeted, efficient monitoring programs, and identify future mitigation strategies (e.g., fish-downs) for lakes with high fish mercury levels.

Activities in 2015-2016

A description of NCP-funded (and related) activities carried out during the 2015-2016 fiscal year. This section should answer the questions: what? where? when? who? how? This section should also include the sub-headings of:

Capacity Building

- Worked with fish harvesters and community members from Liidlii Kue First Nation (3) and fish harvesters and the environmental monitor from Ka'a'gee Tu First Nation (2) to collect fish, invertebrates, and water from Mustard and Kakisa lakes in August and September 2015
- Presentation and hands-on activity with students at Kakisa Lake school (September 2015)
- Upper class from Sambaa K'e school attended annual meeting (Fall 2015)

Communications

- Co-presentation of results at NCP meeting in December 2015 (Vancouver) with Melaine Simba (Environmental Monitor from Ka'a'gee Tu FN)
- Co-presentation of results at regional CIMP meeting in January 2016 (Fort Simpson) with Melaine Simba and other project participants
- Meeting with leadership and resource managers in Liidlii Kue (August 2015)

- Fact sheet regarding project presented and discussed with Dehcho Watershed Ecosystem Advisory Committee meeting (March 2016)
- Fact sheet discussed with Chief Gladys Norwegian (Jean Marie River FN)

Traditional Knowledge Integration

- This project was developed in response to community concerns about levels of mercury in subsistence food fishes
- In previous years, related projects have involved food recall interviews, and quantification of traditional food harvest and consumption
- A related project on human biomonitoring in Dehcho communities involves interviews with knowledge holders.

Results

Mercury results from all lakes and for all species are summarized in Table 1; this table includes data collected in 2013, 2014, and 2015. All mercury concentrations are reported in wet weight. Mean mercury concentrations were highest in Northern Pike from Sanguez Lake and Walleye from McGill Lake, and lowest in Lake Whitefish from Kakisa Lake.

Lake Trout

Lake Trout were only captured in two lakes. Mercury concentrations in Lake Trout varied from a minimum of 0.08 ppm in Mustard Lake to a maximum 0.64 in Trout Lake. Mercury concentrations in Lake Trout were significantly related to fork length (ANCOVA, $F=46.29$, $P<0.0001$, $df=1,59$, $R^2=0.44$), but were not significantly different between the two lakes (ANCOVA, $P>0.05$, $df=2,59$). In Trout Lake, all Lake Trout exceeded the subsistence consumption guideline whereas only 23% of Lake Trout exceeded the commercial sale guideline (Table 2). In Mustard Lake, ~36% of Lake Trout exceeded the subsistence consumption guideline and only 2% of Lake Trout exceeded the commercial sale guideline; this is because the Lake Trout captured in Mustard Lake were smaller than those captured in Trout Lake (Table 1).

Table 1. Mean wet mercury concentrations for each species in each lake

Lake	Species	[Hg] ppm	+/- SD	Fork length (mm)	+/- SD	n
EKALI	Lake Whitefish	0.0786	0.0246	393	88	14
	Nothern Pike	0.3978	0.2668	473	155	25
	Walleye	0.2858	0.0931	366	94	26
	All	*0.2843*	*0.2109*	*413*	*128*	*65*
GARGAN	Lake Whitefish	0.1278	0.0578	449	68	23
	Nothern Pike	0.3495	0.3093	458	210	19
	All	*0.2281*	*0.2372*	*453*	*148*	*42*
KAKISA	Lake Whitefish	0.0386	0.0157	385	56	28
	Nothern Pike	0.2616	0.2355	513	142	18
	Walleye	0.2736	0.1718	409	66	11
	All	*0.1544*	*0.1882*	*430*	*108*	*57*
MCGILL	Lake Whitefish	0.1609	0.0711	499	30	11
	Nothern Pike	0.4833	0.3611	489	186	15
	Walleye	0.9750	0.3395	450	55	16
	All	*0.5862*	*0.4464*	*477*	*117*	*42*
MUSTARD	Lake Trout	0.1855	0.0762	433	48	47
	Nothern Pike	0.1381	0.0780	490	195	6
	All	*0.1801*	*0.0771*	*440*	*78*	*53*
SANGUEZ	Lake Whitefish	0.1280	0.0262	493	43	5
	Nothern Pike	0.9870	0.6031	648	184	12
	Walleye	0.7079	0.3361	515	52	15
	All	*0.7921*	*0.6489*	*561*	*135*	*32*
TATHLINA	Lake Whitefish	0.0835	0.0260	363	44	23
	Nothern Pike	0.3663	0.2812	559	215	19
	Walleye	0.6250	0.2165	464	66	12
	All	*0.3033*	*0.2876*	*454*	*158*	*54*
TROUT	Lake Trout	0.3303	0.1527	669	60	13
	Lake Whitefish	0.0372	0.0089	295	73	10
	Nothern Pike	0.1533	0.0852	570	135	10
	Walleye	0.2929	0.3095	369	139	11
	All	*0.2141*	*0.2101*	*486*	*185*	*44*

Table 2. Percent of fish exceeding subsistence consumption (0.2 ppm wet) and commercial sale (0.5 ppm wet) guidelines in each of the 8 study lakes

		% Exceeding guideline	
Lake	**Fish Species**	**Subsistence Consumption (0.2 pp)**	**Commercial Sale (0.5 ppm)**
Ekali	Lake Whitefish	0.0	0.0
	Northern Pike	68.0	32.0
	Walleye	73.1	0.0
	All	*55.4*	*12.3*
Gargan	Lake Whitefish	8.7	0.0
	Northern Pike	63.2	21.1
	All	*33.3*	*9.5*
Kakisa	Lake Whitefish	0.0	0.0
	Northern Pike	44.4	16.7
	Walleye	54.5	9.1
	All	*24.6*	*7.0*
McGill	Lake Whitefish	18.2	0.0
	Northern Pike	80.0	40.0
	Walleye	100.0	100.0
	All	*71.4*	*52.4*
Mustard	Lake Trout	36.2	2.1
	Northern Pike	16.7	0.0
	All	*34.0*	*1.9*
Sanguez	Lake Whitefish	0.0	0.0
	Northern Pike	92.3	76.9
	Walleye	93.8	81.3
	All	*79.4*	*67.6*
Tathlina	Lake Whitefish	0.0	0.0
	Northern Pike	63.2	21.1
	Walleye	100.0	75.0
	All	*44.4*	*24.1*
Trout	Lake Trout	100.0	23.1
	Lake Whitefish	0.0	0.0
	Northern Pike	40.0	0.0
	Walleye	45.5	27.3
	All	*50.0*	*13.6*

Lake Whitefish

Lake Whitefish were captured in all lakes except for Mustard Lake. Wet mercury concentrations in individual fish ranged from a minimum of 0.02 ppm in Kakisa Lake to a maximum of 0.32 ppm in McGill Lake. Mercury concentrations varied significantly among lakes and with fork length (ANCOVA, F>4.77, P< 0.0003, n=113), and the relationship between mercury concentration and fork length also differed significantly among lakes (ANCOVA, F=5.42, P<0.0001, df=6,113). Among-lake differences in Lake Whitefish mercury concentrations need further investigation, but at present are best explained (74% of variation) by dissolved organic carbon concentrations (linear regression, F=17.9, P=0.0082, 1,6).

Northern Pike

Northern Pike were captured in all 8 study lakes. Wet mercury concentrations in Northern Pike ranged from a minimum of 0.032 ppm in Kakisa Lake to a maximum of 1.989 ppm in Sanguez Lake. Mercury concentrations in Northern Pike varied significantly among lakes, and increased significantly with fork length. The relationship between mercury concentration and fork length also differed significantly among lakes (i.e., there was a significant interaction; ANCOVA (full model), F=52.65, P<0.0001, df=15,123, R^2=0.88).

Among-lake differences in mercury concentrations in Northern Pike were best explained by lake-specific least squares mean age (at 650 mm), and by Chloride concentrations in lake water. Mercury concentrations were significantly and positively related to least-squares mean age, and significantly and positively related to Chloride concentrations in lake water. In a multiple regression, lake Chloride concentration and lake-specific least squares mean age of Northern Pike explained 93% of the variation in least-squares means mercury concentrations (F=33.8, P=0.0027, df=2,7).

In Mustard and Trout lakes, which had the lowest Hg concentrations in Northern Pike, no fish exceeded the commercial sale guideline whereas approximately 17% and 40%, respectively, of fish exceeded the subsistence consumption guideline (Table 2). In Sanguez Lake, which had the highest Hg concentrations in Northern Pike, 77% of fish exceeded the commercial sale guideline, and 92% of fish exceeded the subsistence consumption guideline.

Walleye

Walleye were captured in six of the eight sampled lakes (not captured in Gargan or Mustard lakes). Wet mercury concentrations in Walleye ranged from minimum of 0.036 ppm in Trout Lake to a maximum of 1.9 ppm in Sanguez Lake. Mercury concentrations differed significantly among lakes (ANCOVA, F=15.6, P<0.0001, df=5,82), and were significantly related to fork length (ANCOVA, F=499.31, P<0.0001, df=1,82). The relationship between mercury and fork length did not differ among lakes (i.e., common slope; ANCOVA, P>0.05).

Among-lake differences were significantly and negatively related to chlorophyll-a concentrations in lake water (linear regression, F=56.02, P=0.0017, df=1,5); chlorophyll-a explained 92% of the among-lake variability in size-standardized mercury concentrations in Walleye.

Discussion and Conclusions:

Results of this study update our knowledge and understanding of fish mercury levels in the Dehcho region, NT. As expected, we found that Walleye and Northern Pike had higher Hg concentrations than Lake Whitefish, and that Hg concentrations varied significantly among lakes. Further statistical analysis will allow us to investigate why Hg is higher in Walleye than in Northern Pike in some lakes (e.g., Tathlina, Trout, McGill) whereas the reverse is true in other lakes (e.g., Ekali, Sanguez).

Much of the impetus for this project was uncertainty regarding causes of among-lake variation in fish mercury concentrations. While results are still provisional pending finalization of the dataset, it appears that lake and catchment chemistry are important in predicting fish mercury concentrations. We found that size-standardized, lake-specific least squares mean (LSmean) Hg concentrations in Lake Whitefish were significantly and positively related to dissolved organic carbon (DOC) concentrations, that size-standardized LSmean Hg concentrations in Northern Pike were significantly and positively related to lake Chloride concentrations, and that size-standardized LSmean Hg concentrations in Walleye were significantly and negatively related to chlorophyll-a concentrations.

The relationship between Hg concentrations in biota and DOC in lake water is complex, and has been reported to be a threshold response where there is a positive relationship between Hg in biota and DOC up to a concentration of ~8-10 mg/L of DOC (e.g., Wren et al. 1991; French et al. 2014). This positive relationship reflects DOC-mediated transport of Hg from the watershed to downstream surface waters. Beyond a DOC concentration of 8-10 mg/L, however, a negative relationship can be observed (e.g., Grieb et al. 1990). This is thought to reflect sorption of Hg and MeHg to DOC and concomitant decreases in Hg bioavailability and methylation rates (e.g., Miskimmin et al. 1992; Barkay et al. 1997). In this study, we observed a positive relationship between LSmean Hg in Lake Whitefish and DOC at concentrations of DOC that exceeded 19 mg/L. Further investigation of the source of DOC (autochthonous vs allochthonous) in the study lakes may provide further insight into this result; it is possible that continuing anthropogenic-induced increases in lake water DOC will result in higher Hg concentrations in some fish species.

Size-standardized LSmean Hg concentrations in Northern Pike were significantly and positively related to LSmean age-at-650 mm and Chloride concentrations in lake water. It is well known that Hg accumulates as fish age, therefore the positive relationship between Hg and age is not surprising. The relationship between Hg in and Chloride in lake water requires further investigation. Chloride concentrations in lake water could reflect groundwater inputs, and/or extent of groundwater-surface interactions, and either of these may affect methylation conditions in the lake or catchment. Future research (2016-2017) in a subset of the study lakes will aim to further elucidate the mechanisms behind this relationship.

Among-lake differences in Walleye LSmean Hg concentration (at 450 mm fork length) were best explained by chlorophyll-a. This could be a result of one or both of: i) bloom dilution; and/or, ii) growth dilution. In bloom dilution, the amount of bioavailable Hg is diluted amongst many algal cells, and this reduced concentration of Hg in primary producers is propagated through the food web (Pickhardt et al. 2002). In growth dilution, faster, more efficiently growing fish produce more flesh per unit food (and contaminant) intake, and this results in lower contaminant concentrations (e.g., Essington and Houser 2002). It is likely that both bloom dilution and growth dilution are affecting Hg concentrations in Walleye in the study lakes, but further study of Hg concentrations in algae and Walleye growth rates are required to confirm this.

Expected Project Completion Date:

Provide month and year of expected completion date of the project.

31 December 2016 (original project);
31 December 2017 (extended project)

Project website (if applicable):

If your project has a presence on the internet, including a website or social media page, please provide the link.

Acknowledgments

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NCP Project Statistics and Information

The NCP is obligated to report on its performance on an annual basis, using the information listed below, as well as other measures. This information will also be summarized and published in the Synopsis of Research publication, and shared with the Regional Contaminants Committees. Please assist us by filling out the following table:

References

AMAP. 2011. *AMAP Assessment 2011: Mercury in the Arctic*. Oslo, Nowary: Arctic Monitoring and Assessment Program (AMAP), xiv+ 193 pp.

Barkay, T., Gillman, M., and Turner, R.R. 1997. Effects of dissolved organic carbon and salinity on bioavailability of mercury. *Appl. Environ. Microbiol.* 63: 4267-4271.

Essington, T. E., and Houser, J. N. 2002. The effect of whole-lake nutrient enrichment on mercury concentration in age-1 yellow perch. *Trans. Am. Fish. Soc.* 132: 57–68.

Evans, M.S. 2010, Spatial and long-term trends in persistent organic contaminants and metals in lake trout and burbot from the Northwest Territories. In: *Synopsis of Research Conducted under the 2010-2011 Northern Contaminants Program.* Ottawa: Indian and Northern Affairs Canada. pp. 140-149.

French, T.D., Houben, A.J., Desfoges, J-P, Kimpe, L.E., Kokelj, S.V., Poulain, A.J., Smol, J.P., Wang, Xiaowa, and Blais, J.M. 2014. Dissolved organic carbon thresholds affect mercury bioaccumulation in Arctic lakes. *Environ. Sci. Technol.* 48: 3162–3168.

Grieb, T.M., Driscoll, C.T., Gloss, S.P., Schofield, C.L., Bowie, G.L., and Porcella, D.B. 1990. Factors affecting mercury accumulation in fish in the upper Michigan Peninsula. *Environ. Tox. Chem. 9*: 919-930.

Lockhart, L. Stern, G.A., Low, G., Hendzel, M., Boila, G., Roach, P., Evans, M.S., Billeck, B.N., DeLaronde, J., Friesen, S., Kidd, K., Atkins, S., Muir, D.C.G., Stoddart, M., Stephens, G., Stephensen, S., Harbicht, S., Snowshoe, N., Grey, B., Thompson, S., and DeGraff, N. 2005. A history of total mercury in edible muscle of fish from lakes in northern Canada. *Sci. Total Environ.* 351-352: 427-463.

Miskimmin, B.M., Rudd, J.W.M., and Kelly, C.A. 1992. Influence of dissolved organic carbon, pH, and microbial respiration rates on mercury methylation and demethylation in lake water. *Can. J. Fish. Aquat. Sci.* 49: 17-22.

Pickhardt, P. C., Folt, C. L., Chen, C. Y., Klaue, B., Blum, J. D. 2002. Algal blooms reduce the uptake of toxic methylmercury in freshwater food webs. *Proc. Natl. Acad. Sci. U.S.A*. 99: 4419–4423.

Wiener, J.G., Krabbenhoft, D.P., Heinz, G.H., and Scheuhammer, A.M. 2003. Ecotoxicology of mercury. In: *Handbook of ecotoxicology. 2nd ed*. Edited by D.J. Hoffman, B.A. Rattner, G.A. Burton, Jr., and J. Cairns, Jr. Boca Raton, FL: Lewis Publishers, pp. 409–463.

Wren, C.D., Scheider, W.A., Wales, D.L., Muncaster, B.W., and Gray, I.M. 1991. Relation between mercury concentrations in walleye (*Stizostedion vitreum vitreum*) and northern pike (*Esox lucius*) in Ontario lakes and influence of environmental factors. *Can. J. Fish. Aquat. Sci.* 48: 132-139.

Community-based monitoring of Arctic Char in Nunatsiavut: increasing capacity, building knowledge

Surveillance communautaire de l'omble chevalier au Nunatsiavut : renforcement des capacités et acquisition de connaissances

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Abstract

Ringed seals and sea-run arctic char continue to make up a large portion of the diet of Labrador Inuit as a result of the decline in population of the George River caribou herd and subsequent ban on hunting of the herd. Given the importance of arctic char to both the diet of ringed seals and Labrador Inuit, monitoring of these fish in Nunatsiavut is essential. This community-based monitoring project continues to expand on previous NCP work on contaminant trends in sea-run char conducted by Environment Canada, including a capacity building component and an additional sampling location that has now been sampled for two years. Twenty fish were captured at two locations, Nain and Saglek Fjord, just before the fish returned inland from feeding in the ocean. The char were caught and processed by local community members, with support from staff at the Nain Research Centre, Parks Canada and Nunatsiavut Conservation Officers. The data from this project will be used for a

Résumé

Le phoque annelé et l'omble chevalier anadrome continuent de constituer une part importante du régime alimentaire des Inuits du Labrador par suite de la baisse de la population du troupeau de caribous de la rivière George et de l'interdiction de chasser le troupeau qui en a découlé. En raison de l'importance de l'omble chevalier pour les régimes alimentaires du phoque annelé et des Inuits du Labrador, la surveillance de ce poisson est essentielle au Nunatsiavut. Ce projet de surveillance communautaire continue de prendre appui sur les travaux de recherche sur les tendances en matière de contaminants chez l'omble anadrome qu'Environnement et Changement climatique Canada avait menés dans le cadre du Programme de lutte contre les contaminants dans le Nord (PLCN). Il comportait par ailleurs un volet de renforcement des capacités et un site d'échantillonnage supplémentaire sur lequel des prélèvements sont effectués depuis deux ans à présent. Vingt poissons ont été capturés à deux endroits, soit

variety of purposes such as providing needed information for dietary advice, understanding and determining how contaminant loads are changing as a result of regional changes being experienced due to climate change and increased industrial development.

à Nain et à Saglek Fjord, juste avant qu'ils ne retournent dans la partie continentale après une période d'alimentation en milieu océanique. Les ombles ont été capturés et traités par des membres de la collectivité locale, avec l'aide du personnel du Centre de recherches de Nain et de Parcs Canada ainsi que des agents de conservation du Nunatsiavut. Les données recueillies dans le cadre de ce projet seront utilisées à différentes fins et fourniront, notamment, de l'information qui permettra de formuler des conseils utiles en matière d'alimentation, de mesurer les niveaux de contaminants et de comprendre comment ils évoluent par suite des changements qui surviennent au niveau régional à cause des changements climatiques et de l'intensification du développement industriel.

Key Messages

- A regionally led community-based monitoring program sampling arctic char, while building capacity and addressing contaminant concerns of Labrador Inuit, and providing valuable data to the NCP.
- Staff at the Nain Research Centre travelled to the Environment and Climate Change Canada lab in Burlington, Ontario to see how samples were processed and analyzed, creating a better overall understanding of the research process associated with this project.
- Continued progress towards addressing the recommendations of the ArcticNet IRIS report that community-based monitoring of arctic char should exist to ensure the population is monitored and healthy for consumption
- This project is a result of collaboration between harvesters, community members, youth, Conservation Officers, Parks Canada, Environment Canada and staff of the Nain Research Centre.

Messages clés

- Un programme de surveillance communautaire dirigé à l'échelon régional, dans le cadre duquel on a procédé à un échantillonnage de l'omble chevalier, tout en renforçant les capacités et en répondant aux préoccupations en matière de contaminants des Inuits du Labrador et en fournissant de précieuses données au PLCN.
- Le personnel du Centre de recherche de Nain s'est rendu au laboratoire d'Environnement et Changement climatique Canada à Burlington (Ontario) pour observer comment les échantillons sont traités et analysés, ce qui a amélioré sa compréhension globale du processus de recherche connexe à ce projet.
- On a continué de donner suite aux recommandations émanant du rapport EIRI d'ArcticNet préconisant la surveillance communautaire de l'omble chevalier afin que la population fasse l'objet de surveillance et qu'elle soit propre à la consommation
- Ce projet est le fruit d'une collaboration entre des chasseurs/pêcheurs, des membres de la collectivité, des jeunes, des agents de conservation, Parcs Canada, Environnement et Changement climatique Canada et le personnel du Centre de recherches de Nain.

Objectives

- Continue to implement a regionally led community-based monitoring program of arctic char, while building capacity and addressing contaminant concerns of Labrador Inuit
- Sample arctic char from two locations of importance for Labrador Inuit; Saglek Fjord and Nain
- Measure the concentration of mercury and selenium in arctic char
- Understand food web dynamics through stable isotope analysis
- Meet the recommendations of both the Inuit Health Survey and the IRIS 4 report
- Build capacity in youth, Nain Research Centre staff and harvesters

Introduction

Residents of Nunatsiavut are concerned about the impacts of the shift in diet, from caribou to ringed seals and arctic char, and how this affects their health and wellbeing, both in terms of contaminants as well as nutrition. The Inuit Health Survey identified arctic char as the number one source of selenium, polyunsaturated fats and omega-3 fatty acids for Labrador Inuit (IHS 2008). The Integrated Regional Impact Study (IRIS) for Nunavik and Nunatsiavut identified arctic char as an important food resource that is at risk and that community-based monitoring of arctic char populations should be implemented (Allard et al, 2012).

Char are an essential part to the diet of Labrador Inuit. Torngat Fish Producers Cooperative operate a char processing plant seasonally in Nain, and in partnership with the Nunatsiavut Government, have established a Social Fishing Enterprise where 12,000 pounds of arctic char is distributed to the 5 communities within Nunatsiavut through the community freezers established in each community during freeze-up, when hunting and accessing traditional foods is the most difficult.

Understanding the overall condition of char in Nunatsiavut, including mercury and selenium concentrations, is essential to understanding Inuit health and wellbeing. As climate change continues, mercury concentrations may increase. And as the diet of Labrador Inuit continues to shift towards the consumption of substantially more arctic char, as per the recommendations of the Inuit Health Survey, it is absolutely essential that the condition of these fish are understood. The region has a responsibility to monitor the arctic char to ensure that these recommendations are improving Inuit health and wellbeing and the region needs to be able to respond to community members concerns about the impacts of consuming more arctic char.

Furthermore, as per the IRIS recommendations, community-based monitoring of arctic char needs to exist. This not only ensures that the population is monitored and healthy for consumption, but also builds capacity and provides a variety of training and partnership opportunities. This CBM project is fully integrated into the Aullak, sangilivallianginnatuk (*Going off, Growing strong*) Youth Program. This provides opportunities to educate youth about contaminants and research while providing avenues for knowledge transmission and allowing researchers to learn from harvesters and youth.

Finally, because this project is regionally led and operated, the cost of this research project is substantially smaller than similar projects based in southern Canada. This allows the region to control its research directive while meeting the goals of the Northern Contaminants Program and addressing the concerns of Labrador Inuit.

Activities in 2015-2016

Arctic Char Sampling

Char were sampled in two locations in Nunatsiavut; Saglek Fjord and Nain. Fish were collected in the fall as they were preparing to transition from the ocean environment to the freshwater streams in their respective areas. Fish in Saglek Fjord were collected through a collaboration of local harvesters, Parks Canada, Nunatsiavut Government Conservation Officers, youth and staff from the Nain Research Centre. In Nain, harvesters and youth collected fish as part of the Nunatsiavut Government's *Going Off, Going Strong* youth program. All samples were frozen whole and sent to Environment Canada's laboratory in Saskatoon, Saskatchewan.

Analyses

Fish were weighed, length and gender determined, and aging structures (otoliths) removed. Stomach fullness was assessed and the contents determined at a coarse level, i.e., invertebrates and/or fish. The presence of parasites, skinniness, discolored liver, and any other abnormality was noted. At least 100 g of skin on fillet was removed from the dorsal region for metals and stable isotope (carbon and nitrogen) analyses; unused tissue will be archived for possible later analyses. Due to some extenuating circumstances and some additional miscommunications between the analytical lab and the Nain Research Centre, samples were delayed in shipment and analyses. These issues have been resolved and final analyses are taking place.

Capacity Building

The entire project is based around capacity building and training opportunities. Harvesters teach youth appropriate harvesting methods and help facilitate knowledge transmission to younger generations in the Nunatsiavut region. Staff from the Nain Research Centre and Nunatsiavut Government were present to explain the rationale behind the project and discuss the physiology and biology of the fish with the youth and harvesters.

Communications

Information for this project has been communicated via presentations at the Torngat Mountain Base Camp and Research Station, and at the Nain Research Centre. Additionally, information was communicated at community traditional food celebration events at the Nain Community Freezer, in conjunction with food security programming.

Traditional Knowledge Integration

Given that this project is a regionally led project that receives samples from harvesters and youth, traditional knowledge is at the forefront. Traditional knowledge is used in all aspects of the project from sampling locations, fish collection and appropriate harvest methods. The design of the project allows for the facilitation of knowledge transmission between participants.

Results

The Nunatsiavut Government is still waiting to receive results from Environment Canada for this project. These issues have been resolved, and the results, including all of the raw data, are sent to Nunatsivaut imminently.

Discussion and Conclusions

Despite only having received results via phone, the project was a great success in terms of capacity building and training. It integrated many organizations with harvesters and youth to work towards one goal, while allowing for training and education. Furthermore, because it is a regionally led project, it results in many cost efficiencies, allowing for important data to be collected at a minimal cost.

Project Completion Date

This years project is essentially complete. It is the intention of the Nunatsiavut Government to continue to monitor these char populations, through the continued support of the NCP.

Paulatuk Beluga whales: Health and Local Observational Indicators

Béluga de Paulatuk : indicateurs de la santé et indicateurs d'observation locaux

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Abstract

Recent changes in climate and the ice regime in Darnley Bay have changed and increased the frequency of beluga hunts by the community of Paulatuk in the Inuvialuit Settlement Region. The community of Paulatuk has many questions about the beluga being harvested, in regards to their health and how similar or different they are to whales monitored at Hendrickson Island in Mackenzie Estuary and as such have been leading a beluga monitoring program in partnership with Fisheries and Oceans Canada and the Fisheries Joint Management Committee. This summer two monitors (stationary and mobile) sampled fourteen whales from the harvest. Additionally as part of the LEK/TEK indicators project they participated and collected data to support the joint project. Length measurements were taken, along with jaws for ageing and tissues for mercury and stable isotope analyses. Preliminary results indicate that mercury levels in Paulatuk beluga are similar to previous years.

Résumé

Les récents changements dans le climat et les glaces dans la baie Darnley ont modifié et augmenté la fréquence des chasses aux bélugas par la collectivité de Paulatuk dans la région désignée des Inuvialuits. Très préoccupée par l'état de santé des bélugas chassés ainsi que par ce qui les rapproche ou les différencie des baleines surveillées à l'île Hendrickson dans l'estuaire du Mackenzie, la collectivité de Paulatuk a entrepris de mettre en place un programme de surveillance des bélugas en partenariat avec Pêches et Océans Canada et le Comité mixte de gestion de la pêche. Cet été, deux surveillants (l'un stationnaire et l'autre, mobile) ont prélevé des échantillons sur quatorze baleines chassées. De plus, ils ont participé à un projet sur les indicateurs de connaissances écologiques locales (CEL) et de connaissances écologiques traditionnelles (CET), dans le cadre duquel ils ont recueilli des données visant à soutenir le projet conjoint. On a mesuré la longueur des individus, procédé à un examen des mâchoires afin de déterminer leur âge, et prélevé des échantillons de tissus à des fins

d'analyse du mercure et des isotopes stables. Les résultats préliminaires indiquent que les niveaux de mercure dans le béluga de Paulatuk sont semblables aux années précédentes.

Key messages

- In 2015 the community of Paulatuk had a successful beluga harvest that began in late July and ended in mid-August. Fourteen whales were harvested and sampled for the program. Similar to previous years, the program was merged with the Local and Traditional Ecological Knowledge Indicators project.
- Samples were sent to Winnipeg to estimate age (teeth growth layer groups), measure the contaminant mercury (muscle, liver and skin), and evaluate the diet indicators (fatty acids and stable isotopes) to better define diet and diet drivers of mercury levels.
- Preliminary results revealed similar Hg concentrations to those measured the previous year as well as similar to levels at Hendrickson Island. Whales from both locations were similar in size and age for 2015.
- Observations from the community and harvesters on whale health and condition were collected alongside this program to evaluate these observations in context with measurements taken during this project.

Messages clés

- En 2015, la collectivité de Paulatuk a enregistré une chasse de béluga réussie qui a commencé à la fin juillet et s'est terminée à la miaoût. Quatorze baleines ont été prises, et des échantillons ont été prélevés sur elles dans le cadre du programme. Comme ce fut le cas les années précédentes, le programme a été fusionné avec le projet sur les indicateurs de connaissances écologiques locales et traditionnelles.
- Les échantillons ont été envoyés à Winnipeg pour que l'on estime l'âge des spécimens (groupes de couches de croissance des dents), mesure les concentrations de mercure (dans les muscles, le foie et la peau) et évalue les indicateurs du régime alimentaire (acides gras et isotopes stables) afin de mieux définir en quoi consiste leur régime alimentaire et les constituants de ce dernier qui influent sur les concentrations de mercure.
- Les résultats préliminaires ont révélé des concentrations d'Hg semblables à celles qui ont été mesurées l'année précédente, ainsi qu'aux concentrations à l'île Hendrickson. L'âge et la taille des baleines aux deux endroits étaient semblables à ceux de 2015.
- On a recueilli les observations sur la santé et l'état des baleines qu'ont réalisées les membres de la collectivité et les chasseurs parallèlement aux activités du programme afin d'évaluer en contexte les mesures que l'on avait prises au cours du projet.

Objectives

- Enhance and build the beluga monitoring program by incorporating the local and traditional ecological knowledge (LEK/TEK) program.
- Support similar objectives as the Local Ecological Indicators Project specifically
  - Increase our understanding of the Beaufort Sea ecosystem through the inclusion of LEK and TEK in community-based monitoring.
  - Record observations of beluga whales from a community perspective that are potential indicators of ecosystem changes.
  - Engage community members in beluga sampling and documentation of observations.
  - Provide training to community research coordinators to increase capacity within communities to lead community-based research.
- Determine contaminant levels in beluga whales and the overall health of the whales in context with the Hendrickson Island beluga whales, as well as use the data to establish a baseline for future long term monitoring
- Link program with Hendrickson and other ISR beluga hunt sites as well as other ecosystem monitoring.
- Engage community youth and monitors in sharing back their knowledge at the Beluga Communication Summit, the NCP results form and the ArcticNet Annual General Science Meeting in Vancouver.

Introduction

Inuvialuit lead subsistence lifestyles which include harvesting beluga whales. As such there is concern over their health and contaminant levels. As the environment changes at the global scale (climate change) and the local scale (industrial activities) we suspect beluga may be exposed to more stressors and more contaminants that require ongoing monitoring. As such the community along with DFO are in the process of designating a Marine Protected Area in the Darnley Bay area to support the productive marine ecosystem. Establishing a baseline at this time will assist with future monitoring and management.

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

This raised questions, as it was found that whales collected at Hendrickson had similar mercury concentrations as those collected at other nearby harvest monitoring sites (Kendall Island, East Whitefish) that are located in the Mackenzie Estuary. The habitat near Paulatuk (Darnley Bay) is very different than the Mackenzie Estuary; the Estuary is characterized as a very shallow freshwater environment unlike the deep cold clear waters of Darnley Bay. How habitat is used by beluga differs, and may affect diet and contaminant exposure for beluga whales. Including the Paulatuk harvest location as a satellite monitoring site to Hendrickson not only addresses community questions on health but will also enhances our understanding of this population at a larger scale.

Activities in 2015-2016

Capacity Building: Field-Beluga Harvest Monitoring:

Changes to the program were made to have monitors readily available to collect samples at all locations. PHTC hired 2 Beluga Monitors; one mobile Monitor as well as stationing a Monitor at Tippi.

Samples were obtained from 15 whales harvested this season, with one partially sampled using the Harvester Incentive provided by FJMC. All of the belugas had empty stomachs and all but one were males. Daily observations of beluga and weather were collected. All samples were shipped down to Winnipeg where they were analyzed for mercury and diet indicators (fatty acids and stable isotopes). Note, we are unable to report on nitrogen stable isotopes at this time due to instrument interference, data will be available for next report.

Traditional Knowledge: Field-Beluga Local Observations

In 2015, the 'Local Ecological Indicators Project' operated alongside the Beluga CBM in Paulatuk.

In order to verify potential local and traditional ecological knowledge indicators (LEK and TEK indicators), beluga harvesters (n = 9) anonymously and voluntarily respond to a semi-structured questionnaire about the health and behavior of the whale(s) he or she had harvested. To address data gaps on how and why beluga use the habitat of Darnley Bay, local observations of beluga location, group composition (i.e. presence of calves) and activity were recorded by community members (n = 25). In addition, to verify the potential local indicators for beluga health and habitat use, a focus group was held in August 2015 in Paulatuk with nine participants. A final interview was conducted with one Elder who was unable to participate in the focus group. Participants were selected based on their knowledge of beluga whales and to ensure a diverse representation of age and gender. The same individuals were interviewed separately in February 2016 to verify the project report and provide final input into the development of local indicators. The PHTC provided in kind support towards the administration of this project in Darnley Bay. In total, harvester observations were recorded for over 8 whale sightings in 2013 and 45 sightings in 2014, in Darnley Bay, there were 28 local observations for 2015. Five harvesters shared their observations about hunted whales in 2013, and 10 harvesters completed the questionnaires in 2014 with the assistance of the summer student. In total, 24 harvesters provided observations about harvested whales between 2013 and 2015, and 58 community observations for beluga sightings were recorded during this same interval.

Following the 2015 summer field season, meetings were held in February 2016 with the PHTC and focus group participants to review the project and begin preparations for the 2016 field season. School presentations were also made in Paulatuk about beluga whale research taking place in the ISR and to raise awareness about opportunities for youth to be involved in beluga and ecology research in the ISR.

Capacity Building - Youth:

Two youth, Lauren Green and Melanie Wolki attended the Paulatuk focus group to listen and learn from the beluga experts in their community. Melanie attended the Beluga Summit as the Paulatuk Youth representative and provided her perspective to the community members and research community. Melanie Wolki also met with three community members to review the research results. This year we did not have a student assisting the Beluga Monitors, rather had a junior monitor at Tippi to assist with beluga sampling and collecting beluga observations.

Communications:

This year we held a regional communication meeting, the Beluga Communication Summit in Inuvik from Feb 22-25 2015. There was significant communication with the HTC and community members to plan and organize the event and ensure effective and meaningful communication occur at the event. Paulatuk, like other communities were tasked with prioritizing beluga topics, providing guidance on the approach/method of knowledge sharing and selecting key participants. Lastly the selected participants along with support from the HTC prepared a presentation about the knowledge they wanted to share about beluga whales and harvesting in their region.

General updates and communications of the program have occurred at regular co-management board meetings for the FJMC and IGC and local HTC. Additionally members from this program participated and shared results from this work at the NCP results forum in Vancouver in December 2015.

Results:

Length and Age:

As with previous years, the sample size (n = 14) was less than 20 cautioning how far we can extrapolate results to the population for interpretation. Whales ranged in length from 3.6m to 4.7m (averaging = 4.3m) and were slightly larger than the previous year (Table 1). Unlike previous years these whales were larger in length of whales landed at Hendrickson Island (P 0.003) that averaged 3.9m.

The average age of belugas taken near Paulatuk were similar to those landed last year (mean = approx. 31.5 years; Table 1) and similar to those landed at Hendrickson Island (mean = 26.5years; $P > 0.05$). Beluga age and length were significantly correlated to one another ($P = 0.003$; $r = 0.75$).

Mercury in Tissues

Concentrations of Hg in muscle ranged from 0.7 to 2.1 $\mu g \cdot g^{-1}$ (ww) and averaged 1.2 $\mu g \cdot g^{-1}$. These concentrations were similar to those measured in 2014 (Table 1). These concentrations were similar to Hg measured in muscle from Hendrickson Island whales ($p > 0.05$; 2.0 $\mu g \cdot g^{-1}$ Figure 1). Muscle Hg had a significant positive relationship with age ($r = 0.45$, $p = 0.02$) and weaker trend with length ($r = 0.35$, $p = 0.1$).

Trends for skin Hg concentrations were similar to muscle, with concentrations similar to those in 2014 (Figure 1; mean = 0.6 $\mu g \cdot g^{-1}$). Skin Hg concentrations were not significantly different than the concentrations measured in whales sampled at Hendrickson Island that were slightly lower ($p = 0.2$; mean = 0.4ug g^{-1}). Skin Hg was positively related to muscle Hg concentrations ($r = 0.9$, $p < 0.001$) as well as length ($r = 0.5$; $p>0.05$) and age ($r=0.6$; $p>0.05$).

Concentrations of Hg in liver were variable as is typical for liver concentration, and ranged from 2.8 to 67.3$\mu g \cdot g^{-1}$(ww) with a mean of 17.3 $\mu g \cdot g^{-1}$, that is similar to 2014 range and mean concentrations (Table 1; Figure 2). These concentrations were not significantly different than those measured at Hendrickson Island ($p = 0.3$; mean = 23.8ug g^{-1}). Liver Hg had a positive correlation with age ($r = 0.7$, $p = 0.006$) and also had a positive relation to muscle Hg ($r = 0.8$; $p = 0.001$).

Figure 1. Concentrations of Hg in muscle (ug-g^{-1} ww) from belugas harvested near Paulatuk (black) and Hendrickson Island (grey) near Tuktoyaktuk.

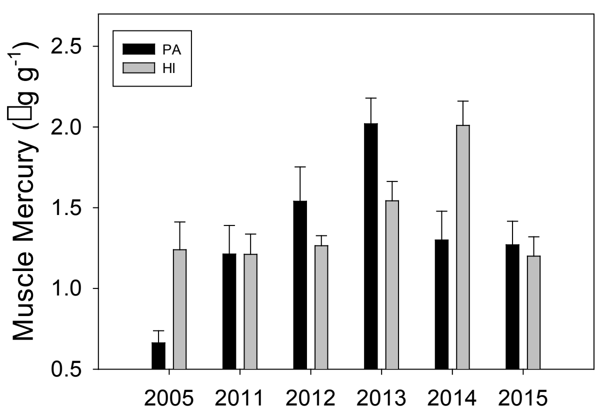
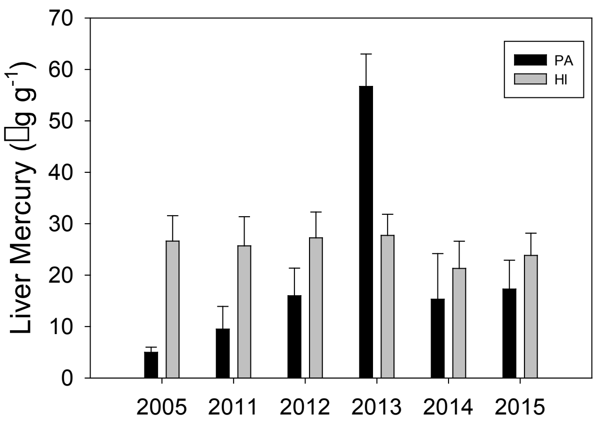


Figure 2. Concentrations of Hg in liver (ug-g^{-1} ww) from beluga whales harvested at Hendrickson Island (grey) near Tuktoyaktuk and near Paulatuk (black).



Stable Isotopes

Isotopes were used to assist with the interpretation of beluga feeding preferences that could drive contaminant levels. We are currently unable to report on δ15N results for 2015. Results for δ13C showed values that were slightly depleted relative to those observed in 2014 in muscle and liver (Table 1). In comparing isotopic means between whales harvested at Paulatuk to those at Hendrickson Island, the δ13C in both liver and muscle showed no significant difference among sites. There were no significant relationships for beluga age and length with any of the tissue δ13C values. Examining trends with Hg no significant trends were found with δ13C values in liver or muscle.

Table 1. Morphometrics, Mercury, and Stable Isotopes of Paulatuk beluga from 2005-2015

	2005			2011			2012			2013			2014			2015			ANOVA output	
	Mean		StD	Mean		StD	Mean		StD	Mean		StD	Mean		StD	Mean		StD	P	r
Morphometrics																				
Length	363.8	±	66.3	404	±	39.9	430.7	±	32.1	427.2	±	10.1	399	±	46.7	426	±	32.2	0.003	0.5
Age	17.1	±	7.3	26	±	12.9	27.7	±	7	36.2	±	9.5	29.5	±	12.2	31.5	±	9.6	<0.0001	0.6
Mercury																				
Liver	5	±	3.7	9.5	±	12.5	16	±	14.2	56.7	±	37.4	15.3	±	8.87	17.3	±	18.6	<0.0001	0.67
Muscle	0.7	±	0.3	1.2	±	0.5	1.5	±	0.6	2	±	0.5	1.3	±	0.1	1.2	±	0.7	<0.0001	0.66
Skin	0.2	±	0.1	0.5	±	0.3	0.7	±	0.3	0.9	±	0.3	0.56	±	0.1	0.6	±	0.5	0.001	0.57
Stable Isotopes																				
δ15N Muscle	15.6	±	0.7	17	±	0.2	17.3	±	0.4	17.1	±	0.2	16.97	±	0.2	N/A				
δ15N Liver	16.8	±	0.6	17.9	±	0.3	17.7	±	0.4	18.2	±	0.3	17.31	±	0.2	N/A				
δ13C Muscle	-20.2	±	0.7	-20.4	±	0.3	-19	±	0.6	-19.7	±	0.4	-18.8	±	0.2	-19.3	±	0.2	<0.0001	0.75
δ13C Liver	-18.2	±	0.5	-18.7	±	0.4	-20.8	±	0.1	-21.5	±	0.3	-19.9	±	0.2	-21.2	±	0.2	<0.0001	0.72

Discussion and Conclusions

The 2015 harvest year was more similar to previous years with regards to when whales were landed, and different than 2014 when whales were landed early on in the summer season. Harvester's observations on beluga health were recorded as part of the "Enhancing community-based monitoring of ecosystem changes in the ISR through the inclusion of Local and Traditional Ecological Knowledge Indicators". Results will be shared in the future following the dissemination in the communities in winter 2017. Including local observations in beluga monitoring will support a stronger understanding of beluga contaminant levels, trends and effects by providing community-based observations about changes in feeding ecology, body condition, and health status.

The whales harvested in 2015 were similar in many aspects to those harvested at Hendrickson Island, whereby size, age and Hg concentrations were similar among locations. In starting to evaluate a temporal trend it is becoming apparent that there is a minimal trend in Hg levels at Hendrickson whereas Paualtuk demonstrates high variability over the recent years. This highlights the variability observed among sites and perhaps the need to continue building a longer time trend to put trend data into a longer term perspective. This study was initiated in response to observations of lower Hg levels that likely reflected the smaller size and young age from samples collected in 2005 (Loseto et al., 2008). In the more recent years of monitoring whales landed near Paulatuk the whales are more similar in size and age to those harvested at Hendrickson Island, however Hg levels typically remain lower at Paulatuk with the exception of results from 2013. A closer analysis is required for the recent data acquired for whales analyzed for Hg for the last three years to quantify the significance of differences if in fact present and the drivers of such.

Stable isotope values of δ13C were largely the same as those measured in belugas harvested at Hendrickson Island, we will carry out a comparison with the δ15N once data is received. These samples have been processed for fatty acids that may provide further insight to differences and similarities in Hg and how they are driven by diet. Additionally, our partnered project work collecting LEK/TEK and observations may assist with the interpretation with the small sample size obtained at this site.

Expected Project Completion Date:

March 2017

Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP)

Programme de surveillance de l'écosystème aquatique des Tłı̨chǫ (PSEAT)

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Abstract

The Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) continues to provide a means of addressing community concerns related to changes in the environment, and builds on work carried out since 2010. The program meaningfully involves community members in many aspects of conducting contaminants-related research and engages them to use scientific as well as Tłı̨chǫ traditional knowledge to answer the questions "Are the fish and water safe to consume?"

In September 2015, a five-day on-the-land monitoring camp was held on Russell Lake, a large lake near the community of Behchokǫ̀. The camp was held at the same location as the 2011 TAEMP monitoring camp and at a location that supports an aboriginal subsistence fishery. The 2015 camp returned to locations on

Résumé

Le Programme de surveillance de l'écosystème aquatique de Tłı̨chǫ (PSEAT) continue de fournir un moyen de réagir aux préoccupations que nourrit la collectivité à l'égard des changements dans l'environnement, et s'appuie sur les travaux réalisés depuis 2010. Le programme fait participer les membres de la collectivité de façon significative à de nombreux volets des travaux de recherche portant sur les contaminants et les invite à faire appel aux connaissances scientifiques ainsi que traditionnelles Tłı̨chǫ pour répondre aux questions : « La consommation de poisson et de l'eau estelle sans danger? »

En septembre 2015, un camp de surveillance terrestre de cinq jours a été organisé au lac Russel, un grand lac situé près de la collectivité de Behchokǫ̀. Le camp s'est tenu au même

Russell and Slemon Lakes where sediment and water sampling occurred in 2011 to allow for comparative sampling. Elders and community members spoke about fish and aquatic ecosystem health, passed on their knowledge to participants, and ensured safe transport to sampling locations. Methods for processing fish and collecting water and sediment samples for lab analyses were demonstrated on shore, and field sampling provided youth with hands-on experience in scientific sampling methods. A results workshop was held in Behchokǫ̀ in April 2016 in order to present the results of the sample analyses to camp participants and to interested community members.

Fish tissue analysis indicated mercury levels were low in both Pickerel and Lake Whitefish, with Northern Pike samples having the highest concentrations overall. None of the species' tissue samples showed levels of mercury that were considered abnormal for northern lakes (e.g. it was primarily the larger, older Northern Pike that were above the guideline for mercury). Water and sediment results supported the expectation that water and sediment quality is "good" (i.e. not abnormal) in Russell and Slemon Lakes.

endroit que le camp du PSEAT de 2011 que les Autochtones utilisent pour la pêche de subsistance. Le camp de 2015 est retourné aux endroits des lacs Russell et Slemon où des échantillons de sédiments et d'eau ont été prélevés en 2011 afin d'effectuer un échantillonnage comparatif. Les anciens et les membres de la collectivité ont parlé de la santé du poisson et de l'écosystème aquatique, ont transmis leur savoir aux participants et ont assuré la sécurité du transport vers les lieux d'échantillonnage. On a effectué une démonstration des méthodes de traitement des tissus de poisson et de collecte d'échantillons d'eau et de sédiments pour les analyses en laboratoire. De plus, les activités d'échantillonnage menées sur le terrain ont permis aux jeunes d'acquérir une expérience pratique des méthodes scientifiques d'échantillonnage. Un atelier sur les résultats s'est tenu à Behchokǫ̀ en avril 2016 afin de présenter les résultats des analyses des échantillons aux participants du camp et aux membres de la collectivité intéressés.

L'analyse des tissus de poisson a révélé que les concentrations de mercure étaient faibles chez le doré jaune et le grand corégone, les concentrations globales observées chez le grand brochet étant globalement les plus élevées. Aucun des échantillons de tissus des espèces n'a présenté des concentrations de mercure considérées comme étant anormales pour les lacs nordiques (p. ex. c'étaient principalement les grands brochets plus âgés de plus grande taille qui dépassaient la ligne directrice pour le mercure). Les échantillons d'eau et de sédiments ont permis de valider l'hypothèse selon laquelle la qualité de l'eau et des sédiments des lacs Russell et Slemon est « bonne » (c.-à.-d. non anormale).

Key messages

- The fish tissue analyses showed that mercury levels were low in both Lake Whitefish and Pickerel, with some of the larger older Northern Pike sampled above the guideline. No contaminant levels measured in any of the species' fish tissue samples were considered to be abnormal

Messages clés

- L'analyse des tissus de poisson a montré que les concentrations de mercure étaient faibles chez le grand corégone et le doré jaune, quelques grands brochets plus âgés de plus grande taille qui avaient été échantillonnés dépassant la ligne directrice pour le mercure. Aucune des concentrations de contaminants mesurées dans les tissus des espèces de poisson n'est considérée comme anormale.

- Water and sediment quality results support the expectation that water quality and sediment quality are good in Russell and Slemon Lakes. No water or sediment contaminant levels were considered to be abnormal
- Community members were pleased with the implementation of the program, citing the importance of continued monitoring near their community of Behchokǫ̀, the participation and education of youth, and the sharing and transfer of both traditional and science-based knowledge among participants
- Community members were pleased that results of sampling were presented in Behchokǫ̀, and that analyses indicated that fish, water, and sediment quality were good (i.e. not abnormal)
- A basic comparison of the 2015 to 2011 results suggests that there are no major changes in the quality of fish, water or sediment

- Les résultats de la qualité de l'eau et des sédiments confirment l'hypothèse selon laquelle la qualité de l'eau et des sédiments est bonne dans les lacs Russell et Slemon. Aucune des concentrations de contaminants mesurées dans les sédiments n'est considérée comme anormale.
- Les membres de la collectivité étaient satisfaits de la mise en œuvre du programme et ont souligné l'importance de la surveillance continue aux environs de leur collectivité de Behchokǫ̀, de la participation et de l'éducation des jeunes et du partage et de l'échange de connaissances traditionnelles et scientifiques entre les participants.
- Les membres de la collectivité étaient également satisfaits que les résultats aient été présentés à Behchokǫ̀ et du fait que les analyses révélaient que le poisson, l'eau et les sédiments étaient de bonne qualité (c.-à.-d. non anormale).
- Une comparaison fondamentale des résultats de 2015 à 2011 donne à penser qu'il n'y a pas eu de changements importants de la qualité du poisson, de l'eau et des sédiments.

Objectives

- Collaborate with TAEMP partners in the long-term implementation of a community-based monitoring program;
- Develop long-term aquatic ecosystem monitoring datasets in Wek'èezhìı, and contribute to concurrent monitoring initiatives in the NWT;
- Provide basic training and opportunities for knowledge transfer among Tłı̨chǫ community members, youth, elders and research scientists; and,
- Engage schools and youth in educational opportunities related to aquatic ecosystems and science-based environmental monitoring.

Introduction

The purpose of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) is to continue to successfully implement an aquatic ecosystem monitoring program based on Tłı̨chǫ and scientific knowledge in order to determine whether fish health, water, and sediment quality are changing over time at locations near Tłı̨chǫ communities. There are historic, currently operating, and proposed developments in the region, and there is concern in Tłı̨chǫ communities that contamination of nearby aquatic ecosystems may occur, or has already occurred. As a result of these concerns and a general lack of information, there is a need to collect information and have ongoing monitoring of the aquatic ecosystems in

Wek’èezhìı in anticipation of continuing pressures on watersheds.

It is important to have Tłı̨chǫ community members (including elders and youth) directly involved in monitoring, and provide a genuine opportunity for community members to exchange knowledge with research scientists in appropriate community and on-the-land settings. By meaningfully involving community members in conducting contaminants-related research, including the collection of samples and observations using both Tłı̨chǫ and scientific knowledge, the TAEMP provides a means to help to address the question: “Are the fish safe to eat and is the water safe to drink?”

The TAEMP rotates sampling through each of the four Tłı̨chǫ communities once every four years. With the conclusion of the 2014 camp near Whatì, the TAEMP completed its initial baseline sampling phase. In 2015, the first round of comparative sampling began with the return of the TAEMP to the community of Behchokǫ̀. The sampling planned from 2015-2018 will continue to build on work carried out since 2010 and allow for comparative analysis of sampling results collected in each of the four communities. The comparative sampling will provide a way in which to continue to address community concerns related to changes in the environment.

Activities in 2015-2016

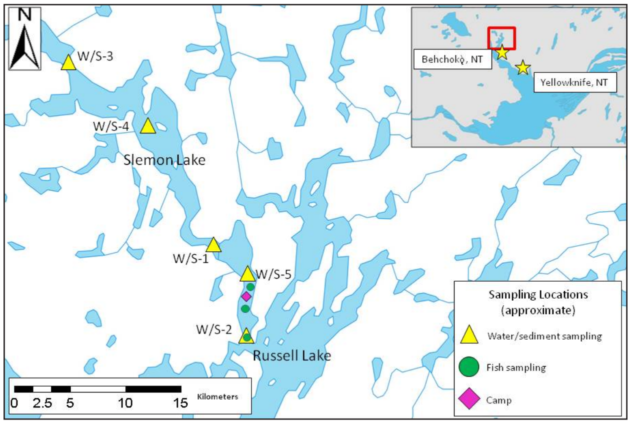
Introductory / Planning Workshops

Workshops were held in late August and early September of 2015 to discuss the TAEMP with community members in Behchokǫ̀. The meetings provided a means to reacquaint community members with objectives/ approach of the TAEMP (i.e. the TAEMP had last occurred near Behchokǫ̀ in 2011), and begin planning for the on-the–land camp. Community members discussed the concept of indicators and their perspectives on the health of the ecosystem with visiting researchers. During the planning meetings, selection of participants was also discussed and preliminary selection was determined based on relevant expertise/ need/availability. The camp location selected was the same location used in 2011: it was close to Behchokǫ̀ and to a number of sampling locations and culturally important sites, because it had a permanent cabin providing shelter (an upgrade from 2011), outhouses, and ample space for tents.

Monitoring Camp (i.e., “fish camp”)

A five-day on-the-land camp was held September 2015. Sampling locations were located as close as possible to 2011 locations by using 2011 GPS coordinates (Figure 1). Weather/ safety considerations affected initial attempts at some of the sampling locations, however, all samples required were collected over the 5 day period. The 5-day camp provided various educational opportunities focused on ways of understanding aquatic ecosystems and assessing the health of the ecosystems through a variety of methods. Participants worked collaboratively, and shared Tłı̨chǫ knowledge with science-based monitoring approaches. Experiences shared at the camp included youth gaining hands-on experience with sampling methods, elders providing a demonstration of a variety of dry-fish preparation techniques, and a visit to gravesites near the camp location. It should be noted that involvement of the youth required both training for the boat captains and insurance for the boats which transported students. Miscommunication led to uncertainties re: availability of boats and captains to transport students, which led to serious concerns about the possibility of student participation. In the future, earlier communications with community schools, agencies, and potential boat captains will help to ensure uncertainties and delays are minimized.

Figure 1. Locations of the on-the-land camp, and locations where samples of fish, water, and sediment were collected on Russell Lake and Slemon Lake during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near the community of Behchokǫ̀), September 2015.



To determine current levels of contaminants in fish tissue, samples were collected from Lake Whitefish, Pickerel, and Northern Pike, the fish species regularly consumed by Behchokǫ̀ residents. Processing the fish for lab analyses was led by biologists from Golder Associates and Environment and Natural Resources. Samples were collected in accordance with Environment Canada (2012) guidelines established for sampling metals in fish tissue and the Golder technical protocol 'Fish Health Assessment-Metals'. All fish captured and selected for tissue sampling were identified by species, measured (fork length), and weighed. Additional data collected included: gender, stage of maturity, and a general assessment of deformities/ abnormalities. Samples collected and archived included otoliths (cleaned, and mounted on slides), and cleithra.

Standard physical and chemical parameters were used as water quality indicators, including: temperature, pH, conductivity, clarity, turbidity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), alkalinity, dissolved Oxygen, major nutrients, ions, and trace metals. These parameters are comparable to AANDC Water Resources' datasets for the Frank Channel on Great Slave Lake, the closest water quality monitoring station. Water sampling was led by the Tłı̨chǫ Government (TG) Wildlife Coordinator and the Wek'èezhìı Land and Water Board (WLWB) Regulatory Technician and WLWB Regulatory Specialist, with youth collecting some water and sediment samples while under close supervision; procedures were followed to minimize contamination, such as implementation of appropriate QA/ QC procedures, in accordance with Taiga Lab instructions. Sediment sampling used methods outlined in *Metal Mining Technical Guidance for Environmental Effects Monitoring* (Environment Canada, 2012), and samples were analyzed for standard physical and chemical properties as well as trace metals. Lake sediments were sampled using an Ekman grab sampler suitable for collecting soft, fine grained sediments typically observed in the area. Of note, one sediment sampling location showed two distinct layers in the sediment, and the top and bottom layers were sampled separately and labeled accordingly.

Results Workshop

A workshop was held in Behchokǫ̀ April 2016 to report lab results back to camp participants and interested community members. The implementation of the results meeting faced a number of unforeseen delays, and occurred later than expected (i.e. results meeting was originally planned for February 2016). In spite of delays, the results meeting was attended by the majority of elders who participated in the 2015 camp, as well as a number of interested community members. Unfortunately, youth participants did not attend, likely due to a half day and community celebration scheduled for the afternoon after the results meeting.

Capacity Building

Elders and youth were exposed to, and participated in, scientific sampling methods typically used to monitor aquatic ecosystems, including: sediment and water quality sampling as well as fish tissue sampling for contaminant analysis. Demonstrations and activities built on knowledge transferred in 2011, and increased understanding of standard methods and the interpretation of results allows community members to have increased knowledge with regards to activities near Tłı̨chǫ communities. Scientists and youth were exposed to Tłı̨chǫ knowledge of the area, which promoted greater understanding of the local aquatic environment to participants, as well as a historical and cultural context to the area around the camp and sampling locations. A four-year rotation through Tłı̨chǫ communities allows for strong potential that community members will repeatedly participate in, contribute to, and learn from the TAEMP. Unfortunately, a number of the elders who participated in the 2011 camp had passed away, though some of the participants from 2011 were able to attend. Importantly, youth were exposed to, and provided basic training on standardized methods for the collection of samples. Though youth who participated in 2015 were not the same youth who were present in 2011, the possibility that youth may continue with more specific training is strengthened by the availability of the Marian Watershed Stewardship Program led by the TG and WLWB. In discussions with support staff, youth participants voiced an interest in continuing training in environmental monitoring, notably including interest in the planning and analyses components of research, in addition to the field sampling components.

The TAEMP involves staff from organizations inherently linked to Tłı̨chǫ communities, including the WLWB and the TG. Long-term capacity building occurs in these organizations through continued support by their trained staff, some of whom are also Tłı̨chǫ citizens living in Tłı̨chǫ communities. TG staff were key in the successful implementation of the TAEMP, and cooperated with Wek'èezhìı Renewable Resources Board (WRRB) staff on a regular basis. TG staff, specifically staff in Behchokǫ̀, coordinated community meetings and assisted with planning and logistics, aiding in the successful implementation of the on-the-land camp. The TG Wildlife Coordinator also assisted with camp operations, including sample collection and youth engagement. The Wildlife Coordinator's prior training and experiences with the TG–led Marian Lake Watershed Stewardship Project and the 2013 and 2014 TAEMP were also beneficial.

It should also be noted that the TG and WRRB are also referral agencies under the *Mackenzie Valley Resource Management Act*, and with up-to-date monitoring information on the state of the aquatic ecosystems in Wek'èezhìı, they will be better able to make informed recommendations to the WLWB, the Mackenzie Valley Land and Water Board, and the Mackenzie Valley Environmental Impact Review Board, regarding land and water uses in Tłı̨chǫ communities and Wek'èezhìı.

Communications

Communication with Tłı̨chǫ communities is a primary focus of the TAEMP, with timely presentation of results back to communities being of utmost importance. Communications with the community of Behchokǫ̀ occurred primarily through the planning workshops, at the on-the-land camp, and at the results meeting. Collaboration with GNWT Health and Social Services (HSS), along with other TAEMP partners, aided the development of appropriate messaging and communication strategies. This approach helps to ensure community members are informed and educated on the status of contaminants in the fish they may be eating and that nutritional guidance is provided to ensure these foods continue to remain healthy choices (GNWT HSS, 2016a,b). Appropriate messaging also informed all WRRB communications regarding 2015 results (e.g. website, social media).

Social media have also provided communications channels to a wide audience. The WRRB website and Facebook page have featured a series of stories related to the TAEMP in order to build interest and provide updates (e.g. notices for meetings). Various links have also been shared via the TG website and Facebook pages, and the WLWB and NWT Water Stewardship Strategy web pages.

An in-person presentation was given by WRRB staff at the 2015 Northern Contaminants Program (NCP) Results Workshop held in conjunction with the ArcticNet Annual Science Meeting. A similar presentation will also be given at the POLAR-NASA-GNWT Science Planning workshop scheduled for early May 2016.

The *Common Fish of the Tłı̨chǫ* Region, a basic field guide to fish found in Wek'èezhìı, is available on the WRRB website. The guide was recently updated, and now includes information on fish habitat in addition to basic information on the characteristics of common fish species in Wek'èezhìı. The updated guide will be available in print and web-based formats in early May, 2016.

Educational videos highlighting activities at the on-the-land camps specific to each Tłı̨chǫ community have been developed by NWT-based filmmakers with assistance from WRRB staff. All have been shown, and are currently available on the WRRB website (www.wrrb.ca). In addition, two new educational videos have been developed that provide a summary of fish, water and sediment sampling. These videos are at the final editing stages, and will be available on the WRRB website in early May; printed dvds will be provided to community members and community schools.

Traditional Knowledge Integration

Elders and other community members guided all aspects of the project, with Tłı̨chǫ knowledge (i.e. Traditional knowledge, or TK) incorporated throughout by design. The application of Tłı̨chǫ knowledge included: selection of participants, selection of the camp location and establishment of the on-the-land camp, direction on where samples were collected (note: with sampling locations initially decided upon in 2011), which culturally significant places are visited, what traditional / cultural activities occur at the on-the-land camp, and what behaviours/ practices are appropriate and respectful while at camp. In addition, the on-the-land component of the TAEMP provides an opportunity for youth to engage with their community elders, assisting in the youth's education in observing, monitoring and understanding the aquatic ecosystem from a Tłı̨chǫ perspective. Elders and community members pass on Tłı̨chǫ knowledge to youth fostering interest in monitoring near communities and assisting with the continuation of Tłı̨chǫ knowledge of aquatic ecosystems and the traditions associated with each community. The TAEMP also offers an opportunity for researchers to learn from traditional knowledge holders in a culturally appropriate on-the-land context. This form of engagement allows for building of mutual respect and trust through exchange of TK and science-based information while completing the sampling required and the various tasks which are needed for the operation of a traditional camp. Lastly, by bringing results back to communities, findings are discussed, which builds a shared appreciation of the perspectives provided by both Tłı̨chǫ knowledge and science.

Results

The three fish species which had tissues collected for contaminant analyses were Northern Pike, Pickerel (Walleye) and Lake Whitefish. These three species are species used for consumption, and the three were the same species for which analyses occurred in 2011.

Northern Pike which had tissues sampled for analyses in 2015 (n=17) ranged from 561-1041mm in length (Fin Length; FL), 1224.7-8210.0g in weight, and were estimated to be 6-15 years of age. Tissue analyses indicated mercury concentrations in tissue ranged from 0.105 to 0.849mg/kg. Approximately half of the fish sampled (9 of 17) were below the mercury concentration guideline of 0.5 mg/kg, (wet weight, wwt; Health Canada, 2012), and ranged from 0.105 to 0.435mg/kg (Figures 2a, 2b and 2c). The fish tissue samples found to be above the guideline (8 of 17) ranged from 0.524 to 0.849mg/kg (wwt); tissue samples above the guideline included some of the largest (e.g. 1041 and 1016mm), heaviest (e.g. 8210.0 and 7983.2g) and oldest fish sampled (e.g. estimated at 14 and 15 years). Review of mercury concentrations in muscle tissue in relation to age, fork length, and weight suggest positive relationships (Figures 2a, 2b and 2c; no regression analyses performed). By comparison, Northern Pike sampled in 2011 (n=13) ranged from 148-1140mm in length (FL) and 20-10970g in weight, and were estimated to be 0-21 years of age. Overall, the mercury concentrations found in Northern Pike tissues sampled in 2015 appear to be similar to the concentrations found in 2011, and visual comparison of scatter plots suggests similar positive relationships between Hg concentrations in tissue relative to length, weight and age (Figures 2a, 2b and 2c; no statistical comparisons were conducted). In 2011 (n=13) mercury concentrations ranged from 0.0221 to 1.01 (with the min/max values representing a very small very young individual, and one of the larger older individuals sampled, respectively). No deformities/ abnormalities were noted in any of the Northern Pike sampled in 2015; parasites (e.g. worms) were found in fish sampled, though not at levels considered to be abnormal.

Pickerel which had tissues sampled for analyses in 2015 (n=11) ranged from 308 to 455mm in length (FL), 45.4-816.5g in weight (n=10), and were estimated to be 7-11 years of age (n=11). All of the pickerel sampled fell below the mercury concentration guideline of 0.5 mg/kg, (wet weight, wwt; Health Canada, 2012), with a range of 0.160-0.228mg/kg (wwt) (Figures 3a, 3b and 3c). In 2015, mercury concentrations in tissue were lower than concentrations found in Northern Pike, and higher than concentrations found in Lake Whitefish. By comparison, Pickerel sampled in 2011 (n=10) ranged from 278-464mm in length (FL) and 214-982g in weight, and were estimated to be 5-20 years of age. Overall, the mercury concentrations found in Pickerel tissues sampled in 2015 were slightly lower than the concentrations found in 2011, and visual comparison of scatter plots suggest a stronger positive relationships between Hg concentrations in tissue relative to length, weight and age in 2011 results versus the 2015 results with 2015 results being more clustered relative to the 2011 results (Figures 3a, 3b and 3c). Mercury concentrations in 2011 ranged from 0.103 to 0.532mg/kg (wwt), a wider range of concentrations than observed in 2015. The tissues with the highest concentrations in 2011 were from the older (e.g. 15 and 20 years), larger (e.g. 462 464mm FL) and heavier (e.g. 946 and 982g) fish.

Figure 2. Comparison of the relationships between mercury concentration in tissues (mg/kg; wet weight) and fork length (mm) (2a), body weight (g) (2b), and age (years; estimated via clethria aging) (2c) of Northern Pike collected during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Behchokǫ̀, September 2015 and September 2011. Health Canada Canadian Standard for mercury concentration in commercial fish 0.5mg/L) provided.

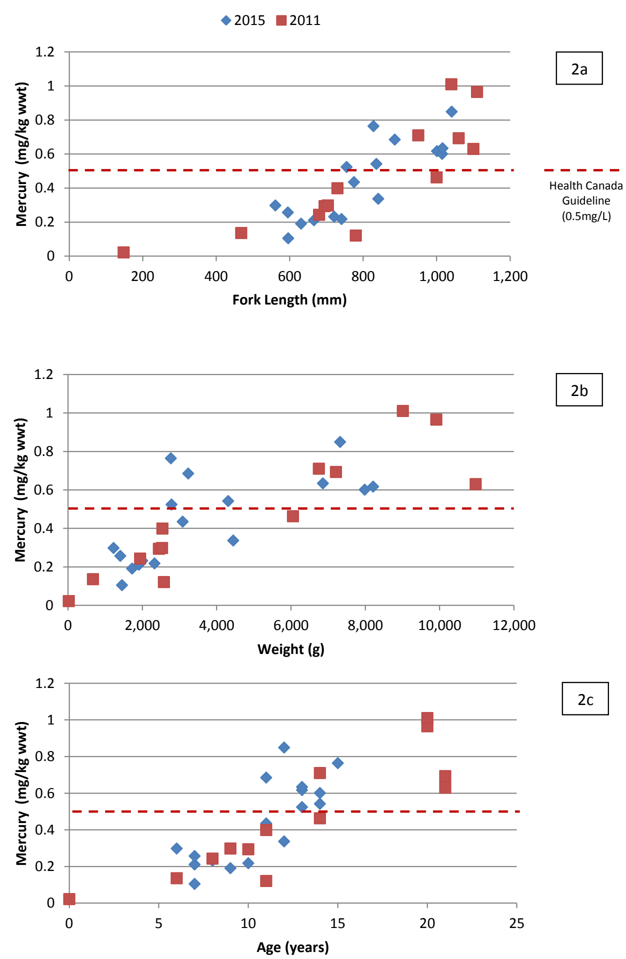


Figure 3. Comparison of the relationships between mercury concentration in tissues (mg/kg; wet weight) and fork length (mm) (3a), body weight (g) (3b), and age (years; estimated via otolith aging) (3c) of Pickerel (Walleye) collected during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Behchokǫ̀, September 2015 and September 2011. Health Canada Canadian Standard for mercury concentration in commercial fish 0.5mg/L) provided.

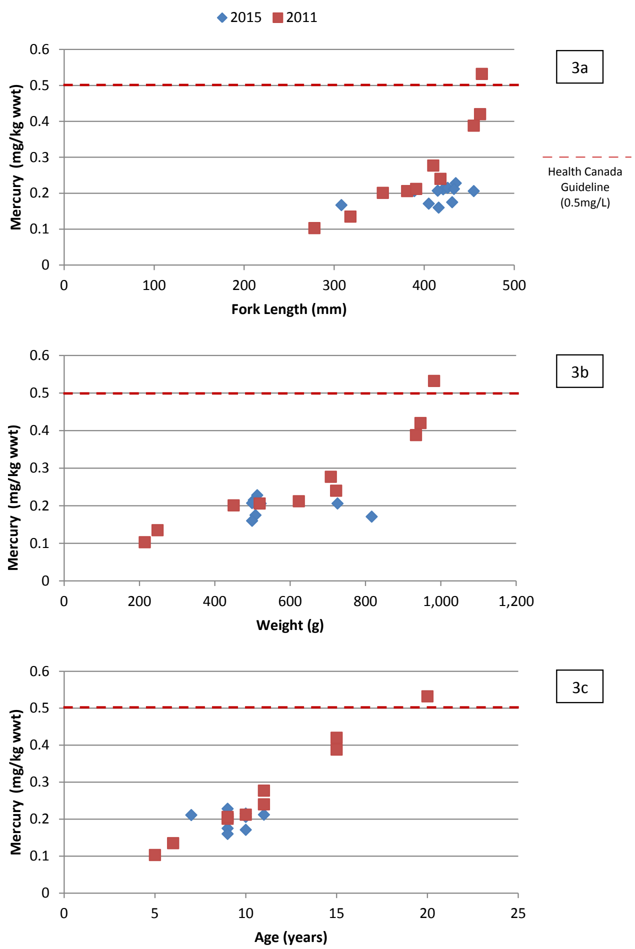
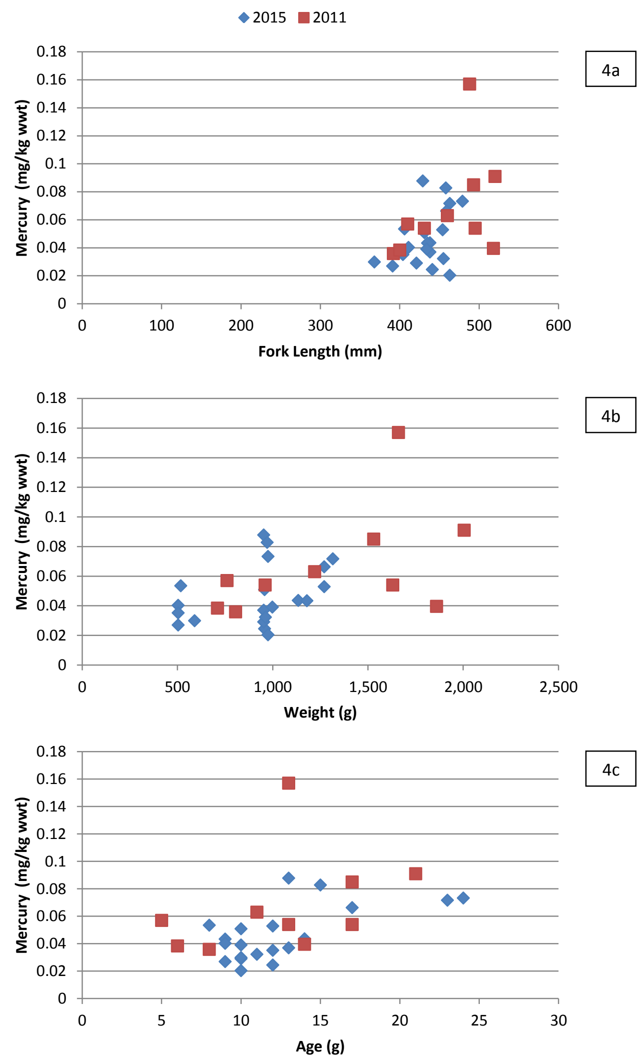


Figure 4. Comparison of the relationships between mercury concentration in tissues (mg/kg; wet weight) and fork length (mm) (4a), body weight (g) (4b), and age (years; estimated via otolith aging) (4c) of Lake Whitefish collected during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Behchokǫ̀, September 2015 and September 2011. Health Canada Canadian Standard for mercury concentration in commercial fish 0.5mg/L) provided.



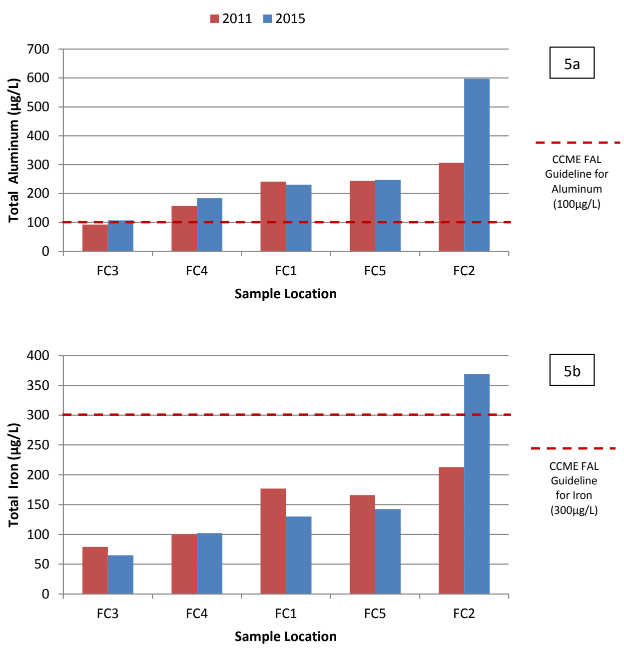
Lake Whitefish sampled in 2015 (n=20) ranged from 363-479mm in fork length, 503.5g-1315.4g in weight, and were estimated to be 8-24 years of age. All of the Lake Whitefish sampled fell well below the guideline for mercury, with a range of 0.0204-0.0878mg/kg (wwt). Review of mercury concentrations in muscle tissue in relation to age, fork length, and weight suggest positive relationships (Figure 4a, 4b and 4c; no regression analyses performed). By comparison, Lake Whitefish sampled in 2011 (n=10) ranged from 392-520mm in length (FL) and 710-2005g in weight, and were estimated to be 5-21 years of age. Overall, the mercury concentrations found in Lake Whitefish tissues sampled in 2015 were similar to the concentrations found in 2011, and visual comparison of scatter plots suggests similar positive relationships between Hg concentrations in tissue relative to length, weight and age for both 2011 and 2015 (Figure 4a, 4b and 4c). In 2011 (n=10) mercury concentrations ranged from 0.0359 to 0.157mg/kg (wwt). No deformities / abnormalities were noted in any of the fish sampled; parasites (e.g. worms) were found in fish sampled, though not at levels considered to be abnormal.

No Lake Trout were caught, which was not unexpected given that only two Lake Trout were caught in 2011 and that community members mentioned that the likelihood of catching Lake Trout was low; tissue samples were not collected for analyses. One white sucker was caught, 434mm in length and 1179.0g in weight; tissue samples were not collected for analyses. There were four inconnu (coney) caught, ranging from 496 to 671mm in length and ranging from 966.2 to 2313.3g weight; tissue samples were not collected for analyses. No deformities/abnormalities were noted in any of the fish sampled; parasites (e.g. worms) were found, though not at levels considered to be abnormal.

Nutrient and physical parameters were found to be similar at all sites. Calcium and magnesium were both low reflecting the softness of the water (1.4-1.5mg/L and 3.95-4.3mg/L, respectively). Water samples indicated the pH ranged from 7.32 to 7.37, and pH results showed very little difference between sampling sites. The water flowing into Slemon Lake from Snare River (W/S-3) had the same pH as the water flowing through the channel into Russell Lake (W/S-2) and the results fell within Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL) guidelines (6.5-9.0) (CCME 2012).

Water sample results indicated that most metal concentrations in Slemon Lake and Russell Lake were very low. Many results were found to be below Minimum Detection Levels (MDL), with only Aluminum and Iron found to be outside the guidelines. Aluminum was outside the FAL guidelines (100µg/L) in all of the sampling locations in 2015, ranging from 107µg/L to 597µg/L (Figure 5a), and aluminum exceeded guidelines in all but one location in 2011, ranging from 93-307µg/L. Similar to results in 2011 the 2015 total aluminum concentration was the lowest where the water flows into Slemon Lake (W/S-3), and concentration increased downstream with the highest level is found at the site furthest downstream (W/S-2). Iron concentration at site W/S-2 (369µg/L) was the only sampling location which exceeded the guideline (300µg/L). Iron concentrations in 2015 ranged from 65-369, and in 2011 sample ranged from 79-213µg/L. Similar to the pattern observed with aluminum, results in 2011 and 2015 showed total iron concentration was the lowest at site W/S-3 (upstream)and highest at W/S-2 (downstream). Comparison of percent dissolved fraction of the metals indicated that aluminum, iron, manganese, titanium and zinc had a majority of the metal present in particulate form (<10% in dissolved form). Arsenic, barium, copper, lithium, nickel, rubidium and strontium had more of the metal present in dissolved form with greater than 60 percent in the dissolved form. Most metals showed a decrease in the percent of dissolved metal downstream (more of the total metal was in particulate form).

Figure 5. Comparison of the total concentrations of Aluminum (5a) and Iron (5b) surface water samples collected during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Behchokǫ̀, September 2015 and September 2011. Sample locations are arranged from those more upstream (Slemon Lake, W/S-3) to downstream (Russell Lake, W/S-2); refer to Figure 1. Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL) provided for Aluminum (100µg/L) and Iron (300 µg/L) provided.



The sediments collected from Slemon and Russell Lakes had relatively high amounts of aluminum, iron, and titanium. There are currently no CCME sediment guidelines for these metals. Most metals concentrations found in the 2015 sediment samples were similar to the results seen in 2011 samples. All metal concentrations in 2015, except for chromium concentration at one location, were below the CCME Probable Effect Levels (PEL) criteria, and all 2011 samples were below PEL criteria. However, a number of samples in both years exceeded the CCME Interim freshwater sediment quality guidelines (CCME 2014). Arsenic concentrations exceeded the CCME Interim Sediment Quality (ISQ) Guideline of 5.9µg/g at all sites sampled except W/S-3 in 2015 and 2011. The concentrations ranged from 5-12µg/g in 2015, and 6.3-9.5µg/g in 2011. Chromium concentrations exceeded the CCME ISQ Guideline of 37.3µg/g at all sites sampled in 2015 and 2011. The concentrations ranged from 45-92µg/g in 2015 and 51.3-80.4µg/g in 2011. Copper concentrations exceeded the CCME ISQ Guideline (35.7µg/g) at one location in 2015, while all the samples in 2011 exceeded the guideline. The copper concentrations ranged from 16 to 38µg/g in 2015, and from 45.1-67.7µg/g in 2011. In 2015 none of the samples collected were above guidelines for Lead, and concentrations ranged from 7 to 14µg/g. Lead concentrations exceeded the CCME ISQ Guideline (35 µg/g) at one site in 2011. The Lead concentration exceeding guideline was found in the upper section of the sediment (40.8µg/g) and in the lower section of the sediment collected (36.9µg/g) at SFC5. Zinc concentrations exceeded the CCME ISQ Guideline (123µg/g) at all sites sampled in 2015 with the exception of W/S-3, however. in 2011 none of the samples collected were above guidelines. In 2015 the concentrations ranged from 109 to 179µg/g, and 69-111µg/g in 2011.

Discussion and Conclusion

The main objective of the 2015 fish, water and sediment quality monitoring program was to repeat the sampling that was done in 2011 to see if any changes had occurred. There was no apparent change in the water quality and sediment quality between 2011 and 2015, with the understanding that some variation of parameters is to be expected with varying natural conditions and low frequency sampling.

Overall, results indicated that fish are healthy and habitat is clean in Russell and Slemon Lakes; no contaminant levels observed in Northern Pike, Pickerel or Lake Whitefish were considered to be abnormal. Though Northern Pike and Pickerel were found to have higher mercury concentrations than Lake Whitefish, this was not unexpected given that they are predatory fish which commonly exhibit higher levels due to bioaccumulation and biomagnification, while Lake Whitefish primarily feed on small fish and arthropods and typically show lower levels of contaminants (GNWT 2016a, b, Health Canada, 2011, Cabana et al. 1994). No statistical analyses of mercury concentrations in muscle tissue in relation to age, fork length, and weight were conducted, given that examination of the scatter plots suggest positive relationships (as expected). Statistical analyses are expected though collaboration with Environment and Climate Change Canada, examining data in the context of the TAEMP, as well as comparing TAMEP data to surrounding lakes which have not been sampled as part of the TAEMP. Additional and more detailed analyses are also expected as part of a WRRB report focusing on comparison between the 2015 and 2011 TAEMP results (completion expected summer 2016).

The general water and sediment quality of Slemon and Russell Lake can be considered to be good (i.e. not abnormal). Aluminum was the only metal in Russell and Slemon Lake that exceeded CCME FAL guidelines. In both sample years the total aluminum concentration was noted to increase downstream as the water flowed from Snare River, through Slemon and Russell Lake. The increased total aluminum concentration was in particulate form as was seen in the percent of dissolved versus total metals in Slemon and Russell Lake. The increase in total aluminum in the water could be explained by the aluminum rich sediment in Slemon and Russell Lakes. The water flowing through the water system is most likely re-suspending the sediment and carrying it further downstream. The concentration of aluminum and iron in water found at each sample site was similar in both sample years with the exception of the sample site near the mouth of the channel flowing into Russell Lake (W/S-2) near the first fish net location. The concentration of aluminum collected in 2015 from W/S-2 was almost double that found in 2011, with the results for iron being similar. The higher concentration of aluminum and iron may be due to disturbance of the sediment as a result of the fish net activities (e.g. community members not associated with the camp setting nets in the area, with support poles placed in the sediment rotating and "churning" the sediment) and windy conditions resulting in further mixing. Sediment sample results showed that sediment collected from the mouth of the Snare River flowing into Slemon Lake (W/S-3), also the most upstream sample site, had lower concentrations of metals than all the other sample sites. 2015 sediment sample results showed that the sediment in Slemon and Russell Lake exceed CCME ISQ Guidelines for arsenic, chromium and zinc. By comparison, the 2011 results did not have zinc in exceedance of guidelines, though copper was in exceedance. Arsenic, chromium, copper, lead and zinc are metals of environmental concern as these metals exceeded CCME FAL guidelines. However, these metals were within CCME guidelines in the water samples.

There has been ongoing concern among the Tłı̨chǫ people regarding whether fish are healthy and safe to eat, and Tłı̨chǫ elders continue to emphasize that up-to-date studies documenting contaminant levels to determine the health of fish are needed. Previously, Lockhart et al. (2005) reported elevated mercury in fish collected in Marian River and Slemon Lake in 1979 and 1983 (respectively), and in Lake Trout sampled from Rae Lakes in 2000. Continued standardized sampling at lakes near Tłı̨chǫ communities in Wek'èezhìı will help to track environmental changes. This will help to address concerns identified by Tłı̨chǫ people, and assist other NWT decision-makers by providing locally-collected data. For example, the Marian sub-watershed (neighboring the Northeastern Great Slave Lake sub-watershed) contains the proposed Fortune Minerals NICO mine location which includes an all season access road, which may also have impact (Cott et al. 2015). The general lack of information on the fish and water quality metrics used to help determine freshwater health in various sub-watersheds in the NWT is highlighted in the WWF Freshwater Health Assessments for Watersheds in Canada (WWF 2015, 2016); the TAEMP will also help address gaps in watershed knowledge associated with Wek'èezhìı. The TAEMP broadens the geographic coverage of sampling for mercury, as recommended in the INAC State of Knowledge Report (2012).

With the conclusion of the TAEMP near Whatì, baseline sampling was completed near all four Tłı̨chǫ communities. In 2015, when the TAEMP returned to Behchokǫ̀, a new phase began: the first round of comparative sampling. The next four years (2015-2018) will provide data that may indicate changes and provide relevant information to assist in cumulative effects analyses and informed decision-making. The TAEMP will contribute to the implementation of the NWT Water Stewardship Strategy (WSS) and Action Plan, and the continuing assessment of contaminant levels in traditional foods through collaboration with Health and Social Services and the Northern Contaminants Program. TAEMP will also complement the Tłı̨chǫ Government's ongoing Marian Watershed Stewardship Program in establishing baseline datasets and evaluating cumulative effects that may occur due to climate change, industrial activities (e.g. Fortune Mineral's proposed NICO project), and/or natural disturbances. Finally, TAEMP continues to assist in the promotion, understanding, and protection of source water for Tłı̨chǫ communities.

Expected Project Completion Date:

Behchokǫ̀ portion of TAEMP completed April 30, 2016.

Project website (if applicable):

See: http://www.wrrb.ca/ for TAEMP updates.

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References

Aboriginal Affairs and Northern Development Canada (AANDC). 2012. A Preliminary State of Knowledge of Valued Components for the NWT *Cumulative Impact Monitoring Program (NWT CIMP) and Audit*. Final Update March 2012 (previously updated 2009).

Arctic Monitoring and Assessment Program (AMAP). 2011. *Arctic Pollution 2011(Mercury)*. Available at: http://www.amap.no/documents/doc/arctic-pollution-2011-mercury/89

Bodaly, R. A., J. W. M. Rudd, R. J. P. Fudge, and C. A. Kelly. 1993. Mercury concentrations in fish related to size of remote Canadian Shield lakes. *Can. J. Fish. Aquat. Sci.* 50: 980-987.

Cabana, G.A., J.Tremblay, and J.B. Rasmussen. 1994. Pelagic Food-Chain Structure in Ontario Lakes: A Determinant of Mercury Levels in Lake trout (*Salvelinus-Namaycush*). *Can. Fish. Aquat.* Sci. 51:381-389.

Canadian Council of Ministers of the Environment (CCME). 2014. *Canadian Environmental Quality Guidelines*. Available at: http://ceqg-rcqe.ccme.ca/en/index.html#void

Cott, P.A., A. Schein, B.W. Hanna, T.A. Johnson, D.D. MacDonald, and J.M. Gunn. 2015. Implications of linear development on northern fishes. Environ. Rev. 23:1-14.

Environment Canada. 2012. *Metal Mining Technical Guidance for Environmental Effects Monitoring*. Available at: https://www.ec.gc.ca/esee-eem/AEC7C481-D66F-4B9B-BA08-A5DC960CDE5E/COM-1434—Tec-Guide-for-Metal-Mining-Env-Effects-Monitoring_En_02%5B1%5D.pdf.

Government of Northwest Territories, Health and Social Services (GNWT). 2016a. *Northwest Territories Contaminants Fact Sheet Series.*

Government of Northwest Territories, Health and Social Services (GNWT). 2016b. General Fish Consumption Guidelines for the NWT. Available at: http://www.hss.gov.nt.ca/sites/default/files/general-fish-consumption-guidelines-nwt.pdf

Health Canada. 2012. *Canadian Standards (Maximum Levels) for Various Chemical Contaminants in Foods*. Available at: http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/contaminants-guidelines-directives-eng.php.

Health Canada. 2011. Mercury in Fish Questions and Answers. Available at:http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/environ/mercur/merc_fish_qa-poisson_qr-eng.php.

Lockhart, W., G.Stern. G. Gow, M. Hendzel, G. Boila, P. Roach, M. Evans, B. Billeck, J. DeLaronde, S. Fiesen, K. Kidd, S. Atkins, D. Muir, M. Stoddart, G. Stephens, S. Stephenson, S. Harbicht, N. Snowshoe, B. Grey, S. Thompson, and N. DeGraff. 2005. A history of total mercury in edible muscle of fish from lakes in northern Canada. *Sci. Tot. Env.* Vol. 351-352: 427-463.

World Wildlife Fund (WWF®). 2015. WWF®-Canada Watershed Report for the Lower Mackenzie Watershed. Available at: http://awsassets.wwf.ca/downloads/wwf_watershed_report_lower_mackenzie_22062015_updated.pdf

World Wildlife Fund (WWF®). 2016. WWF®-Canada Watershed Report, Lower Mackenzie, Health. Available at: http://watershedreports.wwf.ca/#ws-7/by/health-overall/health. Accessed April, 2016. ® “WWF” is a WWF Registered Trademark

Enhancing community-based monitoring of ecosystem changes in the ISR through the bridging of western scientific knowledge with local and traditional ecological knowledge

Renforcement de la surveillance communautaire des changements qui surviennent dans les écosystèmes dans la région désignée des Inuvialuits en combinant les connaissances scientifiques occidentales et les connaissances écologiques traditionnelles et locales

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Abstract

This project was initiated in 2013 to record local observations and to identify local and traditional ecological knowledge indicators of beluga health and habitat use. Beluga sightings were recorded from June to September between 2013 and 2015 in the coastal areas of the Inuvialuit Settlement Region (ISR), NT. Harvesters' observations about beluga whale health and habitat use were collected using semi-structured questionnaires in 2013, 2014 and 2015 at Hendrickson Island (n = 48), East Whitefish Station (n = 25) and

Résumé

Le projet, lancé en 2013, a pour objectif de consigner les observations réalisées à l'échelle locale et de définir les indicateurs de connaissances écologiques traditionnelles et locales qui reflètent l'état de santé et l'utilisation de l'habitat des bélugas. Des observations ont été recensées entre juin et septembre, de 2013 à 2015, dans les zones côtières de la région désignée des Inuvialuits (RDI) des Territoires du Nord-Ouest (T.N.-O.). En 2013, en 2014 et en 2015, on a recueilli les

Darnley Bay (n = 19). In addition, focus groups and one-on-one in-depth discussions were held with 8-10 community knowledge holders in Inuvik, Tuktoyaktuk and Paulatuk to fill knowledge gaps and verify research outcomes.

In this final phase of this project, the community observations and knowledge shared between 2013 and 2015 were analysed and interpreted with Traditional Ecological Knowledge (TEK) holders, harvesters and youth to identify potential 'local ecological indicators' that will be piloted in the 2016 beluga monitoring program. In addition, the observations made about harvested whales will be analysed alongside scientific indicators to identify areas where these observations could assist with the interpretation of scientific findings. Bringing together local and traditional ecological knowledge and scientific knowledge may provide greater insight into how environmental change may impact the Eastern Beaufort Sea beluga population.

observations des chasseurs concernant la santé des bélugas et leur utilisation de l'habitat à l'aide de questionnaires semi-structurés à l'île Hendrickson (n = 48), à East Whitefish Station (n = 25) et dans la baie de Darnley (n = 19). En outre, des groupes de discussion et des discussions individuelles approfondies ont eu lieu avec huit à dix dépositaires du savoir de la communauté à Inuvik, à Tuktoyaktuk et à Paulatuk pour combler les lacunes et vérifier les résultats de la recherche.

Dans la dernière phase de ce projet, les observations communautaires et les connaissances échangées entre 2013 et 2015 ont été analysées et interprétées avec les dépositaires de connaissances écologiques traditionnelles (CET), les chasseurs et les jeunes pour définir des « indicateurs écologiques locaux » potentiels qui seront mis à l'essai dans le programme de surveillance du béluga de 2016. On procédera également à une analyse des indicateurs scientifiques et des observations réalisées sur les baleines chassées, et ce, afin de cibler les occasions lors desquelles ces observations pourraient faciliter l'interprétation de résultats scientifiques. L'utilisation conjointe de connaissances écologiques traditionnelles et locales et du savoir scientifique pourrait permettre de mieux comprendre la façon dont les changements environnementaux peuvent influencer la population de bélugas de la zone est de la mer de Beaufort.

Key messages

- This project was initiated to identify and record local and traditional ecological knowledge for inclusion in beluga monitoring and research.
- From an Inuvialuit perspective, the health of beluga whales is based on the appearance and behaviour of the whales during harvesting activities, the condition of muscle, muktuk and blubber, and the appearance of internal organs.
- Project participants have in-depth knowledge about beluga calving areas, potential nursery areas, feeding areas and travel routes/times

Messages clés

- Le projet a été lancé dans le but de recenser et de consigner des connaissances écologiques locales et traditionnelles et de les utiliser aux fins de surveillance des bélugas et de recherche sur cette espèce.
- Les Inuvialuits évaluent la santé des bélugas en fonction de leur apparence et de leur comportement pendant les activités de récolte, de l'état des muscles, du muktuk et de la graisse ainsi que de l'apparence des organes internes.
- Les participants au projet ont une connaissance approfondie des aires de

in the areas surrounding their communities and harvest sites.

- Scientific measurements and Inuvialuit observations could be recorded following the harvest to monitor beluga health.
- Monitoring beluga habitat use depends on community members sharing their observations in addition to having TEK-holders interpret the observations made in their communities.

mise bas du béluga, des aires de croissance potentielle, des aires d'alimentation ainsi que des voies et des moments de déplacement dans les régions aux alentours de leurs collectivités et sites de chasse.

- Les mesures scientifiques et les observations des Inuvialuits pourraient être enregistrées à la suite de la récolte pour surveiller la santé des bélugas.
- La surveillance de l'utilisation de l'habitat par les bélugas nécessite que les membres de la collectivité fassent part de leurs observations et que les personnes possédant des connaissances écologiques traditionnelles interprètent les observations faites dans leurs collectivités.

Objectives

- Record observations of beluga whales from a community perspective that are potential indicators of ecosystem changes.
- Engage community members in beluga sampling and documentation of observations.
- Increase our understanding of the Beaufort Sea ecosystem through the inclusion of local and traditional ecological knowledge in community-based monitoring.
- Partner with existing beluga and CBM programs in the ISR to evaluate linkages between local observations, changes in the ecosystem, and contaminant trends.
- Provide training to community research coordinators to increase capacity within communities to lead community-based research.

Introduction

Monitoring of the Eastern Beaufort Sea beluga population has taken place in the Mackenzie Delta since the 1970s (Harwood et al., 2015). The beluga-monitoring program established in the Inuvialuit Settlement Region (ISR) has been focused on traditional scientific indicators (e.g. general morphometrics, health indices, stable isotopes, fatty acids, diseases and contaminants). The development and documentation of local ecological knowledge indicators in the ISR was initiated to provide a mechanism for local and traditional ecological knowledge to be included in the long term monitoring of beluga whales.

Scientific and local observations of environmental change can be brought together to identify new avenues for further exploration, compare observations from different scales and discuss potential mechanisms that explain both sets of observations (Huntington et al., 2004). The inclusion of all knowledge holders and users in developing research and management plans creates an enriched understanding of the changes occurring in arctic marine ecosystems and supports knowledge generation and sharing (Tengo et al., 2014). Knowledge and wisdom held by the Inuvialuit about beluga whale behaviour and predation is associated with decades of observations (e.g. Byers and Roberts, 1995). The findings from this study will advise and feed into long term monitoring. For example, bringing together local ecological indicators and traditional scientific knowledge may provide greater insight into how environmental change is impacting the Eastern Beaufort Sea beluga population. The co-production of knowledge is an approach for connecting knowledge systems that engages mutual processes at all stages of knowledge generation, including the setting of goals, the generation of knowledge and the re-assessment of knowledge gaps and new questions (Tengo et al. 2014).

Activities in 2015-2016

This program is embedded in the community based beluga monitoring program that occurs annually in the Inuvialuit Settlement Region. This project took place in the communities of Ulukhaktok, Inuvik, Paulatuk and Tuktoyaktuk. Field-based observations were recorded at: Hendrickson Island (69.484304, -133.582239); East Whitefish (69.373805, -133.635798); and Tippi (69.594667, -124.245798). This was the final year for research in identifying and interpreting local ecological indicators. This project provided the opportunity for community members in the ISR to contribute their knowledge to the beluga monitoring program (Table 1).

Harvesters provided their observations about the health and behavior of the harvested whales using a questionnaire developed with the community and Sonja Ostertag. Beluga habitat use was documented by community members through participatory mapping in 2013, harvester questionnaires in 2013-2015, and shore/boat-based observations 2013-2015. In 2015, Jocelyn Noksana and Devalynn Pokiak coordinated the collection of boat-based and shore-based beluga whale observations by harvesters and community members from Tuktoyaktuk and Diane Ruben coordinated the collection of local observations in Paulatuk. Focus groups and one-on-one indepth discussions were held with 8-10 community knowledge holders in Inuvik, Tuktoyaktuk and Paulatuk to fill knowledge gaps and verify research outcomes.

In 2015, beluga sightings were recorded by community members in Tuktoyaktuk and Paulatuk (Table 2). Very few individuals used GPS to mark the locations of beluga in Kugmallit Bay; therefore, we relied on community mapping to identify where beluga are usually observed, and paper maps to identify where beluga were harvested. General mapping indicated key locations of past beluga sightings and final maps are currently being generated for expected beluga habitat use.

Table 1. Number of participants from the ISR in this project between 2013 and 2015. Participation was through open community meetings, focus groups, sharing beluga observations, and interviews.

	2013	2014	2015
Participants at community meetings	79	81	28*
Number of observation forms completed	13	84	119
Number of harvester questionnaires completed	28	33	33
Participation rate for questionnaire	78%	87%	79%
Number of interview participants	na	45	

* Focus Group meetings were held in 2015 instead of open community meetings.

Table 2. Number of shore-based observations forms completed and uploaded using the pilot online App in summer 2015.

Community	Number of forms completed by community members	Number of entries input with the App?
Inuvik	0	0
Paulatuk	16	0
Tuktoyaktuk	45	45
Ulukhaktok	0	0

Two apps were developed using ArcGIS online (Collector App) to collect information about harvested or observed whales. The app could be used both on and offline; data could be synched with the server when internet was available. Five tablets were distributed to Hunters and Trappers Committees and/or whale monitors in early July, 2015, to be used in conjunction with paper forms filled out by monitors, researchers and community members. Each community had a unique ArcGIS account that could be used for uploading data.

Capacity Building: To date, 19 youth and community research assistants from Inuvik, Tuktoyaktuk, Ulukhaktok and Paulatuk were engaged in this project since 2013: DevaLynn Pokiak, Shaeli Pokiak, Cole Felix, Lionel Kikoak, Courtney Kikoak, Kate Snow, Kayla Hansen Craik, Bernadette Green, Brandon Green, Melanie Wolki, Glen Ruben, Ray Ruben Sr., Joe Illasiak Jr, Megan Kimiksana, Paden Lennie, Andrew Gordon Jr, Robert Memogana, Roland Notaina and Verna Pokiak. In 2015, six youth from Inuvik, Tuktoyaktuk and Paulatuk participated in the field program for this project, six youth participated in the focus groups and two youth also participated in the Beluga Summit.

The youth and research assistants contributed to one or more of the following activities: recording observations, distributing observation forms, leading or supporting community interviews, collecting household data, transcribing interviews, assisting with community meetings, providing Inuinnaqtun language translation and interpretation, and co-presenting to classrooms in the participating communities. One youth employed by the DFO also assisted with camp logistics at Hendrickson Island and focus group preparations, one youth was employed in Tuktoyaktuk as a community coordinator and one youth was employed briefly in Paulatuk to assist with project completion. S. Ostertag worked closely with the delegates and beluga monitors from Paulatuk and Tuktoyaktuk to support them with their preparations for the Beluga Summit. This support consisted of assisting with arranging for the delegates to meet before the Summit and providing guidance on presentation outlines and content. In addition, S. Ostertag worked closely with the Paulatuk HTC to strengthen their community-based monitoring program by facilitating a meeting with the program coordinator (D. Ruben), two beluga monitors and the junior whale monitor at the end of the beluga harvest season.

In Ulukhaktok, T. Pearce worked closely with Roberta Memogana, who collected household data on how beluga mukluk and meat were shared among households. Roland Notaina assisted T. Pearce with the recruitment of participants for interviews on beluga behaviour, ecology, hunting and mukluk preparation, and assisted in conducting interviews, including providing Inuinnaqtun language translation and interpretation

Five project participants from the ISR travelled to Vancouver for the Northern Contaminants Program meeting in December 2015 and participated in a panel on beluga monitoring and research in the ISR. One youth and one whale monitor co-presented with S. Ostertag during the class visit in Paulatuk. S. Ostertag mentored two Masters students whose research is based in Paulatuk and Tuktoyaktuk, and provided guidance to one postdoctoral fellow whose research is based in the ISR.

Communications: Focus group meetings were held in Inuvik, Tuktoyaktuk and Paulatuk in the summer of 2015. S. Ostertag met with the

HTCs in February 2016 to review the project results and timeline. Research updates were shared through articles in the Beluga Bulletin and a poster at the Beluga Summit. Project updates were provided to the Inuvialuit Game Council in June 2015, to Northern Contaminants Program in December 2015 and the FJMC in January 2016. Project results were reviewed with the focus group participants in advance of the preparation of a final research report for the participating communities in the ISR. Five project participants from the ISR travelled to Vancouver for the Northern Contaminants Program meeting in December 2015 and participated in a panel on beluga monitoring and research in the ISR. Classroom presentations were also given to students in Paulatuk and Tuktoyaktuk.

Traditional Knowledge Integration:

The Local Ecological Indicators project is responding to the need to more effectively include LEK and TEK in beluga monitoring programs in the ISR. This project documented community perspectives and observations of beluga whales that may be used as indicators of beluga health and environmental change. Traditional Ecological Knowledge, as defined as "knowledge gathered and maintained by groups of people, based on intimate experience with their environment" (Huntington et al., 2004), is the focal point of this study.

Traditional and local knowledge about belugas was collected and verified through focus group meetings held in Tuktoyaktuk, Inuvik and Paulatuk with community experts selected by the HTCs. Nine or ten community experts were selected by the community Hunters and Trappers Committee and were youth, current harvesters, Elders, women and beluga monitors. Meeting with community members and HTCs guided the inclusion of TEK and LEK in the selection of novel indicators in beluga monitoring. We worked with the whale monitors, harvesters and community liaisons to document the observations for the selected indicators.

In 2015, a TEK expert was employed on Hendrickson Island to assist with assessing the health of harvested whales alongside the research team and provide insight into changes in beluga habitat use in Kugmallit Bay. John Noksana Sr. from Tuktoyaktuk was hired as the TEK holder to share his knowledge and perspective about beluga whales to the research team on Hendrickson Island. In addition, he provided advice and feedback on all camp activities. John provided his observations about the harvested whales and about the whales in Kugmallit Bay in 2015 compared to previous years. This was a unique opportunity for the TEK holder to share his/her knowledge of beluga with the research team, during the necropsies conducted as part of the beluga health assessment taking place at Hendrickson Island. The TEK holder worked closely with the research team to share his observations alongside western ecological knowledge at the harvest camp. TEK of beluga was recorded at the harvest camp using audio recording and survey forms.

Traditional knowledge (TK) of marine systems and beluga in Paulatuk and Ulukhaktok were captured in 2015 and early 2016 through partnered projects and a third project was initiated in Tuktoyaktuk to record TEK about beluga whales. TK holders related to beluga were identified in as a continuation of this project and were invited to share their knowledge through phased assertion, semi-structured interviews with open-ended questions, etc. TEK held by Elders was recorded for harvested belugas at Hendrickson Island and Tippi through semi-structured interviews.

Results

This project built on the previous work that developed tools for recording LEK/TEK in Kugmallit and Darnley Bays. In the third year of this project, we synthesized potential LEK/TEK indicators for Eastern Beaufort Sea (EBS) beluga whales. We brought together Inuit TK holders, harvesters, scientists and managers to identify key indicators for beluga whales from the perspective of diverse knowledge holders.

Beluga habitat use in the coastal areas on the ISR were recorded through participatory mapping and maps of general beluga habitat use and travel routes are being finalized for Kugmallit Bay, Darnley Bay and Kendall Island areas. Mapping beluga sightings and general habitat use provided a snapshot of beluga presence/absence, group composition and potential use of habitat for feeding and moulting. Two applications were developed using the by the DFO to support the collection of local observations about beluga whales. These apps were field-tested and the outcome from the testing indicated that the initial software used was poorly suited to collecting field data and problems arose with synchronizing the data on the tablet with ArcGIS online. Therefore, a new software was identified and used to develop the second phase of the App, which will be field-tested in 2016.

Indicators were evaluated by LEK and TK knowledge-holders and selection was based on consensus from focus group participants. Local ecological knowledge indicators were identified based on the results from semi-structured questionnaires and interviews, and their inclusion in beluga monitoring will be piloted in 2016 at Hendrickson Island, East Whitefish and Darnley Bay. In addition, local observations will be analyzed by scientists to determine how local observations and TEK might add knowledge about samples collected or generate new questions, which can assist in the interpretation or analysis of results.

Through intensive workshops bridging diverse knowledge systems, the scientific and northern communities were brought together to synthesize knowledge of beluga health, contaminants, habitat use and future impacts. Through the breakout groups and discussion at the Beluga Summit, key questions and data gaps were identified and areas for knowledge integration highlighted.

Discussion and Conclusions

Participants in this project shared their knowledge about beluga health and habitat use through the use of questionnaires that were administered alongside regular monitoring activities. The information shared in 2013, 2014 and 2015 was reviewed by TEK holders, harvesters, monitors and youth to identify local indicators of beluga health that can be included in beluga monitoring. In addition, the observations made about harvested whales will be analysed alongside scientific indicators to identify areas where these observations

Table 3. Local indicators for harvested beluga whales based on community-based research in Inuvik, Paulatuk and Tuktoyaktuk from 2013-2015. The relationship between local indicators and contaminants were based on the impacts of contaminants on immune function and the importance of diet on the accumulation of contaminants.

Indicator	Potential implication/significance related to contaminants
Presence of calf with harvested whale	Lower contaminant levels due to different feeding ecology
Location of beluga	Changes in spatial and temporal distribution of beluga could affect contaminant exposure and/or feeding ecology
Feeding observed	Beluga diet provides information about potential sources of contaminants and if the feeding ecology is changing in beluga.
Condition of meat	The condition (quantity) of meat could affect mobilization of heavy metals from muscle stores.
Condition of muktuk	The condition (quantity) of muktuk could affect mobilization of organic contaminants stored in blubber.
Colour of beluga blubber	May reflect beluga diet with implications for contaminant levels.
Overall condition of whale	Overall condition of whale could be impacted by contaminant exposure.
Abnormalities of internal organs	Illness and immune function could be impacted by contaminant exposure.
Cysts in the meat or muktuk	Health status and immune function could be impacted by contaminant exposure.

could assist with the interpretation of scientific findings. The relationship between local indicators about beluga health and contaminant exposure will be explored.

Local indicators of harvested beluga whales provide unique and valuable information about the health status of the whales and their feeding ecology (Table 3). The significance of these indicators for contaminant levels and trends vary from providing information about contaminant levels and exposure based on diet and feeding ecology, or characterizing beluga health.

The complexity of beluga habitat use and how it changes due to environmental variation makes monitoring beluga habitat use challenging. Therefore, we developed an App that could be used throughout the ISR to record beluga sightings and environmental conditions to support the monitoring of beluga in the region and identify changes in beluga timing and distribution. The distribution, timing and activity of beluga whales could indicate changes in feeding behavior. As this population of whales is consistently harvested with empty stomachs in the ISR, additional observations about annual beluga habitat use could assist in the interpretation of scientific results on contaminants and diet.

In the final year of this three year project, we demonstrated that local observations about beluga health and habitat use can be successfully documented in Kugmallit and Darnley Bays by harvesters and other community members, using paper forms, in-person interviews and community meetings. This project supports the development of testable hypotheses about Eastern Beaufort Sea beluga and ecosystem health by bridging western ecological knowledge and LEK/TEK. Through increased research capacity in the ISR, we continued to integrate scientific findings from aerial surveys, hydroacoustic, water chemistry data and beluga monitoring with observational data about beluga whale behavior, characteristics and health. The Beluga Summit held in Inuvik in February 2016 provided the opportunity to begin developing a framework for bringing together western ecological and traditional ecological knowledge systems, for the interpretation of observations and the development of future monitoring goals.

This work goes beyond involving Inuit stakeholders in beluga research and monitoring, to engage with TEK of the marine ecosystem and of beluga, and facilitate the co-production of knowledge, which will guide how the research and monitoring occurs. This has direct implications for beluga management as stakeholders were involved in all aspects of research and monitoring activities, from development to implementation.

Expected Project Completion Date:

March 31st, 2017

References

Byers, T. and L. W. Roberts. 1995. *Harpoons and ulus: collective wisdom and traditions of Inuvialuit regarding the beluga ("qilalugaq") in the Mackenzie River estuary*. Byers Environmental Studies and Sociometrix Inc. Available: Fisheries Joint Management Committee, Box 2120, Inuvik, NT Canada X0E 0T0. 76p.

Harwood, L.A., Kingsley, M.C.S., and Pokiak, F. 2015. Monitoring beluga harvests in the Mackenzie Delta and near Paulatuk, NT, Canada: harvest efficiency and trend, size and sex of landed whales, and reproduction, 1970-2009. Can. Manuscr. Rep. Fish. Aquat. Sci. 3059: vi + 32 p.

Huntington, H., Callaghan, T., Fox, S., Krupnik, I. 2004. Matching Traditional and Scientific Observations to Detect Environmental Change: A Discussion on Arctic Terrestrial Ecosystems. *Ambio*, S13: 18-23.

Tengo M, Brondizio E, Elmqvist T, Malmer P, Spierenburg M. (2014). Connecting Diverse Knowledge Systems for Enhances Ecosystem Governance: The Multiple Evidence Base Approach. AMBIO. 43:579-591.

Mercury in fish from Old Crow, Yukon (2014-2015)

Mercure dans les poissons d'Old Crow (Yukon)

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Abstract

This project measured mercury (Hg) levels in seven commonly harvested fish species from the Old Crow area, to determine whether they continue to be healthy food choices for northerners. The fish were collected by traditional harvesters and processed by a community member with the assistance of an experienced contaminant researcher. Species, age, total length and fork length significantly affected Hg concentrations while sex and weight did not. Of the fish species studied, only loche averaged a higher Hg concentration than the guideline for commercial sales, supporting the current recommendation that women of childbearing years and children under the age of 12 should only eat 1-2 meals of large loche each week. Hg concentrations in inconnu from Old Crow were higher than previously found in other parts of the Yukon. The Chief Medical Officer of Health has recommended an interim guideline for inconnu from Old Crow, similar to that for loche: Women of childbearing years and children under the age of 12 should only eat 1-2 meals of inconnu each week. The new recommendation has been communicated to

Résumé

Ce projet visait à mesurer les concentrations de mercure (Hg) chez sept espèces de poissons communément pêchés dans la région d'Old Crow, afin de déterminer s'ils constituent encore des choix alimentaires sains pour les résidants du Nord. Les poissons ont été pris par des pêcheurs traditionnels, puis traités par un membre de la collectivité épaulé par un chercheur spécialisé dans les contaminants. L'espèce, l'âge, la longueur totale et la longueur à la fourche influaient fortement sur les concentrations de Hg, contrairement au sexe et au poids. Parmi les espèces de poisson pêchées, seule la lotte atteignait en moyenne une concentration d'Hg supérieure à la ligne directrice pour la vente commerciale, ce qui corrobore la recommandation actuelle préconisant que les femmes en âge de procréer et les enfants de moins de 12 ans ne prennent qu'un ou deux repas de grande lotte par semaine. Les concentrations d'Hg chez l'inconnu d'Old Crow étaient supérieures à celles qui avaient précédemment été constatées dans d'autres régions du Yukon. Le médecin en chef a recommandé une ligne directrice

the community of Old Crow as well as Chief and Council of the Vuntut Gwitch'in First Nation and other stakeholders.

provisoire pour l'inconnu d'Old Crow, semblable à celles pour la lotte : les femmes en âge de procréer et les enfants de moins de 12 ans ne devraient prendre qu'un ou deux repas d'inconnu par semaine. La nouvelle recommandation a été communiquée à la collectivité d'Old Crow ainsi qu'au chef et au Conseil de la Première Nation des Vuntut Gwitch'in et à d'autres parties intéressées.

Key Messages

- Mercury levels in chinook, chum, coho, whitefish and pike from the Old Crow area are low and not of concern for consumers of those fish
- Mercury levels in loche from the Old Crow area were, on average, higher than the guideline for commercial sales, supporting the current recommendation that women of childbearing years and children under the age of 12 should only eat 1-2 meals of large loche each week
- Although mercury levels in inconnu from the Old Crow area were somewhat lower than those for loche, the Chief Medical Officer recommended an interim guideline for Old Crow, similar to the guideline for loche: women of childbearing years and children under the age of 12 should only eat 1-2 meals of this fish each week

Messages clés

- Les concentrations de mercure chez les saumons quinnat, kéta et coho, ainsi que le corégone et le brochet de la région d'Old Crow sont faibles et ne sont pas préoccupantes pour les personnes qui consomment ces poissons.
- Les concentrations de mercure chez la lotte étaient en moyenne supérieures à la ligne directrice pour la vente commerciale, ce qui corrobore la recommandation actuelle préconisant que les femmes en âge de procréer et les enfants de moins de 12 ans ne prennent qu'un ou deux repas de grande lotte par semaine.
- Bien que les concentrations de mercure chez l'inconnu de la région d'Old Crow aient été légèrement inférieures à celles de la lotte, le médecin en chef a recommandé une ligne directrice provisoire pour l'inconnu d'Old Crow, semblable à celles pour la lotte : les femmes en âge de procréer et les enfants de moins de 12 ans ne devraient prendre qu'un ou deux repas d'inconnu par semaine.

Objectives

- To determine levels of Hg in commonly harvested fish from the Old Crow area so that community members may be better able to make informed choices regarding consumption of these traditional foods.
- To provide training to northerners in designing contaminant projects and in collecting and processing samples for contaminant analysis.

Introduction

Hg in fish can be a human health concern for people in the Canadian North (Lockhart *et al.* 2005), depending on fish species and geographic location. The Yukon Contaminants Committee database on fish contaminants indicated that few fish from the Old Crow area have been analyzed for Hg (personal communication, Pat Roach, YCC). Muscle samples from eight chum salmon collected from the Old Crow area in 1998 averaged 0.067 $\mu g\ g^{-1}$ wet weight while muscle from five pike collected from Cadzow Lake in 2006 averaged 0.138 $\mu g\ g^{-1}$ wet weight, and ranged up to a maximum of 0.498 $\mu g\ g^{-1}$. Residents of the Old Crow area are concerned about Hg in the fish they traditionally harvest and consume and have designed this research project in their own area to determine if the local fish remain a healthy food choice, particularly for children and women of child-bearing years. Although the Vuntut Gwitch'in First Nation has limited experience in this area, working with an experienced contaminants researcher ensured the scientific validity of the project and increased the capacity of the First Nation to conduct more of this type of research in the future.

Activities in 2014-2015

In total, 67 fish of 7 species were collected for this project in the summer of 2014 by local fishers. Morphometrics were taken from each fish (length, weight, gender, maturity). Muscle samples were extracted and then analyzed for total Hg by the National Laboratory for Environmental Testing, Burlington, ON. Otoliths were aged by North/South Consulting, Winnipeg, MB. While the intention was to use the remainder of the collected fish for a community feast, the fish were badly freezer burned, and were unfit for human consumption. They were used as food for local sled dogs.

Since the data were not normally distributed, the effect of species on Hg concentration was tested using an ANOVA on ranks. The effect of sex was tested using a Mann-Whitney Rank Sum Test and the effect of total and fork lengths and age were tested using Spearman's Rank Correlation. In all cases significance was assumed at $a>0.05$.

Capacity Building

In January and again in April, 2015, M Gamberg travelled to Old Crow to process fish and to train a community member (Robert Kay) in the extraction of samples for contaminant analysis and in taking fish morphometrics. (Extreme cold during the first trip made it impossible to process samples as the working environment was unable to be maintained above freezing.).

Communications

Results of the project were presented to Chief and Council of the Vuntut Gwitch'in First Nation, at a community meeting and to the Chief Zzeh Gittlit School in Old Crow in January, 2016. The content of the communication was developed in cooperation by the PI (William Josie), the environmental researcher (Mary Gamberg) and the Chief Medical Officer of Health for Yukon (Brendan Hanley). Immediately following the communication of results to the community of Old Crow, a press release was sent to local newspapers and radio, and a summary sent to the Old Crow Community Health Center, the North Yukon Renewable Resources Council, the Gwitch'in Tribal Council, the Council of Yukon First Nations, Yukon Environment, the Yukon Contaminants Committee and the NCP secretariat. The news story was carried on all the local media and although there was some discussion of the results in the community meeting and later in local resource council meetings (Mike Suitor, personal communication), community residents were accepting of the new (and old) recommendations for fish consumption.

Traditional Knowledge Integration

This program relied on the traditional knowledge of local Vuntut Gwitch'in members when collecting the fish for this project. All fish were collected from traditional areas, at the time of year they are traditionally harvested.

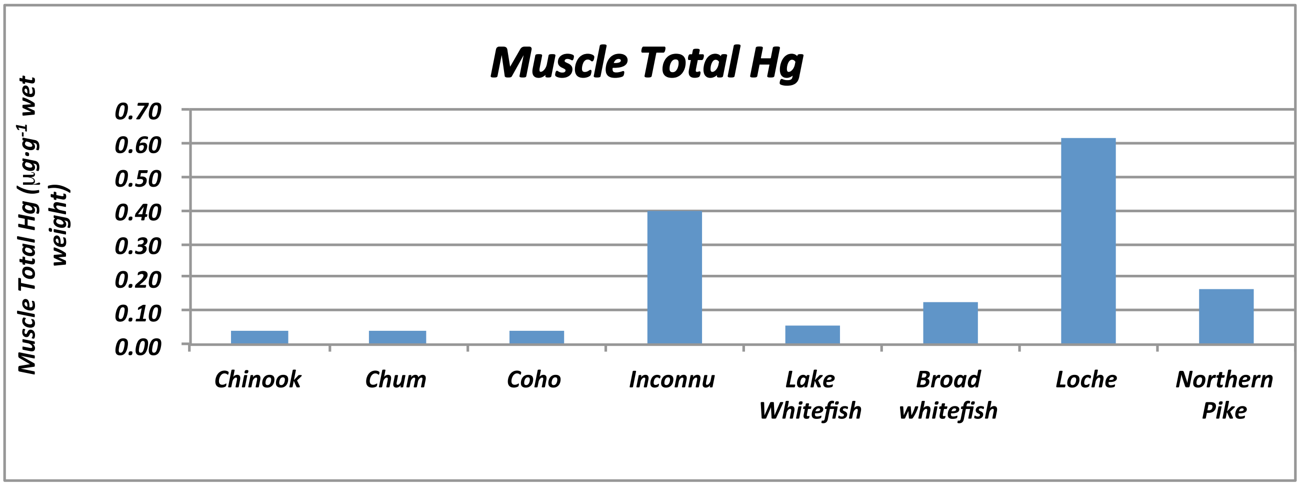
Results

Collection data, morphometric measurements and Hg concentrations are given in Table 1. Species (Figure 1), age, total length and fork length significantly affected Hg concentrations while sex and weight did not. While age was the most significant predictor of Hg concentrations with $p<0.001$ and $r^2=0.65$, total length was also significant ($p=0.006$, $r^2=0.124$) and is more practical for fishers when deciding whether to consume a particular fish (Figure 2).

Table 1. Total Hg concentrations in muscle of fish caught from the Old Crow area, fall 2014.

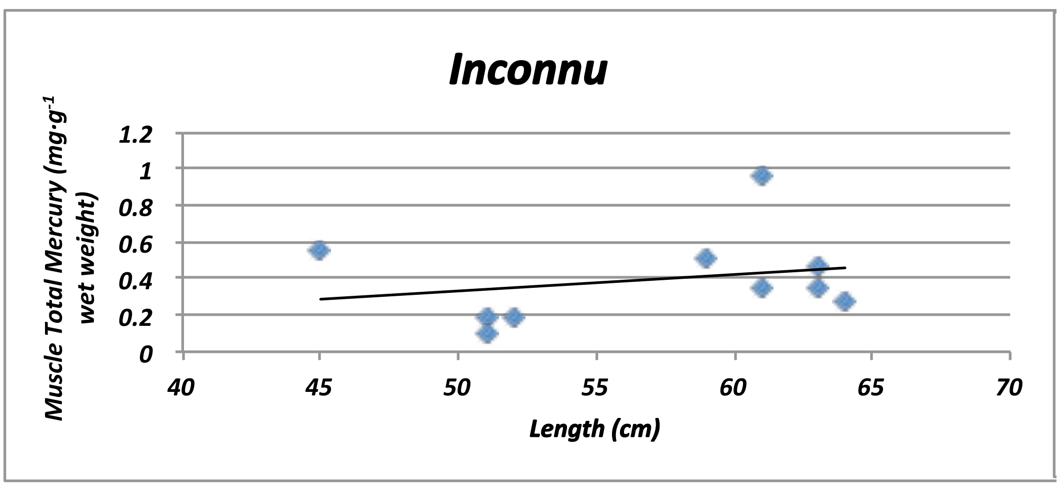
Species	Sex	N	Age (yr)	Weight (kg)	Total length (cm)	Fork length (cm)	Muscle Total Hg ($mg \cdot kg^{-1}$ wet weight)		
							Mean	±	SE
Chinook Oncorhynchus tshawytscha	M	2	2.5	2.85	61.00	61.50	0.04	±	0.005
Chum Oncorhynchus keta	Combined	12	4.0	3.28	66.38	62.46	0.04	±	0.003
	F	5	3.8	2.80	63.60	60.90	0.05	±	0.007
	M	7	4.1	3.63	68.36	63.57	0.03	±	0.002
Coho Oncorhynchus kisutch	Combined	7	3.5	2.63	61.21	58.29	0.04	±	0.002
	F	1	3.0	3.30	68.00	64.00	0.04		
	M	6	3.6	2.52	60.08	57.33	0.04	±	0.003
Inconnu Stenodus leucichthys	Combined	11	9.5	2.39	60.36	58.18	0.40	±	0.074
	F	1	10.0	2.40	66.00	63.00	0.34		
	M	10	9.4	2.39	59.80	57.70	0.40	±	0.083
Lake Whitefish Coregonus clupeaformis	Combined	9	6.0	2.34	53.00	47.11	0.06	±	0.009
	F	2	6.0	2.90	56.50	51.00	0.07	±	0.004
	M	7	6.0	2.19	52.00	46.00	0.05	±	0.011
Broad whitefish Coregonus nasus	M	1	5.0	2.50	55.00	50.00	0.12		
Loche Lota lota	Combined	14	12.9	2.94	71.43	71.43	0.61	±	0.131
	F	8	13.8	2.99	70.38	70.38	0.64	±	0.112
	M	6	11.7	2.88	72.83	72.83	0.59	±	0.269
Northern Pike Esox lucius	Combined	11	6.7	2.78	66.09	63.09	0.17	±	0.023
	F	5	7.8	3.34	73.00	69.20	0.18	±	0.026
	M	6	5.8	2.32	60.33	58.00	0.16	±	0.037

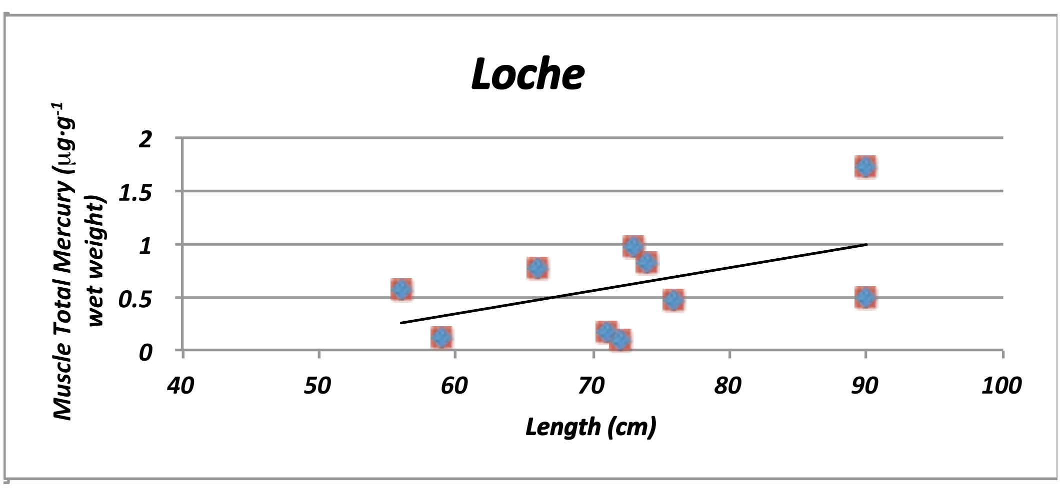
Figure 1. Total Hg in fish muscle collected from the Old Crow area, fall 2014.



Description: This figure shows a bar graph indicating mercury concentrations in chinook, chum and coho (each was 0.04 mg·g^{-1} wet weight), inconnu (0.40 mg·g^{-1} wet weight), lake whitefish (0.06 mg·g^{-1} wet weight), broad whitefish (0.12 mg·g^{-1} wet weight), loche (0.61 mg·g^{-1} wet weight) and northern pike (0.17 mg·g^{-1} wet weight).

Figure 2. Total Hg in muscle related to total length in inconnu and loche collected from the Old Crow area, fall 2014.





Description: This figure shows two panels of scatter plots with regression lines showing the relationship between total mercury in muscle to length in two species of fish. The first panel shows data for inconnu with a slightly increasing trend from about 0.30 $mg \cdot g^{-1}$ wet weight mercury in a 45 cm fish to about 0.42 $mg \cdot g^{-1}$ wet weight mercury in a 65 cm fish. The second panel shows data for loche with a more sharply increasing trend from about 0.25 $mg \cdot g^{-1}$ wet weight mercury in a 55 cm fish to about 1.0 $mg \cdot g^{-1}$ wet weight in a 90 cm fish. There is a fairly wide scatter of points around both regression lines.

Figure 1 shows that only loche has an average Hg concentration higher than the guideline for commercial sales (0.5 $\mu g \cdot g^{-1}$ wet weight). These concentrations were similar to those previously found in loche (burbot) in other parts of the Yukon, supporting the current recommendation that women of childbearing years and children under the age of 12 should only eat 1-2 meals of large loche (>24 inches) each week. This guideline can be found in the Yukon Fishing Regulations Summary, and states that other adults do not need to limit their intake of loche, and smaller loche (<24 inches) can be enjoyed by everyone.

Hg concentrations in inconnu from Old Crow were higher than previously found in other parts of the Yukon. The Chief Medical Officer of Health has recommended an interim guideline for inconnu from Old Crow, similar to that for loche: Women of childbearing years and children under the age of 12 should only eat 1-2 meals of inconnu each week. Other adults do not need to limit their intake of inconnu. This new recommendation has been communicated to the community of Old Crow as well as Chief and Council of the Vuntut Gwitch'in First Nation and other stakeholders.

As there is continuing concern regarding the effect of the nuclear accident in Fukushima on salmon being consumed in Old Crow, the salmon collected for this project will also be analysed for cesium-137, cesium-134 and iodone-131. Results from this additional work are expected in spring, 2016.

Expected Project Completion Date:

This project has been completed.

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References

Lockhart WL, Stern GA, Low G, Hendzel M, Boila G, Roach P, Evans MS, Billeck BN, DeLaronde J, Friesen S, Kidd, K, Atkins S, Muir DCG, Stoddart, M, Stephens, G, Stephenson S, Harbicht S, Snowshoe N, Grey B, Thompson S, DeGraff N. 2005. A history of total Hg in edible muscle of fish from lakes in northern Canada. Sci Tot Environ 351–352:427-463.

An East Hudson Bay Network research initiative on regional metal accumulation in the marine food web

Initiative de recherche du réseau de l'est de la baie d'Hudson sur l'accumulation de métaux dans le réseau trophique marin de la région

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Abstract

Communities in East Hudson Bay are concerned about ecosystem changes observed in recent decades, particularly related to sea-ice and oceanographic conditions. Additionally, communities are concerned about the potential impacts of contaminants from long-range atmospheric transport and regional human activities. A community-driven research network¾the East Hudson Bay Network (EHBN)¾has been established to measure and better understand large-scale cumulative environmental impacts in East Hudson Bay. Building on EHBN collaborations and activities in five communities (Sanikiluaq, Kuujjuaraapik, Inukjuak, Umiujaq, Chisasibi), this NCP project is generating new information on contaminants (specifically metals) that provide a regionally-integrated perspective on metal exposure in the

Résumé

Les collectivités de l'est de la baie d'Hudson s'inquiètent des changements de l'écosystème qu'ils ont constatés au cours des dernières décennies, particulièrement de ceux qui touchent les conditions de la glace de mer et océanographiques. En outre, les collectivités nourrissent des préoccupations au sujet des effets éventuels des contaminants provenant du transport atmosphérique à grande distance et des activités humaines régionales. Un réseau de recherche communautaire – le réseau de l'est de la baie d'Hudson (REBH) – a été établi afin de mesurer et de mieux comprendre les effets environnementaux cumulatifs à grande échelle dans l'est de la baie d'Hudson. En s'appuyant sur les collaborations du réseau et les activités réalisées dans cinq collectivités (Sanikiluaq, Kuujjuarapik, Inukjuak, Umiujaq

East Hudson Bay marine environment. The five communities are sampling coastal bioindicator species (blue mussel, common eider) annually for three years in order to understand and quantify metal accumulation levels in the coastal ecosystem. Offshore bioindicators (ringed seal, herring gull, plankton, fish) are additionally being collected from Kuujjuaraapik and Sanikiluaq. These locally-important bioindicators of metal accumulation will be used to characterize geographic and habitat-specific variation (coastal and offshore zones) in East Hudson Bay. Community-driven execution of biological collections as well as parallel ecosystem measurements on sea ice and water will allow for more integrated research in the context of environmental change.

et Chisasibi), ce projet du PLCN produit de nouvelles données importantes sur les contaminants (particulièrement les métaux) qui fournissent une perspective intégrée au plan régional sur la présence de métaux dans le milieu marin de l'est de la baie d'Hudson. Les cinq collectivités prélèvent des échantillons d'espèces bioindicatrices côtières (moule bleue, eider à duvet) chaque année depuis trois ans afin de comprendre et de quantifier les accumulations de métaux dans l'écosystème côtier. Des échantillons sont en outre prélevés sur des espèces bioindicatrices en mer (phoque annelé, goéland argenté, plancton, poisson) par les collectivités de Kuujjuarapik et Sanikiluaq. Ces bioindicateurs de l'accumulation de métaux, particulièrement importants à l'échelle locale, seront utilisés afin de caractériser les variations géographiques et les variations propres à un habitat particulier (dans les zones côtières et extracôtières) dans l'est de la baie d'Hudson. La collecte communautaire de données biologiques ainsi que les mesures écosystémiques effectuées parallèlement sur la glace de mer et l'eau permettront d'adopter une approche plus intégrée en matière de recherche dans le contexte de l'évolution de l'environnement.

Key messages

- In the first year of this project (2015), blue mussels, common eiders, ringed seals, and herring gull eggs were collected by community team members in East Hudson Bay
- Tissues were analyzed for levels of mercury and other metals (such as lead and cadmium)
- Information on the project and specific animal collections has been posted on a web-based platform called Interactive Knowledge Mapping Platform

Messages clés

- Au cours de la première année de ce projet (2015), des moules bleues, des eiders à duvet, des phoques annelés et des œufs de goéland argenté ont été recueillis par des membres de l'équipe communautaire dans l'est de la baie d'Hudson.
- Les tissus ont été analysés pour déterminer les concentrations de mercure et d'autres métaux (comme le plomb et le cadmium).
- De l'information sur le projet et des collections d'animaux a été publiée sur une plateforme Web nommée *Interactive Knowledge Mapping Platform* (carte interactive des connaissances) [en anglais seulement].

Objectives

The overarching objectives of this NCP project (2015-2018) are to:

- Establish meaningful participation in regional contaminants monitoring by community members in East Hudson Bay through local training and employment;
- Collect much needed baseline information on metal levels in the East Hudson Bay marine food web to allow for future tracking of impacts from environmental change, long-range atmospheric transport, and regional human activities; and
- Integrate information from environmental monitoring of metals among five communities (Sanikiluaq, Kuujjuaraapik, Umiujaq, Inukjuak, Chisasibi) to support regional environmental stewardship initiatives.

Introduction

Trace metals are a priority of the Northern Contaminants Program (NCP) due to their long-range transport to the Arctic from global anthropogenic sources and high levels found in some traditional foods. The Arctic is undergoing rapid environmental change that may impact the transport and cycling of these metals. In addition, long-range sources of metals are shifting as a result of emission regulations in Europe and North America, coupled with vast economic development in Asia. Long-term monitoring in the Canadian Arctic indicate that seabird metal levels have increased in recent decades (particularly for mercury, cadmium and zinc), including in northern Hudson Bay (NCP 2012; Mallory et al. 2014). The drivers and processes leading to these changes are not well understood and more information is needed on metals in the Arctic environment.

Locals from East Hudson Bay communities have observed ecosystem changes in recent decades including altered length and timing of seasons, the appearance of new animal species, and different sea ice movements (McDonald et al. 1997). Located in the Canadian sub-Arctic, East Hudson Bay is undergoing major environmental change as a result of climate warming that may impact the distribution and health of animals that live there (Ferguson et al. 2010; Peacock et al. 2010). Ice conditions in Hudson Bay have been changing over the last three to four decades, with an increase in the length of the ice-free season (Hochheim et al. 2010). There is also concern that massive winter-time discharges of fresh water into James Bay from the La Grande hydro-electric complex may be altering marine currents and sea ice conditions in Hudson Bay (e.g., Déry et al. 2011; Eastwood et al. 2014). The EHBN was developed out of efforts initiated in the early 2000s to conduct community-based monitoring of sea-ice and wildlife conditions from Sanikiluaq and the Belcher Islands, and to better understand the cumulative effects of hydro-electric developments and climate change in Hudson Bay.

There is surprisingly little information on metal bioaccumulation in food webs of Hudson Bay¾the world's largest northern inland sea¾despite its economic, cultural and subsistence importance for more than 20 communities that line its coasts. Mercury distribution in the Hudson Bay marine environment and especially sediments has been studied and developed into a preliminary budget describing the relative importance of various sources (Hare et al. 2008, 2010). Several bioindicator species, namely seabirds, ringed seal, beluga and polar bears are routinely monitored for metal levels at a few locations in Hudson Bay under the NCP (NCP 2012). Little information is available for metal levels near the base of the food web although notably there are two recent studies on mercury bioaccumulation, one on fish from northern Hudson Bay (Braune et al. 2014) and a second on zooplankton by Foster et al. (2012), with comprehensive spatial information for many sites on Hudson Bay in the latter. However, gaps remain in our understanding of the relative importance of various sources and other factors that may give rise to regional variation in mercury concentrations in the food web.

This project will directly support NCP's priority of community-generated contaminants science and will be tied to a broader research network on ecosystem change in East Hudson Bay. The collection of comprehensive baseline information on metal levels in the marine food web will allow for environmental stewardship initiatives including tracking future impacts from environmental change, long-range atmospheric transport, and regional human activities.

Activities in 2015-2016

A list of the indicator species, tissue types and sample sizes collected in 2015 from East Hudson Bay are provided in Table 1.

In June 2015, hunters from Sanikiluaq and Kuujjuaraapik conducted searches for herring gull colonies near their communities. A total of 10 herring gull eggs were collected from 2 islands near Sanikiluaq on June 26. The eggs were shipped to Ottawa and received for laboratory processing in good condition. No herring gull colonies were found on islands near Kuujjuaraapik though the search was hindered by poor conditions on the bay. An earlier technical report indicated that herring gull colonies were present in the early 1990s (Somer 1993) but their local distribution may have changed in the last two decades.

In the fall of 2015, the animal collections were initiated at the five communities. Blue mussels were collected from 5 sites (10 mussels per site) near each community except for Umiujaq where mussels were retrieved from only 1 site. Liver and muscle of eight common eiders were collected from each of the communities of Sanikiluaq, Kuujjuaraapik and Umiujaq. Hunters from Sanikiluaq and Kuujjuaraapik collected ringed seal near their communities. A total of 16 seal were captured (8 per community). Length and girth were measured on each seal, and muscle, liver, and blubber samples were collected. Tissue samples were shipped to the National Wildlife Research Centre in Ottawa for homogenization, freeze-drying and chemical analysis.

Communications: In December 2015, the Arctic Eider Society released a beta version of its Interactive Knowledge Mapping Platform (IK-MAP) for community-driven research, which can be viewed on-line (https://arcticeider.com/map/). This online tool provides near-real

Table 1. Tissue types, sample sizes, and locations of indicator species collected in 2015 in East Hudson Bay.

Indicator species	Tissue type	Total sample size	Communities (sample size)
Blue mussel (Mytilus edulis)	Whole body (no shell)	21	Chisasibi (5 pools) Kuujjuaraapik (5 pools) Sanikiluaq (5 pools) Umiujaq (1 pool) Inukjuak (5 pools)
Herring gull (Larus argentatus)	Egg	10	Sanikiluaq (10)
Common eider (Somateria mollissima)	Liver, muscle	24	Kuujjuaraapik (8) Sanikiluaq (8) Umiujaq (8)
Ringed seal (Pusa hispida)	Liver, muscle	16	Kuujjuaraapik (8) Sanikiluaq (8)

time results to communities in a user-friendly social media framework with data and meta-data available on interactive maps. This facilitates data management and information exchange among remote communities in East Hudson Bay, stakeholders and the public. It allows hunters in each community to see how their efforts are contributing to the larger research program in East Hudson Bay, engaging them in the process of research design and interpreting results using their own knowledge system. Each community member has a profile and each of their research contributions are cross-referenced on their profile, with their community, on profiles for each wildlife species, and on the map where all of the wildlife sampling conducted in 2015 is shown (Figure 1). This provides a compelling way to engage northerners in the project on an ongoing basis and see how their efforts are contributing to larger-scale research on cumulative impacts and environmental stewardship across the region.

Results and Discussion

Size measurements were made on ringed seal captured at Sanikiluaq and Kuujjuaraapik, which are summarized in Table 2. The ring seal were similar in length between communities but had a larger girth and blubber thickness at Kuujjuaraapik than at Sanikiluaq. This difference may be related to the timing of collection, since the animals were generally collected later in autumn at Kujjuaraapik than at Sanikiluaq, and autumn is an important period of blubber accumulation for ringed seal (Quakenbush et al. 2011).

Most chemical analyses of tissues were still in progress at the time of preparation of this report. Preliminary results were available for mercury and other element concentrations in herring gull eggs from Sanikiluaq (Figure 2) as well as mercury concentrations in muscle of common eider (Figure 3).

Figure 1. An example screen view of the on-line Interactive Knowledge Mapping Platform (IK-MAP) showing geographic locations of animal collections near Sanikiluaq (right side) and field notes for one of the blue mussel collections (left side).

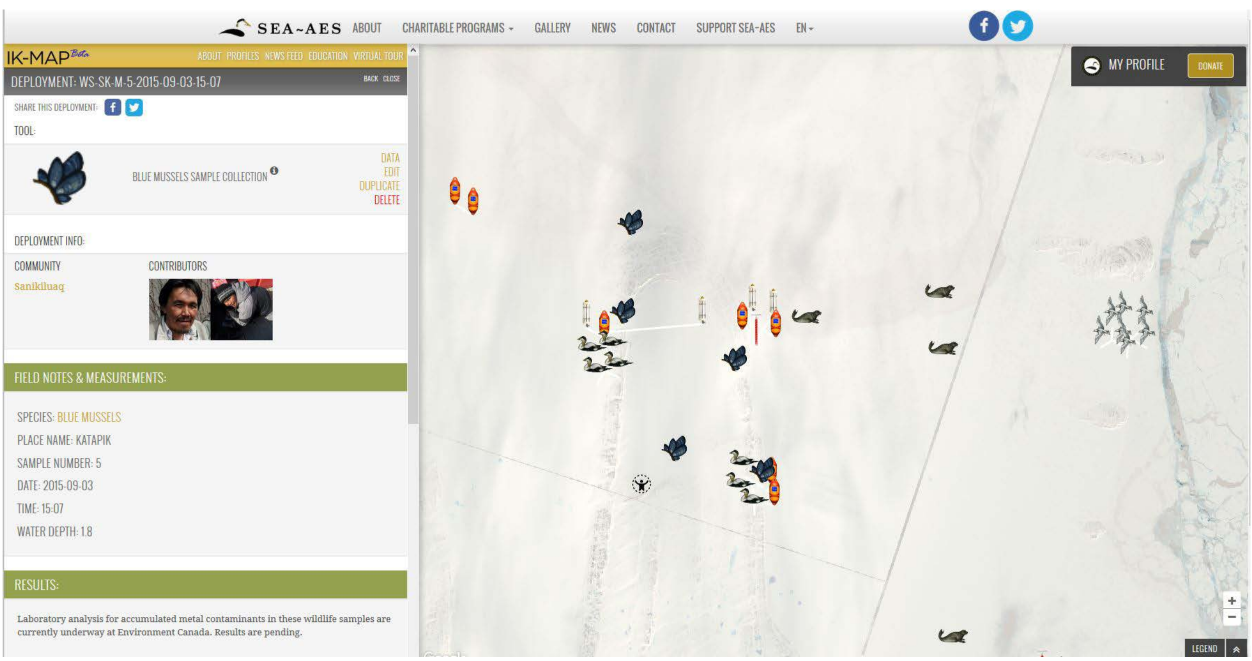


Table 2. Size measurements of ringed seal captured at Sanikiluaq and Kuujjuaraapik in autumn 2015.

Measurement	Kuujjuaraapik (n=8)		Sanikiluaq (n=7)[a]	
	Average	Range	Average	Range
Length (cm)	136	107-163	131	110-155
Axial girth (cm)	101	76-114	87	67-97
Maximum girth (cm)	106	81-123	90	69-102
Blubber thickness (cm)	6.0	4.4-7.0	4.2	3.2-5.1

[a] Note that 8 ringed seal were captured but measurements were not made on one of the seals.

Mercury concentrations in muscle of common eider were relatively low (<0.7 µg/g dry weight; <0.18 µg/g wet weight) although some variability was observed among individual birds and locations (Figure 2). Mercury concentrations were highest at Kuujjuaraapik and lowest at Umiujaq. Additional eiders collected in 2016 and 2017 will allow for a more detailed investigation of biological factors (e.g., sex, diet) that may be driving the differences among birds and locations.

The average mercury concentration of herring gull eggs collected near Sanikiluaq was 1.47 µg/g dry weight (± standard error = 0.18, n =10) (Figure 3). This average concentration is elevated relative to southern gull colonies on the Atlantic coast (Burgess et al. 2013) or inland in the Great Lakes (Weseloh et al. 2011) but similar to levels observed in colonies of the western sub-Arctic (Hebert et al. 2015). Levels of arsenic, copper and selenium are also presented in Figure 3, which are in the range of values reported elsewhere for herring gull eggs (Burger and Elbin 2015; Huber et al. 2015). Some metal such as cadmium, lead, nickel were below analytical detection limits in the eggs.

Figure 2. Box plots showing the distribution (median, 25th and 75th percentiles) of total mercury concentrations in muscle of common eider (n=8 per community) collected at Sanikiluaq, Kuujjuaraapik and Umiujaq in autumn 2015.

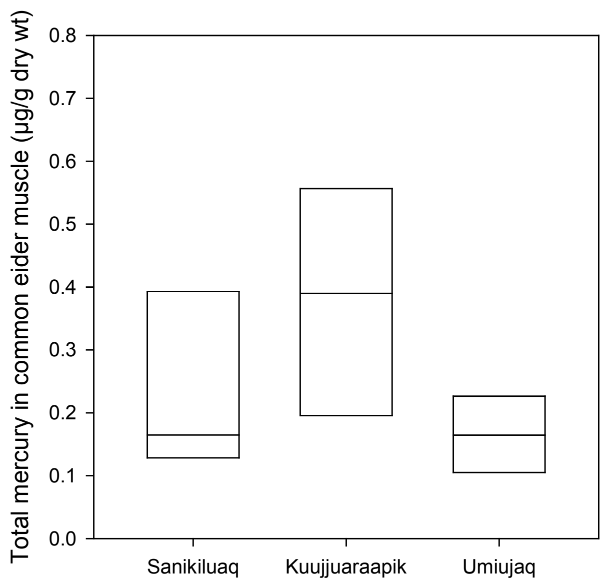
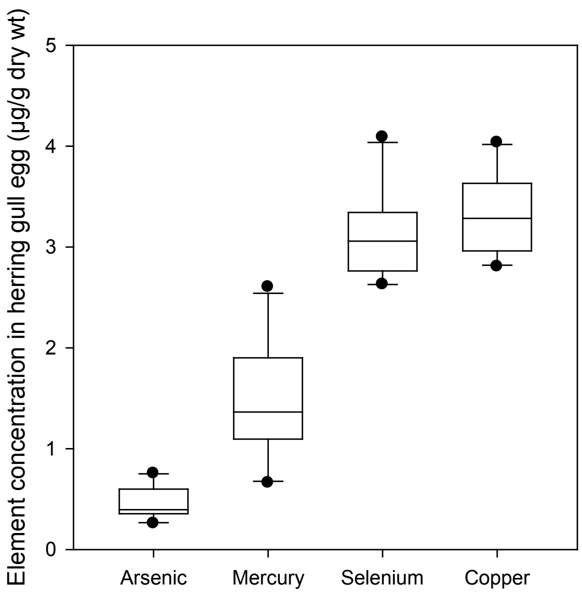


Figure 3. Box plots showing the distribution (median, 5th, 25th, 75th and 95th percentiles) of arsenic, mercury, selenium and copper concentrations in herring gull eggs (n=10) collected at Sanikiluaq in June 2015.



Conclusions

The first year of the project was completed successfully, with 16 individuals from 5 communities participating in the collection of tissues of 4 indicator species. In the second year of the project (2016), the collection of new species and repeat sampling of some indicator species will strengthen the characterization of metal levels in the marine food web of East Hudson Bay and will allow for a more detailed analysis of environmental controls on metal bioaccumulation. Further development of the online interactive mapping platform (IK-MAP) will enhance the communication of project activities among participating communities, stakeholders and the public.

Expected Project Completion Date:

The expected completion date is March 2018.

Project website (if applicable)

More information on the project can be found on the website of the Arctic Eider Society (https://arcticeider.com/map#).

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References

Burger, J., S. Elbin. 2015. Contaminant levels in Herring (*Larus argentatus*) and Great Black-backed Gull (*Larus marinus*) eggs from colonies in the New York harbor complex between 2012 and 2013. *Ecotoxicology* 24:445-452.

Burgess, N.M. et al. 2013. Mercury trends in herring gull (*Larus argentatus*) eggs from Atlantic Canada, 1972-2008: Temporal change or dietary shift? *Environ. Pollut.* 172:216-222.

Braune, B. et al. 2014. Organohalogen contaminants and total mercury in forage fish preyed upon by thick-billed murres in northern Hudson Bay. *Mar. Pollut. Bull.* 78:258-266.

Déry, S.J. et al. 2011. Interannual variability and interdecadal trends in Hudson Bay streamflow. J. Mar. Systems 88:341-351.

Eastwood, R.A. et al. 2014. First Observations of Oceanographic Conditions under the Landfast Sea Ice in Southeast Hudson Bay, Presentation, Arctic Change, Ottawa.

Ferguson, S.H. et al. 2010. The rise of killer whales as a major Arctic predator. *In*: Ferguson, S.H. et al. [Eds] A Little Less Arctic: Top Predators in the World's Largest Northern Inland Sea, Hudson Bay. Springer, p 117-136.

Foster, K.L. et al. 2012. Mercury biomagnification in marine zooplankton food webs in Hudson Bay. *Environ. Sci. Technol.* 46 :12952–12959.

Hare, A. et al. 2008. Contemporary and preindustrial mass budgets of mercury in the Hudson Bay Marine System: The role of sediment recycling. *Sci. Total Environ.* 406, 190-204.

Hare, A.A. et al. 2010. Natural and anthropogenic mercury distribution in marine sediments from Hudson Bay, Canada. *Environ. Sci. Technol.* 44, 5805-5811.

Hebert, C. et al. 2015. Spatial and temporal trends of mercury in colonial waterbird eggs. Poster presentation, NWT Wildlife Forum, Fort Smith, November.

Huber, S. et al. 2015. A broad cocktail of environmental pollutants found in eggs of three seabird species from remote colonies in Norway. *Environ. Toxicol. Chem.* 34:1296-1308.

Hochheim, K. et al. 2010. Changing sea ice conditions in Hudson Bay, 1980-2005. *In*: Ferguson, S.H. et al. [Eds] A Little Less Arctic: Top Predators in the World's Largest Northern Inland Sea, Hudson Bay. Springer, p 39-51.

Mallory, M.L. et al. 2014. Increasing cadmium and zinc levels in wild common eiders breeding along Canada's remote northern coastline. *Sci. Total Environ.* 476-477:73–78.

McDonald, M. et al. 1997. Voices from the Bay: Traditional Ecological Knowledge of Inuit and Cree in the Hudson Bay Bioregion. Canadian Arctic Resources Committee & Environmental Committee of Municipality of Sanikiluaq. 98pp.

NCP 2012. Canadian Arctic Contaminants Assessment Report III: Mercury in Canada's North. Northern Contaminants Program (NCP), Aboriginal Affairs and Northern Development Canada. pp. xxiii + 276.

Peacock, E. et al. 2010. Polar bear ecology and management in Hudson Bay in the face of climate change. *In*: Ferguson, S.H. et al. [Eds] A Little Less Arctic: Top Predators in the World's Largest Northern Inland Sea, Hudson Bay. Springer, p 93-115.

Quakenbush, L. et al. 2011. Biology of the ringed seal (Phoca hispida) in Alaska, 1960-2010. Final Report to the National Marine Fisheries Service. Alaska Department of Fish and Game, Fairbanks, Alaska.

Somer Inc. (1993). Complexe Grande-Baleine. Avant-projet Phase II. La contamination du milieu et des resources fauniques de la zone d'étude du complexe Grande-Baleine. Rapport présenté à Hydro-Québec, Vice-présidence Environnement. Montréal, Québec: p 105, plus annexes.

Weseloh, D.V.C. et al. 2011. Current concentrations and spatial and temporal trends in mercury in Great Lakes Herring Gull eggs, 1974-2009. *Ecotoxicology* 20:1644-1658.

Tracing the origin of mercury contamination in the lakes and fish of the Jean Marie River First Nation lands

Retracer l'origine de la contamination au mercure des lacs et des poissons de la région de la Première Nation de Jean Marie River

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Abstract

This project assesses the presence of mercury in degrading permafrost and its contribution to the contamination of the Jean Marie River First Nation (JMRFN) lakes and fish. Studies conducted on water and fish indicate a rising level of mercury contamination and the potential health impacts of this contamination are causing concern in community members and researchers alike. Permafrost peat bogs are known to naturally store mercury and it is important to know their impact on the contamination of the fish used to feed the community. Community members fish and practice traditional activities in the Five Lake Area, which is comprised of Ekali, Sanguez, Gargan, McGill and Deep Lake. This project focused on analysing total mercury (THg)

Résumé

Dans le cadre de ce projet, on évalue la présence de mercure dans le pergélisol qui se dégrade et sa contribution à la contamination des lacs et du poisson de la Première Nation de Jean Marie River (PNJMR). Des études qui ont été effectuées sur l'eau et le poisson indiquent que la contamination au mercure augmente et que ses éventuels effets sur la santé inquiètent les membres de la collectivité autant que les chercheurs. Les tourbières du pergélisol sont une source naturelle connue de mercure; il est donc important de connaître les répercussions qu'elles peuvent avoir sur la contamination des poissons utilisés pour nourrir la collectivité. Les membres de la collectivité pratiquent la pêche et des activités traditionnelles dans la Région des cinq lacs, qui englobe les lacs Ekali, Sanguez,

content in permafrost cores collected during previous permafrost studies in JMRFN from three different sites and newly collected permafrost cores from the McGill lake area. Total mercury measurements carried on permafrost cores show mercury concentrations ranging from 8.8 to 65.0ng.g-1, with the average for all cores analyzed being 20.5ng.g-1. These concentrations are consistent with results found in literature for organic soil deposited before the industrial age. Using total mercury measurements and the permafrost vulnerability map, the total mercury content of the two first meters of permafrost was roughly approximated to about 1350 kg for a 38km² north to Ekali Lake. Finally, a pathway between permafrost and the contaminated lakes using digital elevation models (DEM) in a geographical information system (GIS) is starting to be established This needs to be studied further to better understand the processes leading to the contamination. Identifying degrading permafrost as a source of mercury contamination brings a new understanding of the current state and functioning of the ecosystem. Future research would aim to fully quantify the mercury content of the permafrost in the study area. This requires a more extensive study with more permafrost sampling and mercury analysis. The results of the project will benefit neighbouring First Nation communities as well as other northern communities facing similar environmental challenges.

Gargan, McGill et Deep. Ce projet porte principalement sur l'analyse de la teneur totale en mercure de carottes de pergélisol prélevées lors de précédentes études du pergélisol à trois différents endroits de la PNJMR et de carottes de pergélisol nouvellement prélevées dans la région du lac McGill. Les mesures de la teneur totale en mercure effectuées sur les carottes de pergélisol indiquent des concentrations de mercure allant de 8,8 à 65,0 ng/g, la moyenne pour toutes les carottes analysées s'établissant à 20,5 ng/g. Ces concentrations sont conformes aux résultats figurant dans la documentation sur les sols organiques déposés avant l'ère industrielle. Au moyen des mesures de la teneur totale en mercure et de la carte de vulnérabilité du pergélisol, la teneur totale en mercure des deux premiers mètres du pergélisol a été estimée à environ 1 350 kg sur 38 km² au nord du lac Ekali. Enfin, une voie de cheminement entre le pergélisol et les lacs contaminés faisant appel à des modèles altimétriques numériques (MAN) dans un système d'information géographique (SIG) commence à être déterminée. Il faut l'étudier davantage afin de mieux comprendre le processus aboutissant à la contamination. La détermination que le pergélisol qui se dégrade est une source de la contamination au mercure apporte une nouvelle compréhension de l'état actuel et du fonctionnement de l'écosystème. De futurs travaux de recherche viseraient à quantifier intégralement la teneur en mercure du pergélisol dans la région faisant l'objet de l'étude. Ceci exige une étude plus vaste faisant appel à davantage d'échantillons de pergélisol et d'analyses du mercure. Les résultats du projet profiteront aux collectivités des Premières Nations avoisinantes et aux autres collectivités du Nord qui sont confrontées à des défis environnementaux semblables.

Key Messages

- Permafrost in the JMRFN traditional lands is contaminated with mercury
- Mercury content varies in function of the nature of frozen material
- The total mercury content of the two first meters of permafrost was roughly approximated to about 1350 kg
- Thawing permafrost around JMR can be considered as a potential source of mercury contamination for water and fish
- The drainage and flow direction of the terrain can create a pathway for the mercury down to the lakes

Messages clés

- Le pergélisol sur les terres ancestrales de la PNJMR est contaminé au mercure.
- La teneur en mercure varie en fonction de la nature de la matière gelée.
- La teneur totale en mercure des deux premiers mètres du pergélisol était estimée à environ 1 350 kg.
- Le pergélisol qui dégèle autour de JMR peut être considéré comme une source éventuelle de la contamination au mercure de l'eau et du poisson.
- Le drainage et le sens de l'écoulement du terrain peuvent créer une voie de cheminement vers les lacs pour le mercure.

Objectives

Short term objectives:

- Assess permafrost as a possible origin of mercury contamination;
- Measure mercury content in permafrost samples
- Use traditional land use data to assess the impact of permafrost thawing and potential mercury release on country food around McGill and Deep Lake.

Long term objectives:

- Establish a monitoring program of permafrost temperature and rate of degradation to assess the rate of permafrost-originating mercury release into the watershed.
- Develop a better understanding of the processes leading to mercury contamination in northern discontinuous permafrost Northern regions.

Introduction

Our community, Jean Marie River First Nation (JMRFN) is located in the Northwest Territories 127km east of Fort Simpson. Currently, two of our main concerns are the contamination of our food by heavy metals and the impacts of climate change on our country food supply. We have already taken measures to have a better understanding of the local impacts of these two concerns. Our community has actively participated in several studies concerning mercury levels and country food that were led by George Low from AAROM. We have also led several climate change studies including two studying the vulnerability of the land to permafrost thawing and its relation to country food supplies.

The major source of mercury exposure is through the consumption of locally derived food sources. When a contaminant enters the food chain, it is passed on from prey to predator, successively increasing in concentration. This process is known as bioaccumulation. Once it enters the food chain, mercury is bio-accumulated as methylmercury (Atwell et al., 1995), and results in our community's exposure to methylmercury primarily through the consumption of contaminated fish (World Health Organization, 1990). The studies of mercury contamination, conducted by AAROM and the Dehcho First Nation, revealed that the water and fish of a number of lakes in the close proximity of our community are contaminated to a point that it is a threat to human health (AAROM, 2013). A Health Advisory sign has been erected at Ekali Lake to inform people that northern pike and walleye should not be eaten more than two times a week for the general population, one time per month for children and two times per month for pregnant women. These lakes are used by our community members for fishing and are a very important source of food supply for the entire community. With these results, we know that our concerns regarding the quality of the fish are real. There is a real need for us to understand what the source of the mercury contamination is and to locate non contaminated lake where it will be safe for us to go fishing.

The permafrost studies led by our community from 2012 to 2014, show that the permafrost present on our land is warm and vulnerable to degradation. Several areas are already experiencing severe degradation processes (JRMFN, 2014). With the ground temperature being close to 0°C, it is possible that the degradation process will be completed in only a few decades. When permafrost thaws, a lot of water is released in the environment which reaches the lakes and rivers surrounding the permafrost areas. Our most recent vulnerability map shows that 50% of the land around JMRFN is vulnerable to permafrost thawing including a large area very rich in peat located on the north shore of Ekali Lake. This leads us to question whether the mercury contamination of Ekali Lake and other lakes could, at least partially, come from the thawing peat. Indeed, several scientific studies suggest that the degradation of a certain type of organic-rich permafrost is a source of mercury contamination (Leitch, 2006; Rydberg et al 2010).

Providing country food to our people is one of our strongest traditional values. We have already noticed a change in the quality of the fish and have stopped fishing is some lakes and from the Mackenzie River. Concerns are rising about the potential presence of contaminants. It is essential for us to know where to access to healthy fish supply, as for us it is less culturally acceptable to get our fish from the market food supply than from our homelands. Therefore, we need to assess how permafrost degradation will impact the acceptability and appropriateness of the country food for our community.

Activities in 2015-2016

1. Community meeting

The community meeting took place on August 10th 2015. It was coordinated by Margaret Ireland and facilitated by Cyrielle Laurent.

The first part was to present the project background, objectives, activities and methodology. Community meetings are very important for us. This is the ideal opportunity for community members to learn about the project and to meet the researchers who work with us. At this time, we presented the project and explained its benefits for our community, our way of life, how it addresses our concerns and in this case how it relates to other projects. In particular, we discussed the mercury contamination in the lakes and fish, our concern toward health and traditional activities and the partners explained the link between the contamination and permafrost and the importance of tracing the origin of this contamination.

The second part, was the presentation of the field work (originally planned as a working group meeting). The partners shared their observations from the field, showed us pictures and preliminary results, and we reviewed the next steps of the project. Finally, we discussed our concerns regarding country food for today and for the future as well as projects to implement in the next years.

2. Communication

It is essential for us to share our work with other Dehcho communities. Our objective was to held a community conference in JMRFN where all Dehcho communities could present their project related to climate change and mercury contamination. Our budget would not allow us to bring our partners back to JMRFN a second time, therefore we tried to held this event in the summer. Unfortunately, summer is a busy time for all communities we could not find a time to get a majority of community representatives together. Instead, we created web presentations[1] and invited all Dehcho communities to watch. This allowed us to at least share our project and its results which can greatly benefit other communities.

In terms of media coverage, two web articles were published related to our project2. CBC Yellowknife came to JMRFN to interview community members, conducted interviews with our partners and collaborator.

Our partners were present at the NCP workshop held in Vancouver in December 2015, were they presented a poster (poster available on the Yukon College website3). They also attended the ArcticNet conference and took the opportunity to discuss the project informally with other researcher. We will continue to present our project in meetings and conferences as the opportunities arise.

3. Traditional Knowledge integration

Our community always aims to use traditional knowledge at several stages of the project we conduct and to involve our Elders as much as possible. For this project, Elders provided us with guidance in the early stage of the project as they are always consulted before deciding to conduct such work.

They were also involved in the preparation of field work to advise the selection of field sites. Our elders know the land very well and they are the best qualified to indicate eventual difficulties of travel in certain areas and showing which areas to avoid.

Our traditional land use database was also used to analyze the fishing sites potentially threatened by mercury contamination. It is very important for us to use traditional knowledge all along the project as well as scientific knowledge.

4. Field work and capacity building

The partners coordinated with several community members to organize the logistic of the field work. As per recommendation of NCP and available funding only one site was to be sampled for permafrost core at Deep or McGill lake. Both lakes are very remote and can be access only by boat or helicopter in the summer. With their knowledge of the land, community members had established that the water level was too low to travel by boat. Therefore, JMRFN provided helicopter travel as an in-kind contribution to the project to bring the field team to McGill lake. McGill lake was chosen over Deep lake because of its higher density of traditional activities and its closer location.

Other locations to visit were the three permafrost stations previously installed between 2012 and 2014. Station 1 is located close to the road and is accessible by foot. Station 2 is also a remote location, we decided to make a stop with the helicopter on our way to McGill lake, and station 3 across Ekali lake was accessed by boat.

The community was actively involved during the geological survey that occurred from August 4th to 9th, 2016 (see Figure 2.1). Richard Sanguez helped to guide our partners in the field and ensured field safety from wildlife. He assisted with the geological fieldwork such as permafrost drilling and coring. Hiring field assistants from the community is a very good way

1 http://www.geocardinal.ca/Links.html

2 http://www.cbc.ca/news/canada/north/thawing-permafrost-threatens-food-security-in-jean-marie-river-n-w-t-1.3234198

http://www.cbc.ca/news/canada/north/permafrost-study-could-help-forecast-mercury-levels-in-dehcho-lakes-1.3182276

3 https://www.yukoncollege.yk.ca/research/publications/tracing_the_origin_of_mercury_contamination_in_the_lakes_and_fish_of_jmr_fi

for building capacity and ensuring exchange of knowledge between researchers and community. Field assistant provide insight and knowledge of the land as well as traditional stories while researchers share their scientific view and knowledge of the environment they work in.

Figure 1: Richard Sanguez and Louis-Phillipe Roy drilling permafrost at station 4, McGill Lake

A light and portable GÖLZ Earth-drill system was used to drill shallow boreholes. Boreholes were initiated by shoveling a fore hole down to the thaw front. At the thaw front, the Earth-drill system drill was used. The drill was mounted on a small Stihl engine with a high-speed transmission (600 rpm).

The site was first described (e.g., hydrology, vegetation type and density, topography), photos were taken, and locations were recorded using a hand-held GPS. Each core sample was photographed and described in situ (e.g., soil type, soil moisture, presence or absence of organic matter, any notable features). Each sample extracted from a borehole was identified by borehole name and depth. Samples were put in polybags and sealed immediately after being extracted. Samples were kept frozen and stored in a freezer that was taken back to the laboratory for further analyses. At the laboratory, each core was cleaned with cold water to remove drilling mud and then photographed.

After the borehole was drilled, PVC tubes were inserted in the ground with four temperature sensors placed at 0.5, 1.5, 3.0, and 3.79 m. These sensors record the temperature every 2 hours, i.e. 12 times per day. Once installed, temperature can be downloaded using a HOBO (U12-008) four-channel external data logger or directly on a laptop. Temperature data was downloaded at Station 4 as well as the 3 other stations installed in 2013.

5. Permafrost grain size and ice content analysis

Laboratory analyses were carried out to measure the properties of the permafrost samples. Both soil grain characteristics and ice characteristics were evaluated. To evaluate soil grain characteristics, a grain-size analysis was performed on selected samples. To evaluate ice characteristics in permafrost samples, the cryostructure, volumetric ice content and gravimetric ice content were quantified.

These methods are described below. For more information, please refer to Andersland and Ladanyi 2004.

Grain-size analysis

Sieve and hydrometer analyses of grain size were performed following a specifically modified American Standard and Testing Method protocol (ASTM D422-63, 2000). The sieves used were 4, 2, 1, 0.5, 0.25, 0.125 and 0.063 mm.

Cryostructure

Permafrost cryostructure (the geometry of the ice in the permafrost) depends on water availability, the soil's ice-segregation potential, and the time of freezing, all of which affect the development of ice structures in the soil matrix. Information such as soil genesis, climate conditions at the time of freezing, permafrost development history, and ground vulnerability when permafrost degrades can be interpreted from cryostructure (the shape of the ground ice), cryofacies (groups of cryostructures) analysis, and general cryostratigraphy (assemblages of cryofacies).

Because field descriptions are based only on a visual interpretation of the core, the samples were described a second time more thoroughly in the laboratory using standard terminology (Murton and French 1994). Frozen core samples were warmed to near 0°C and any refrozen mud was scraped off before the sample was described.

Gravimetric ice content

Ice content was calculated using:

$$u1= \frac{(M_i)}{(M_s)}$$

where M_i is the ice weight, measured as weight loss after drying (g), and M_s is dry soil weight in grams. Results are expressed as percentages (dimensionless).

Volumetric ice content

The volumetric ice content was calculated by immersing the frozen sample, bagged in vacuum- sealed polybags, in a recipient to measure its volume (Vtot). The sample was then thawed and put in the oven to dry. The remaining dry material was immersed again to determinate its volume (Vsed). The volume of excess content was calculated using:

$$Vtot - Vsed = Vice$$

The volumetric ice content is expressed as percentages (fundamentally meaning cm^3/cm^3).

Borehole logs

A borehole log was created by assembling laboratory photos of the cores. Borehole logs include maximal depths, grain size ratio and volumetric ice content.

6. Permafrost mercury analysis

Nineteen permafrost cores were used for the mercury analysis from four different locations; station 1, Tthoogée Tué, Ekali Lake, and McGill Lake. Three of these locations were sampled in 2013 for other permafrost study. The cores were preserved in a freezer. With the current project one more location was sampled at McGill Lake. The permafrost cores were subsampled at different depth and five subsamples per station (except for Tthoogée Tué, only 4 subsamples were analyzed) were analyzed for their concentration in total mercury (THg).

The subsamples were sent at BIOTRON laboratory at Western University and the mercury analysis were conducted by Dr. Heidi Swanson. Freeze-dried, homogenized sediment and peat samples were analyzed for total Hg on a Milestone® DMA-80 Direct Mercury Analyzer using methods described in EPA method 7473 (U.S.EPA, 2007). The calibration detection limit was 1 $ng.g^{-1}$. Every 10 samples, duplicate samples were analyzed (% deviation: 3.7 and 13.6, n=2). A certified reference material (CRM; MESS-3 (0.091 ± 0.009 mg/kg Hg) was analyzed at the start and end of the run (mean recovery: 93.0 ± 0.06, n=3). Blanks were analyzed at the start, end, and every 10 samples (mean: 0.08 ± 0.03 ng, n=4).

Results

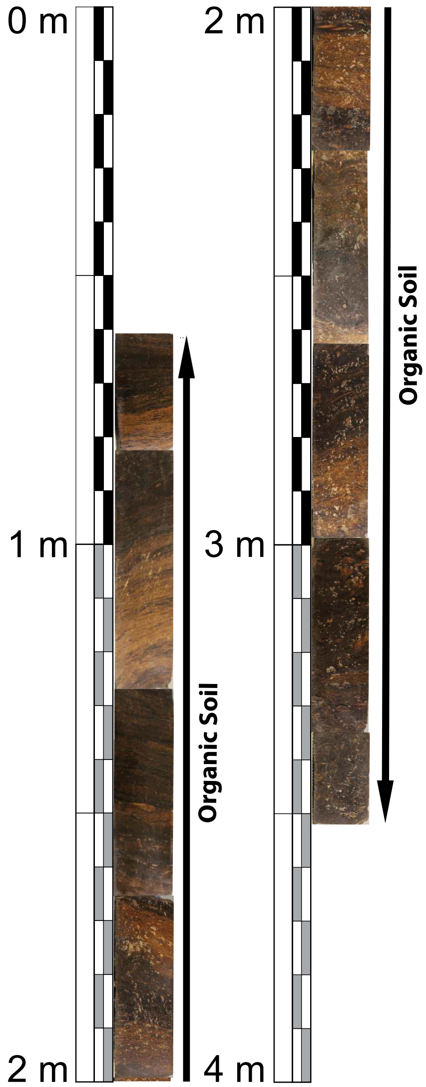
7. Permafrost coring

Station 4 was drilled on a permafrost mound in a peatland 900m from McGill lake. The thawing front occurs at a depth of 56 cm. The coring showed that the permafrost consisted of ice-rich frozen peat from the top to the base of the borehole (3.51m), see table 1 and figure 2. The top of the water table was also reached at that depth, preventing further coring. The frozen peat appeared to be very ice-rich, and saturated with water. Both microlenticular and lenticular cryostructures where observed. The excess ice content, i.e. the volume of ice in the ground which exceeds the total pore volume that the ground would have under natural unfrozen conditions, seems to range from 37 to 62%. The organic content was very high, ranging from 93 to 100%.

Table 1: Permafrost geotechnical analysis

Site	Depth (cm)	Soil stratigraphy	Excess Ice Volume Content (%)	Moisture Content (%)	Organic Content (%)	THg (ng/g)
Station 1	50-163 cm	Organic peat	34	86	86	22.19
	163-338 cm	Sandy (62%) Clay (12%)	17	33	*	37.55
Station 2	55-98 cm	Organic peat	37	93	94	18.74
	98-283 cm	Sandy (86%) Clay (13%)	46	53	*	11.16
	283-608 cm	Clayey (49%) Sand (45%)	43	49	*	65
Station 3	43-247 cm	Organic peat	34	92	98	14.1
Station 4	56-351 cm	Organic peat	50	94	98	13.97

Figure 2: Station 4 borehole log



8. Permafrost temperature monitoring

Ground temperature curves and Mean Annual Ground temperature profiles, like figures 3, 4, and 5, were created for all four stations. These graphs show the relationship between ground depth and soil temperature and create a baseline comparison over time. The temperature records suggest that permafrost at every station is very warm, and remains close to 0°C throughout the year. The data gathered also shows a significant amount of liquid water in the soil witch can explain the delay at which the ground freezes at the beginning of the winter due to latent heat contain by the liquid water. This phenomenon can also be responsible to prevent the permafrost from cooling off. Temperature graphs for all stations are available on demand.

Figure 3: Ground temperature curves from September 2013 to August 2015 with the monthly average ground temperature for station 3.

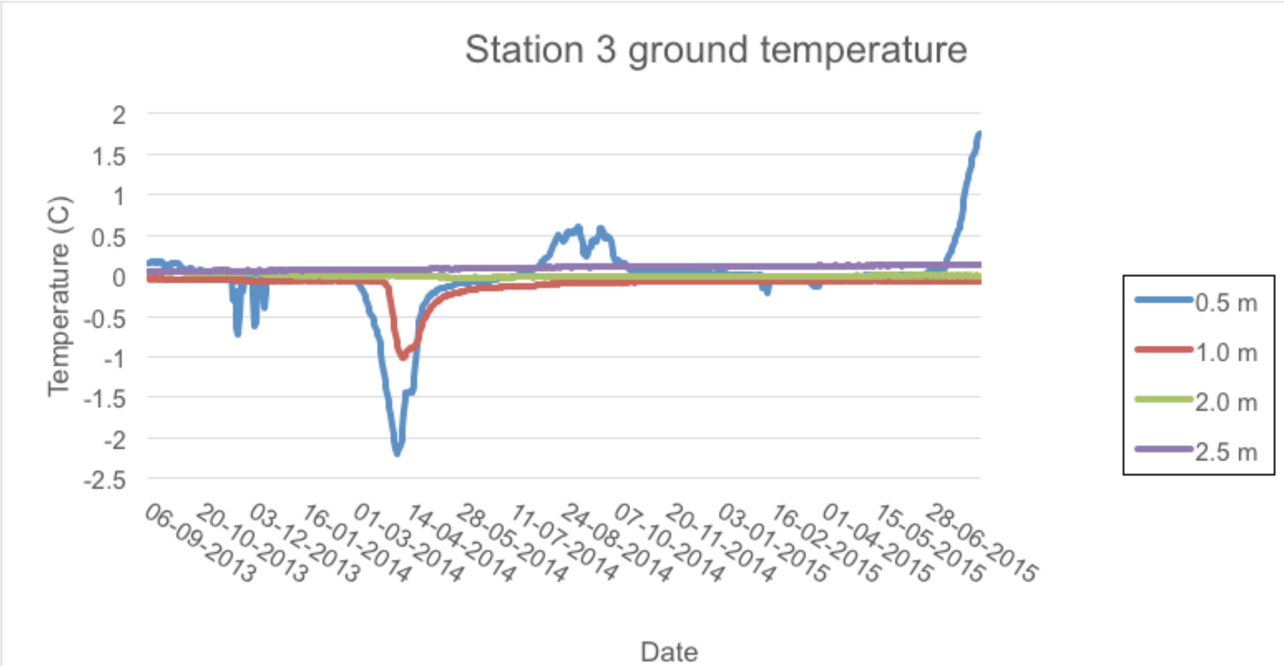


Figure 4: Station 3 Mean Annual Ground temperature profile for year 2014 and 2015.

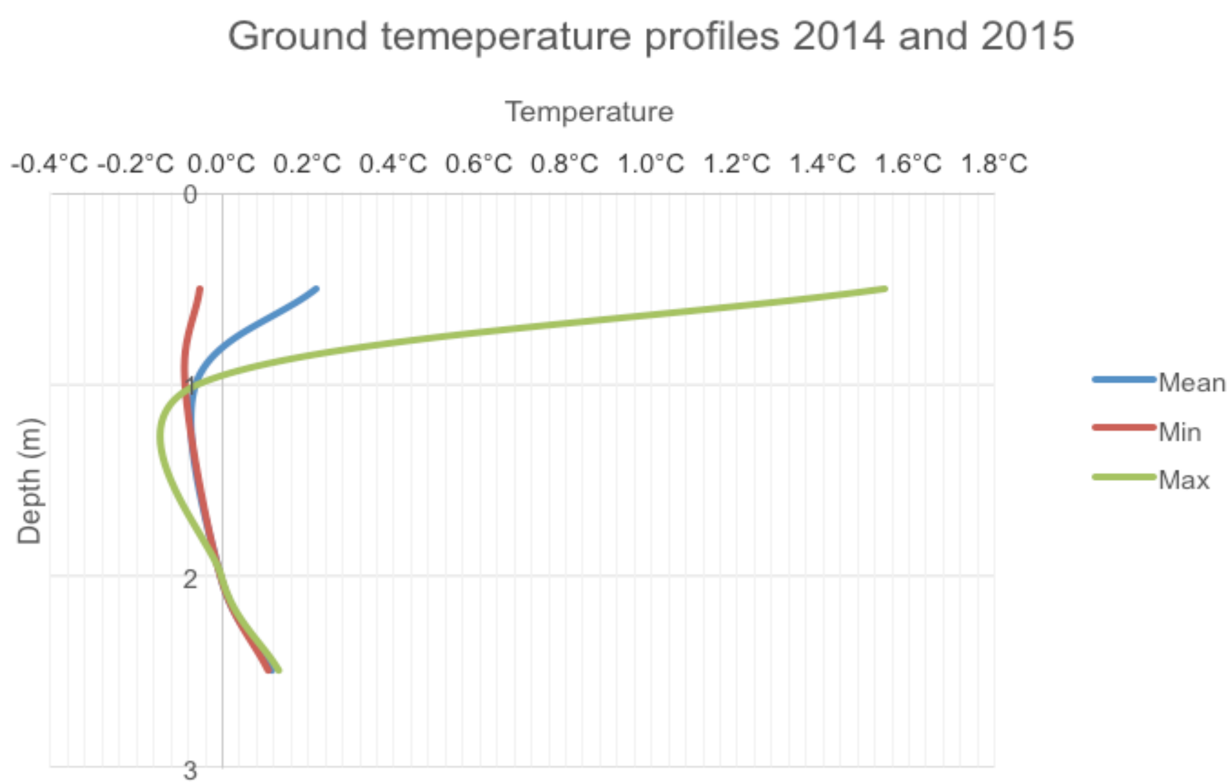
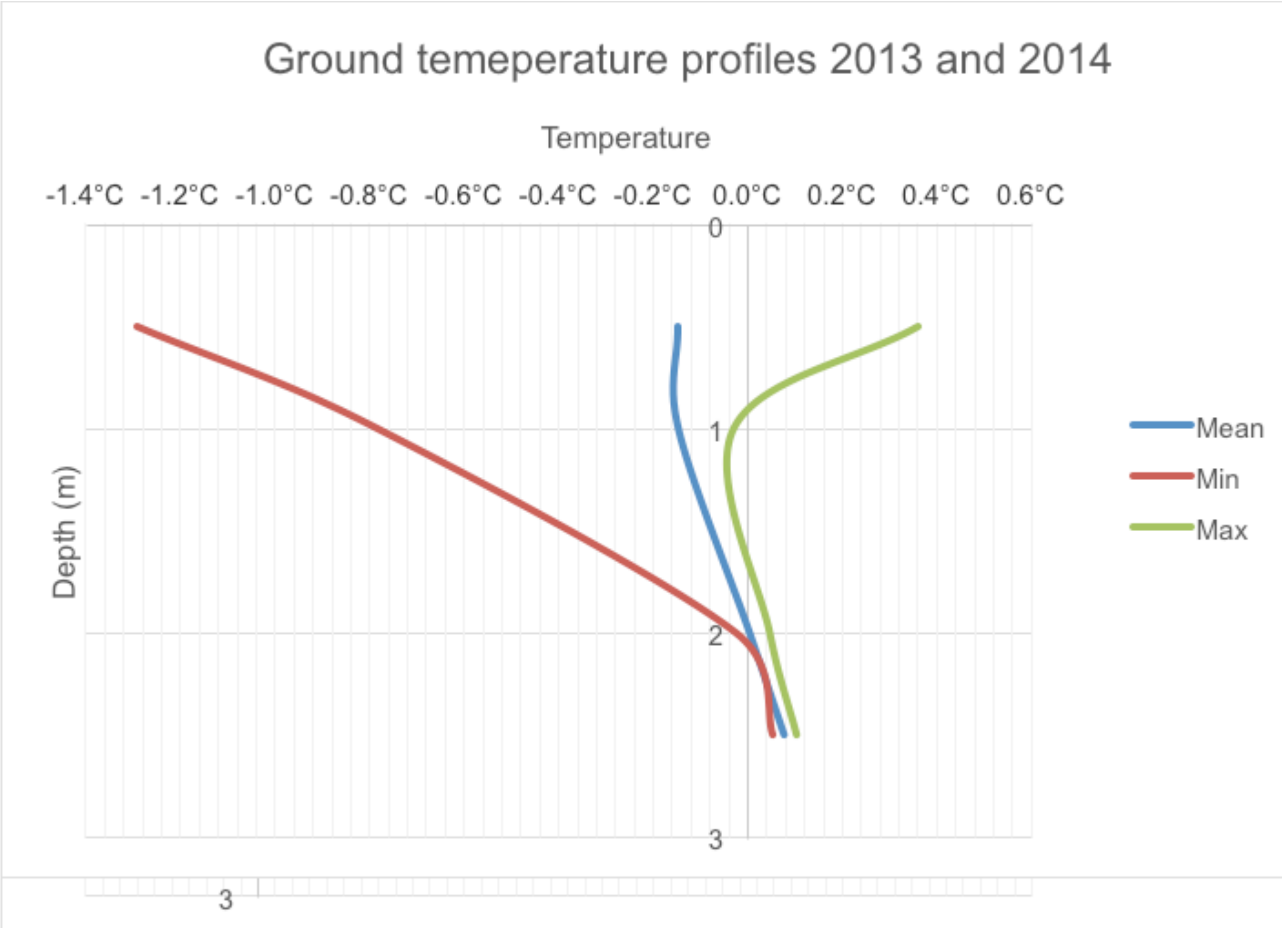


Figure 5: Station3 Mean Annual Ground temperature profile for year 2013 and 2014.



9. Mercury analysis on permafrost

The results of the laboratory analysis confirm that permafrost contain levels of mercury ranging between 8.81 and 65ng.g^{-1}. According to Dr. Brian Branfireun, head of the BIOTRON laboratory at Western University, these levels of THg are consistent with those found in similar environments in Canada. Figure 6 shows the THg concentration per subsample and represents the values graphically. The highest concentration of mercury resides at Ttooghé Tué at a depth of 4m and station 1 has the highest average THg.

Total mercury concentration in fish for Ekali Lake and McGill Lake were also made available by Heidi Swanson, collaborator on this project. We found a positive relationship between the mercury contamination in the water and the permafrost (see table 2). Indeed, the THg in both water and permafrost is higher at McGill lake than Ekali lake. This gives us a first indication that the contamination could originate at least partially from the permafrost.

Figure 6: Mercury concentration in permafrost at four locations in the JMRFN traditional lands

Sample	Depth (cm)	Location	THg ($ng.g^{-1}$)
S1-50-1	50	Station 1	38.26
S1-100-2	100	Station 1	26.21
S1-150-3	150	Station 1	22.19
S1-250-4	250	Station 1	37.55
S1-350-5	350	Station 1	20.37
S2-56-1	56	Ttooghée	10.59
S2-100-2	100	Ttooghée	18.74
S2-150-3	150	Ttooghée	11.16
S2-400-4	400	Ttooghée	65.00
S3-40-1	40	Ekali	15.23
S3-100-2	100	Ekali	23.17
S3-150-3	150	Ekali	8.81
S3-200-4	200	Ekali	10.19
S3-236-5	236	Ekali	13.01
S4-56-1	56	McGill	12.80
S4-100-2	100	McGill	10.41
S4-150-3	150	McGill	18.57
S4-250-4	250	McGill	14.61
S4-350-5	350	McGill	13.47

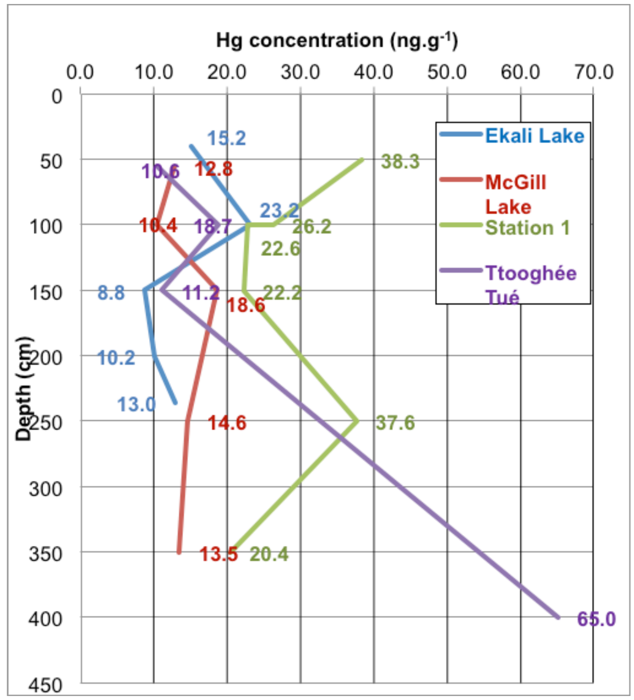
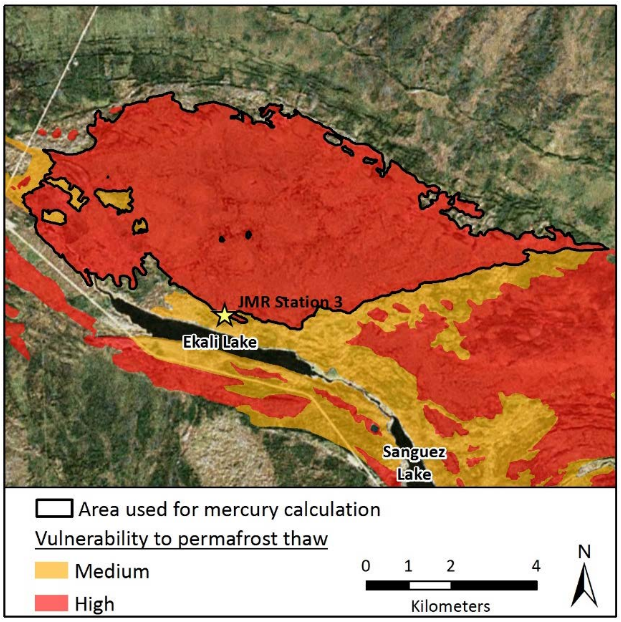


Table 2: Average concentration of mercury in permafrost and water for Ekali lake and McGill Lake.

	Permafrost THg ($ng.g^{-1}$)	Water THg ($ng.L^{-1}$)
Ekali Lake	14.08	0.448
McGill Lake	13.97	0.386

We were able to extrapolate the concentration of mercury contained in the permafrost sample to a volume of soil using the permafrost vulnerability map produced in the previous years. For this we chose a large and highly vulnerable area north to Ekali Lake, see figure 6. The THg concentration at a depth of 73cm at station 3 (Ekali Lake) is 0.0148g/m³. The red area delineated in black on figure 7 represents 38,000,000m³ of peat for the first top meter of permafrost, which multiplied by the THg concentration gives a content of 562.5kg of mercury. The same calculation at a depth of 141cm would represent 789.5kg of mercury. With permafrost thawing all this mercury can potentially reach the lake and keep contributing to the water and fish contamination. To have a better estimation of the quantity of mercury currently trapped in permafrost we would require more Hg analysis at several other sites and more data indicating the depth of permafrost. It would be very valuable to apply the same analysis to the McGill Lake area which would require to develop the permafrost vulnerability map.

Figure 7: Permafrost vulnerability around Ekali Lake



10. Flow direction analysis

A mapping analysis was also conducted with ArcGIS based on digital elevation models that show orientation of the relief and the flow direction. For both Ekali and McGill Lake, the flow direction from the permafrost sampling sites lead towards the lake, therefore the general drainage of these areas is directed at the lake and that any contaminated water released by permafrost thawing should flow toward the lake. The flow direction between Station 3 and Ekali lake follows a East-South-East and then a South direction, figure 8. The flow direction between Station 4 and McGill lake follows a North-West direction, figure 9. This is a good indication that the mercury contamination in the water can originate at least partially from the permafrost.

Figure 8: Relief and flow direction between station 3 and Ekali Lake

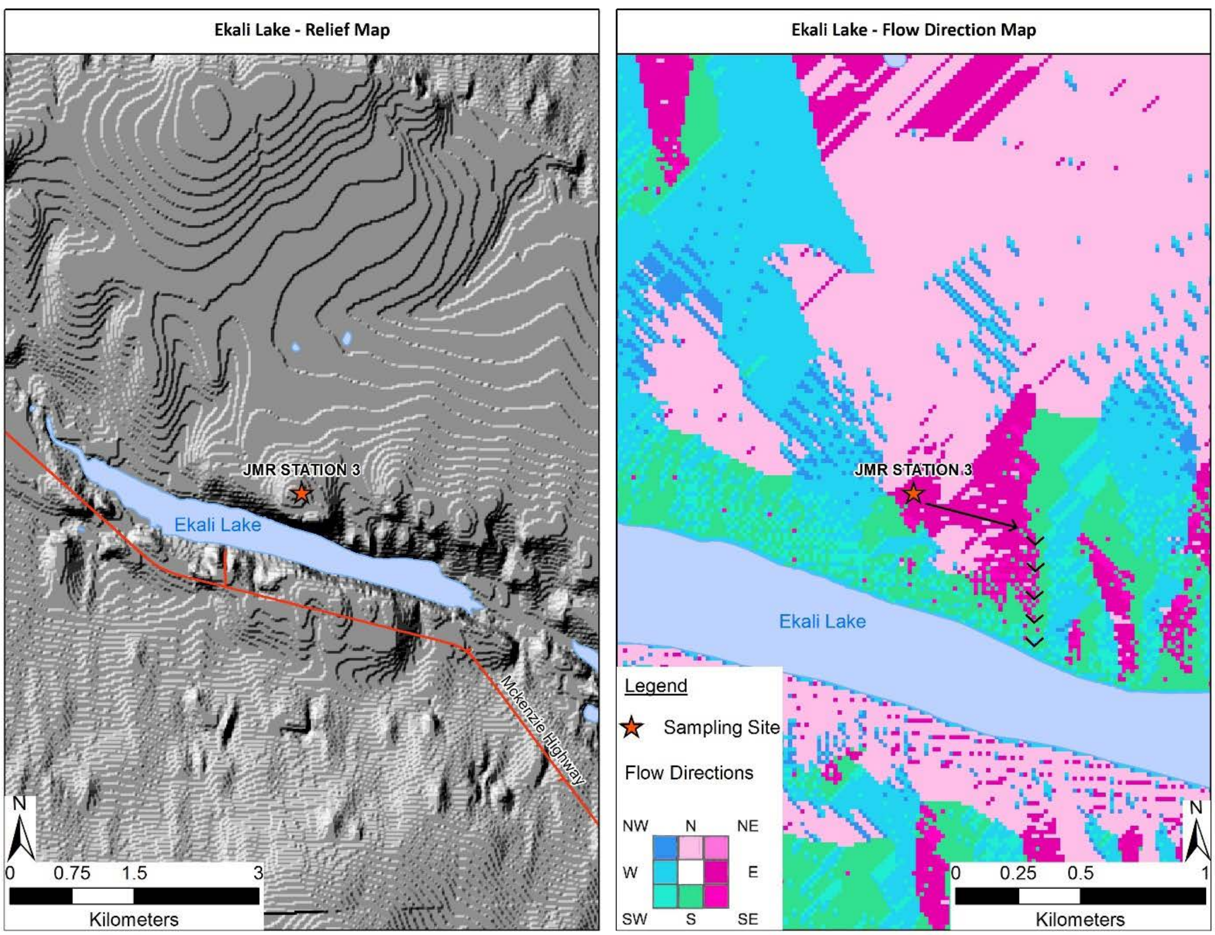


Figure 9: Relief and flow direction between station 4 and McGill Lake

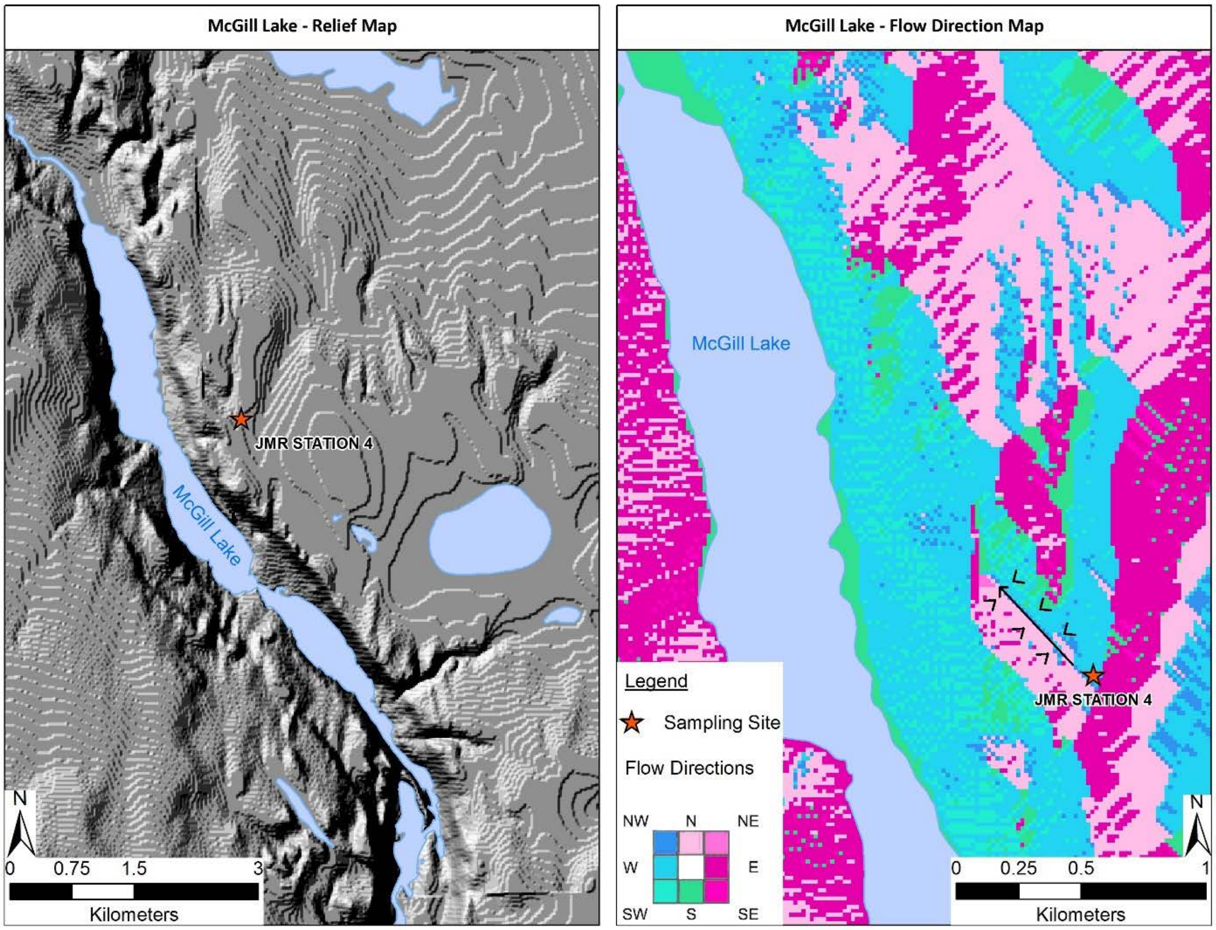
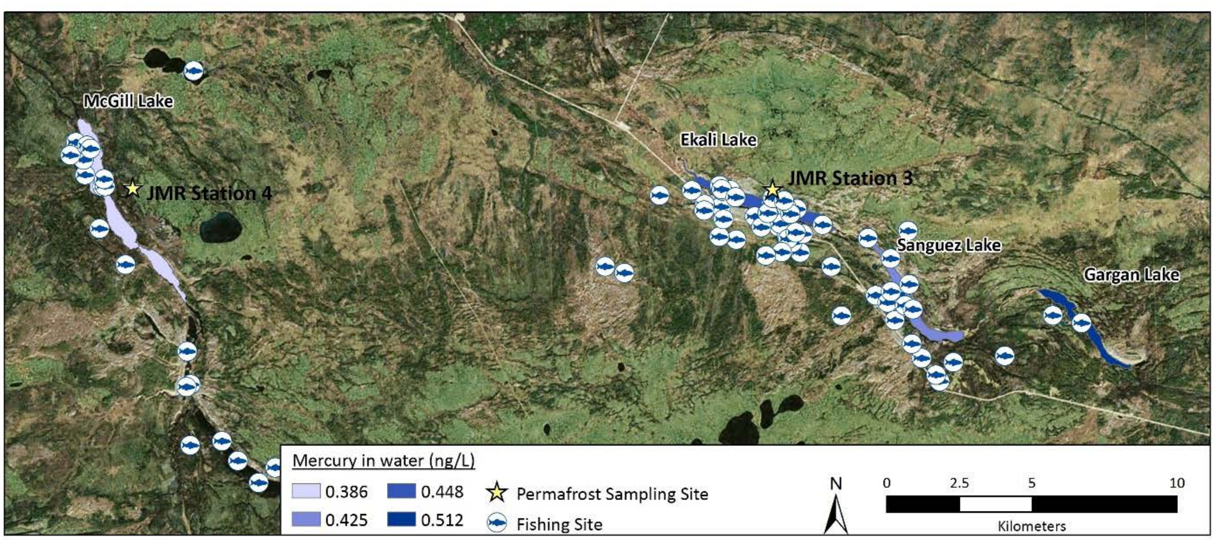


Figure 10: Fishing sites and mercury contamination in water



11. Mercury contamination and Traditional Land Use

Many of our community members practice traditional activities and are very active on the land. Concerns regarding food security have been growing in our community as we have seen the quality of fur and meat of the animals we hunt as well as the quality of the flesh of the fish degrading. We know that mercury levels in the fish and water have been increasing and we have legitimate reasons to be concerned about eating these fish. Figure 10 shows that the five lakes (Ekali, Sanguez, Gargan, McGill, and Deep Lake) are heavily used for fishing activities and all of them are contaminated by mercury. These are the closest and most accessible lakes for your community members to go fishing and it is extremely important for us to keep studying the origin of this contamination.

Discussion and conclusions

The permafrost assessment shows that the frozen peatland located near the contaminated lake are susceptible to degrade. Ground temperatures only are one or few tenths of degree below 0°C. Permafrost is ice-rich and its thaw will translate in major settlements, giving place to water bodies. The material released during degradation processes will be either peat, organic sediment, or lacustrine clay.

Total mercury measurements carried on permafrost cores show mercury concentration ranging from 8.8 to 65.0ng.g^{-1}; the average for all analysed core being 20.5 ng.g-1. These concentrations are consistent with results found in literature for organic soil deposited before industrial age (Klaminder et al, 2008). The maximum concentration was measured in the lacustrine clay at Ttooghée Tué, were permafrost is the thickest and mainly consist of lacustrine clay. The origin of mercury is likely atmospheric in the organic sediment and peat; while its origin in clay remains unclear without further analyses. It might be the result of diffusion from the bedrock, or attributable to bioaccumulation occurring at the bottom of the lake at the time of sediment deposition.

Using total mercury measurements and the permafrost mapping, the total mercury content of the two first meters of permafrost was roughly approximated to about 1350 kg. This approximation is partial as it only concerns permafrost first two meters. It is important to note that no active layer sample were analysed, but literature shows that this upper layer of the peatland is likely to be more contaminated, tenfold or more, because vegetation developed during industrial age when significant amount or mercury were rejected in the atmosphere. Consequently, this first 50 cm layer may bear more mercury content than several meters of underlying permafrost.

This study proves that mercury is present in the permafrost of the Jean Marie River First Nation territory. This mercury content varies in function of the nature of frozen material. Because of the nature of permafrost degradation, consisting of collapsing and erosion, mercury is likely to be mobilized following permafrost thaw. A first assessment of Ekali Lake area shows that once freed, the drainage and flow direction can create a pathway for the mercury down to the lake. The same conclusion can be reached for McGill Lake.

The present study provides precious insights about the processes that may have led to lake and fish mercury contamination in JMRFN territory. While it confirms permafrost as a potential contributor to the contamination, several unknown factors remain. More analyses are required to fully quantify mercury content of the permafrost in the study area, notably from the active layer. Also, the pathway between permafrost and lakes have to be studied to understand the processes leading to the contamination. Acquiring these new understandings will help our community to address the issue of mercury contamination in our lakes. Our community members who are still very active on the land, fishing, hunting, and gathering plants and animals are eager to keep studying the origin of the mercury contamination in our environment. Understanding the natural processes will help us adapt our ways of life and build a stronger, safer future for the generations to come.

Expected Project Completion Date

The current project was a one-year project and ended on March 31, 2016. However, our community wish to see this work prolonged in the future. More of our lakes are contaminated with mercury and we would like to keep studying the mercury contamination in permafrost and better quantify the amount of mercury trapped in the frozen peat.

Project website

Our partners, Geo Cardinal and Yukon College graciously provides information about this project and our permafrost mapping projects on their web site.

http://www.geocardinal.ca/Links.html

https://www.yukoncollege.yk.ca/research/publications/tracing_the_origin_of_mercury_contamination_in_the_lakes_and_fish_of_jmr_fi

Acknowledgments

The JMRFN project team would like to thank the JMRFN leadership council and community members for actively participating in this project and being so supportive in the project activities.

We also want to thank our partners, Geo Cardinal and the Yukon Research Center (Yukon College), who invested so much time and effort in this project and provided in-kind contributions. They offer the scientific and technical expertise we need. This kind of project could not be completed without their participation.

Thank you to our collaborators, Heidi Swanson and George Low who provided assistance for the mercury analyses and who shared data of their own project with us.

Finally, we sincerely thank NCP for funding this project.

References

AAROM, 2013. Mercury Levels in Food Fish Species in Lakes used by Dehcho Community Members with a focus on Choice and Risk Perception of eating Traditional Country Food. Northern Contaminant Program. 11p.

Atwell, L., Hobson, K.A., & Welch, H.E. 1995. Biomagnification and bioaccumulation of mercury in an Arctic marine food web: Insights from stable nitrogen analysis. Canadian Journal of Fisheries and Aquatic Science, 55, 1114-1121.

Jean Marie River First Nation, Calmels, F., Watertight Solutions, 2014. Food Security Vulnerability Assessment Related to Permafrost Degradation in the Jean Marie River First Nation. 90p

Klaminder and al. 2008. An explorative study of mercury export from thawing palsa mire. Journal of geophysical research, vol.113.

Leitch D.R., 2006. Mercury distribution in water and permafrost of the lower Mackenzie Basin, their contribution to the mercury contamination in the Beaufort Sea marine ecosystem, and potential effects of climate variation. University of Manitoba. 129p.

Rydberg and al. 2010. Climate driven release of carbon and mercury from permafrost mires increases mercury loading to sub-arctic lakes, Science of the Total Environment 408, 4778-4783.

WHO (1990). World Health Organization. Methylmecury, Vol. 101. World Health Organization, International Program on Chemical Safety, Geneva, Switzerland

Muskox health program: Contaminants in country foods in Kitikmeot, NU

Programme de santé des bœufs musqués : contaminants dans les aliments traditionnels de la région de Kitikmeot au Nunavut

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Abstract

Muskoxen are an important country food for people of the Kitikmeot region of Nunavut. Although contaminants have been measured in the muskoxen of Banks and Victoria Islands, no contaminant measurement has been done on muskoxen from this region. The residents of Kugluktuk are concerned about contaminants in this country food and this project will measure a wide range of contaminants in muskoxen. During a community-based sampling initiative under the muskox health program led by the Government of Nunavut, hunters from Kugluktuk, Cambridge Bay and Gjoa Haven will be requested to submit kidney, liver, muscle and tooth samples from 20 muskoxen from the regular hunting season in 2015/16. Teeth will be used to age the animals. Kidney, liver and muscle

Résumé

Le bœuf musqué constitue un aliment traditionnel important pour les peuples de la région de Kitikmeot au Nunavut. Bien que les concentrations de contaminants aient été mesurées chez les bœufs musqués des îles Banks et Victoria, aucune mesure de contaminants n'a été effectuée chez les bœufs musqués de cette région. Les résidants de Kugluktuk sont préoccupés par la présence de contaminants dans cet aliment traditionnel et ce projet permettra de mesurer un grand éventail de contaminants chez le bœuf musqué. Au cours d'une initiative communautaire d'échantillonnage mise en œuvre dans le cadre du programme de santé du bœuf musqué dirigé par le gouvernement du Nunavut, des chasseurs de Kugluktuk, Cambridge Bay et Gjoa Haven seront invités à soumettre

will be analyzed for 34 elements and liver will be analyzed for PFOS, PFCAs and PBDEs. Results of the study will be presented to the involved communities in the fall of 2017.

des échantillons de rein, de foie, de muscles et de dents prélevés sur 20 bœufs musqués issus de la saison de chasse régulière de 2015-2016. Les dents seront utilisées pour déterminer l'âge des animaux. Les tissus rénaux, hépatiques et musculaires seront analysés en fonction d'une série de 34 éléments, et les tissus hépatiques seront analysés pour détecter les PBDE, le SPFO et les APFC. Les résultats de l'étude seront présentés aux collectivités participantes à l'automne 2017.

Key Messages

- Collection of 30 sample kits across the Kitikmeot region has been completed
- Levels of most elements measured in muskox are still being analyzed
- Productive discussions were held with HTO boards and communities, regarding participation in a community-driven monitoring program

Messages clés

- La collecte de 30 trousses d'échantillonnage dans l'ensemble de la région de Kitikmeot est terminée.
- Les concentrations de la plupart des éléments mesurés chez le bœuf musqué sont encore en cours d'analyse.
- Des discussions productives se sont tenues avec les conseils d'administration des organisations des chasseurs et trappeurs et les collectivités au sujet de la participation à un programme communautaire de surveillance.

Objectives

To determine levels of contaminants in Arctic muskoxen in order to:

Provide information to residents of the Kitikmeot region regarding contaminants in this important country food, 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 muskox populations.
- To develop a baseline for current contaminant loads within muskoxen in the Kitikmeot.

Introduction

Muskoxen provide an important food resource for the western communities of Nunavut, such as Kugluktuk and Cambridge Bay, and might become an important source of alternative wildlife with declining barren-ground caribou herds across Nunavut. To date, few in depth studies have been undertaken to monitor the bioaccumulation of contaminants and heavy metals in this species. Given their different natural and life histories, grazing habits and nutritional requirements, as well as their characteristic sedentary lifestyles, developing baseline data for this Arctic ungulate compared to past toxicology studies elsewhere on muskoxen are anticipated.

Activities in 2015-2016

Sample kits were prepared to allow for collection of kidney, liver and muscle tissue in addition to lower incisor bars to determine age of harvested animals. Most of the activities completed in 2015-2016 were focused on capacity building and increasing awareness of the need to collect these new samples. Despite the on-going muskox sample collection for diseases under the Nunavut General Monitoring Program (NGMP), a considerable amount of time was required to educate and coordinate the work in additional communities in which samples could be collected. Kits were presented to HTO boards in the Kitikmeot Region during the muskox management plan consultations in September 2015 as well as the Kitikmeot Regional Wildlife Board (KRWB) Annual Meeting in October 2015 to discuss the objectives of the program, how the kits would be best prepared, and how to properly collect the samples and ship the kits once completed.

Capacity Building

In fall 2015, community consultations regarding updated muskox population numbers, changes to muskox management zones, harvest season and quota allocation were discussed with the communities of Cambridge Bay, Kugluktuk, Taloyoak, Gjoa Haven and Kugaaruk. Knowledge gaps were identified, such as the importance of knowing whether muskoxen are safe to consume. Although a base line study has been developed for disease, little is known on the accumulation of potential contaminants in muskoxen. This knowledge gap helped propel the interests and participation of the community in addressing this question Changeover within the HTO's and HTO managers allowed for the opportunity to have face-to-face meetings to discuss capacity building and cooperative program management in addition to potential training and funding opportunities. Late fall and early winter was a great time to increase awareness and educate the hunters in view of the upcoming spring muskox harvest.

Communications

A summary of this project was presented by the PI's to each of the HTO boards in the Kitikmeot region during a consultation tour on the draft muskox management plan for the region. Thus, the HTOs of Kugluktuk, Cambridge Bay, Taloyoak, Kugaaruk and Gjoa Haven were all consulted in addition to the community members themselvespublic consultations occurred during the same period of time.

Local high schools were also visited during these community visits to discuss the roles of muskox and other ungulates from both an ecological and cultural perspective and the importance of keeping communities and local environments clean for the benefit of wildlife and future generations.

Traditional Knowledge Integration

Local and Inuit knowledge was at the foundation of this program. This program relies on the implementation of traditional when both hunting collecting samples from Muskoxen for analysis. Traditional and Local Ecological Knowledge is incorporated into both the community and sport hunting practices and traditional harvesting and butchering is used during sample kit preparations. For example, the sample kit design was adapted to harvest parts from that animal that would allow for easier transportation via snowmobile, leaving more room to bring back meat for subsistence purposes.

Results and Discussion

Collection of samples is always challenging as it involve the coordination between the hunting season and when the program is ready in place. Thus, in 2015 and 2016 we have successfully collected 30 samples were collected from the communities of Kugluktuk (4), Cambridge Bay (15), Bathurst Inlet and Bay Chimo (5) Gjoa Haven (1) and Taloyoak (5) over the course of the 2015-2016 winter. Samples were collected from both community hunters and sport hunting guides operating with the Cambridge Bay HTO. These samples are currently undergoing analysis by collaborator Mary Gamberg for a suite of 34 elements using ICP-MS by NLET, Environment Canada. Consequently, no results are available at time for discussion and this project remains therefore on going.

Co-management partners are concerned about contaminant levels in this country food and this has been a recurrent message since 2014 when the co-management partners recommended more study on muskox health. Thus, the data collected and the future results for the analysis will provide baseline data for current contaminant levels in muskox as potential new contaminant begin emerging in the Arctic. By working jointly with the Territorial Health Official in this program, we will have the help needed to undertake a public health assessment in the context of a risk/benefit perspective. Muskoxen are an important food source for people in the Kitikmeot region and promoting a safe alternative country food from caribou might become essential in the near future.

Expected Project Completion Date:

2016

Acknowledgement

We would like to acknowledge the effort of all the project team members in making this research project happen. To all the hunters that spend additional time to collect the samples in the cold months of winter. Least but not last, a special thank you go to the each of the HTO manager; Lena Adjun in Kugluktuk, Beverly Maksagak in Cambridge Bay, William Aglukkaq in Gjoa Haven, Sam and Peter Kapolak in Bay Chimo and Bathurst Inlet and Jimmy Oleekatalik in Taloyoak, who assisted with the coordination of the sample collections with the hunter and shipping. This project was funded by the Northern Contaminants Program, Aboriginal Affairs and Northern Development Canada and administered by the Yukon Conservation Society.

Understanding contaminant levels in commonly consumed fish of Kluane Lake, Yukon

Comprendre les concentrations de contaminants présents dans les poissons du lac Kluane au Yukon qui sont consommés de façon régulière

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Abstract

The Kluane Lake area in the southwestern region of Yukon Territory is the traditional territory of the Lù'àn Män Ku Dän, the Kluane Lake People. Situated primarily in the small community of Burwash Landing, the closest grocery store for community members is 300km away. Residents depend on fish from Kluane Lake as important sources of subsistence and nutrition in their daily diets. Climate change and other factors may be affecting contaminant levels in the lake. In partnership with the University of Waterloo, Kluane Research Station, and the Arctic Institute of Community-Based Research, a small-scale study assessing current mercury levels in Lake Trout (*Salvelinus namaycush*) and Lake Whitefish (*Coregonus clupeaformis*)

Résumé

La région du lac Kluane, dans la partie sud-ouest du Territoire du Yukon, est le territoire ancestral des Lù'àn Män Ku Dän, le peuple du lac Kluane. Située principalement dans la petite collectivité de Burwash Landing, l'épicerie la plus proche pour les membres de la collectivité est distante de 300 km. Les résidents comptent sur le poisson du lac Kluane comme source de subsistance et de nutrition importante dans leurs régimes alimentaires quotidiens. Les changements climatiques et d'autres facteurs peuvent influer sur la concentration de contaminants dans le lac. En partenariat avec l'Université de Waterloo, la station de recherche du lac Kluane et l'Arctic Institute of Community-based Research, une étude à petite échelle pour évaluer les concentrations

was undertaken in Kluane Lake. In total, 65 individual fish were analyzed for mercury levels, and for stable carbon and nitrogen isotope ratios. As expected, we found that Lake Trout occupy a significantly higher trophic position than Lake Whitefish. Lake Trout also had higher mean mercury concentrations than Lake Whitefish (0.086 ± 0.091 ppm and 0.022 ± 0.008 ppm, respectively), however, only Lake Trout greater than 800 cm fork length exceeded the Subsistence Consumption Guideline for mercury (0.2 ppm). None of the Lake Whitefish sampled exceeded the Subsistence Consumption Guideline. Preliminary statistical analysis shows that fork length and stable nitrogen ratio together are the best predictors of mercury concentration in Lake Trout and Lake Whitefish. Analysis for other trace metals, including nutrients Zn, Se, and omega-3 fatty acids) and persistent organic pollutants (POPs) is on-going. Community capacity building, engagement, and outreach have been important components of this collaborative and well-leveraged project.

actuelles de mercure chez le touladi (*Salvelinus namaycush*) et le grand corégone (*Coregonus clupeaformis*) a été entreprise dans le lac Kluane. Au total, 65 poissons ont été analysés afin de déterminer les concentrations de mercure et les ratios d'isotopes de carbone et d'azote stables. Comme nous nous y attendions, nous avons découvert que le touladi occupe une situation trophique considérablement plus élevée que le grand corégone. Le touladi présente également des concentrations moyennes de mercure plus élevées que le grand corégone (0,086 ± 0,091 ppm et 0,022 ± 0,008 ppm, respectivement); cependant, seuls les touladis d'une taille supérieure à 800 mm à la fourche dépassent la ligne directrice pour la consommation de subsistance en ce qui concerne le mercure (0,2 ppm). Aucun des grands corégones échantillonnés ne dépassait la ligne directrice pour la consommation de subsistance. L'analyse statistique préliminaire indique que la longueur à la fourche et le ratio d'azote stable constituent ensemble les meilleures variables explicatives de la concentration de mercure chez le touladi et le grand corégone. L'analyse effectuée pour trouver d'autres métaux-traces, y compris les éléments nutritifs (Zn, Se et les acides gras oméga3) et les polluants organiques persistants (POP) est en cours. Le renforcement des capacités, la mobilisation et la sensibilisation de la collectivité ont été des éléments importants de ce projet mené en collaboration et bien appuyé.

Key messages

- Fish in Kluane Lake have relatively low mercury concentrations compared to other northern lakes (Lake Trout 0.086 ± 0.091 ppm, n = 40; Lake Whitefish 0.022 ± 0.008 ppm, n = 25)
- Fork length and $\delta^{15}N$ (nitrogen ratio) predict, significantly and positively, mercury levels in both species
- Community capacity building, partnership, engagement, outreach, and leveraging of funds from several sources have ensured the success of this project

Messages clés

- Le poisson du lac Kluane affiche des concentrations de mercure relativement faibles comparativement à celui d'autres lacs nordiques (touladi 0,086 ± 0,091 ppm, n = 40; grand corégone 0,022 ± 0,008 ppm, n = 25).
- La longueur à la fourche et $\delta^{15}N$ (ratio d'azote) permettent de prévoir, de façon significative et positive, les concentrations de mercure chez les deux espèces.
- Le renforcement des capacités, le partenariat, la mobilisation et la sensibilisation de la collectivité et l'obtention de fonds de plusieurs sources ont garanti le succès de ce projet.

Objectives (re-scoped as per comments from the review committee):

- To assess levels of contaminants and fatty acids in Lake Trout and Lake Whitefish in Kluane Lake.
- To understand and address local perceptions of contaminants in traditional foods.
- To build capacity of local Yukon students and community members in research practices.

Introduction

The Kluane Lake area in the southwestern region of Yukon Territory is the traditional territory of the Lù'àn Män Ku Dän, the Kluane Lake People. Kluane First Nation (KFN) is a self-governing First Nation and hosts its administration in the community of Burwash Landing, located on the shores of Kluane Lake and borders of Kluane National Park and Reserve. The nearest grocery store is located in the Yukon's capital city Whitehorse, approximately 300 km away; hence Kluane First Nation rely greatly on traditional foods.

Traditional foods have high nutritional value, including many vitamins, protein, iron, and omega-3 fatty acids. With an increased shift to consuming more market foods in the North, this is resulting in diets lower in iron, folacin, calcium, vitamin D, vitamin A, fibre, fruit and vegetables, and diets higher in fats and sugars (Van Oostdam et al. 2009; Willows 2005). This shift in food consumption patterns has been attributed to higher levels of chronic diseases such as cardiovascular disease, diabetes, and obesity (Berti et al., 2008; Lambden et al., 2006). With changing environmental, social, cultural, and economic conditions, the relationship people have with their food is also changing. Diet is also the main source of exposure to many environmental contaminants.

Declining populations of fish and wildlife, overharvesting, predator competition, climate-related changes to the land, and government hunting regulations have influenced KFN's traditional food-sourcing activities. Residents fish for Whitefish, Lake Trout, and Lingcod (Burbot) from Kluane Lake, however members of the community have expressed concerns about contaminants in the fish in the lake, and some are apprehensive to harvest fish. Commonly consumed species include Lake Trout (*Salvelinus namaycush*) and Lake Whitefish (*Coregonus clupeaformis)*. Lake Trout are known to have higher levels of mercury, particularly older fish – this can be a significant source of mercury to the people who consume them (NCP Blueprints, 2014). While long-term monitoring programs have been set up in other areas of the Yukon (e.g., Kusawa Lake and Lake Laberge), there were little to no data on fish from Kluane Lake. As Kluane First Nation is working to develop and implement a community food security strategy, we wanted to have a better understanding of the levels of contaminants in fish from our lake; this information will support health messaging related to the promotion of consuming a diet that includes traditionally eaten fish.

Activities in 2015-2016

During July and August 2015, 248 fish samples were collected from Kluane Lake: 115 Lake Trout samples were donated by participants in the Kluane Lake Fishing Derby; the remaining samples, which include Lake Whitefish, Round Whitefish (*Prosopium cylindraceum*), and Longnose Sucker (*Catostomus catostomus*) were collected by Kluane First Nation using gill nets set during their annual Harvest Camp. The University of Waterloo participated in all sample collection activities.

Feedback on our initial proposal was that funds should be used almost exclusively for research and analysis; therefore, capacity-building, community engagement, and traditional knowledge integration were conducted using leveraged funds from several other sources.

Capacity Building (other funding sources, but crucial to success of the project)

- July 3 to 5, 2015: Researchers and community members participated in sample collection during the Kluane Lake Fishing Derby.
- Mid-July 2015: A group of youth, including the youth researchers, were taught about environmental contaminants and the value of traditional food by members of the research team: two of these youth were hired to work with the research team. Also during this period, research team members joined community youth at their annual summer camp, to teach them about aquatic insects, including how to capture them, identify them, and their importance to the lake ecosystem.
- August 2015: KFN held their annual Harvest Camp, a community gathering on the land where traditional foods are prepared for the coming winter. During this camp, the research team, youth researchers, and community members set gill nets in Kluane Lake, to collect Lake Whitefish samples. The youth researchers learned the traditional way of setting nets from members of the community and how to sample these fish for scientific analysis from members of the research team. During Harvest Camp, youth researchers worked with research team members to conduct local and traditional knowledge interviews with elders and community members.
- March 2016: the two youth researchers, accompanied by the Youth Councillor from KFN, N Kassi from the research team, and an aboriginal film-maker, travelled to Waterloo, ON, to work alongside members of the research team (H Swanson, University of Waterloo, and B Branfireun, Western University), to complete the scientific research process. Youth homogenized freeze dried fish tissues collected in 2015, dissected whole fish, and learned about otolith ageing methods and aquatic invertebrate identification. The youth were trained to operate a Direct Mercury Analyzer by members of B Branfireun's lab group, and collected new mercury data for their samples.

Communications (Funds from Other Sources, with the exception of travel to NCP Results)

Open, respectful, and two-way communication has been maintained throughout this research project. Every opportunity was taken to communicate progress and provide updates to the community regarding research progress and results.

Preliminary mercury results were shared with KFN Chief and Council prior to their dissemination at the annual NCP Results Workshop in December 2015. A digital copy of these results can be found on the KFN website. The research team presented these results to the Kluane Lake community in April 2016, during the Dän Keyi Renewable Resource Council Annual Open House and during a community lunch, organized by partnered researchers.

Much of the research conducted by our team gathered media attention across Canada, providing insight to the general public. Please find these media references in Appendix I.

Traditional Knowledge Integration (Funds from Other Sources)

Traditional knowledge provided the groundwork for this research project. Key Elders were continuously engaged as representatives on the research advisory committee and as contributors of local and traditional knowledge collected by our youth researchers. Traditional knowledge gathered provided the basis for fishing locations. All traditional knowledge collected has been returned to Kluane First Nation.

Results

In total, 40 Lake Trout and 25 Lake Whitefish have been analyzed for total mercury and stable carbon/nitrogen isotope ratios.

Lake Trout and Lake Whitefish do not differ significantly in mean δ13C ratio (general linear model, $F(1,63) = 0.555$, $p = 0.459$). However, these species do differ significantly in mean δ15N ratio (general linear model: $F(1,63) = 91.765$, $p < 0.001$). As expected, Lake Trout have a higher mean $\delta^{15}N$ ratio than Lake Whitefish (11.043 ± 1.079‰ and 8.392 ± 1.096‰, respectively) (Figure 1). Lake Trout also have a significantly higher mean wet mercury concentration (0.086 ± 0.091 SD ppm) than Lake Whitefish (0.022 ± 0.008 SD ppm) (General Linear Model, $F(1,63) = 12.224$, $p < 0.001$) (Figure 1). For Lake Trout, fork length is the best predictor of log wet tissue mercury concentration ($R2 = 0.724$), but $\delta^{15}N$ is also significantly and positively related to log wet tissue mercury concentration (Figures 2,3). Once all data are available, we will perform additional analyses to determine the best combination of variables (e.g., stable isotopes, fork length, wet weight, age) for explaining mercury levels in Lake Trout. No single covariate measured is significantly correlated to Lake Whitefish wet tissue mercury concentration.

Figure 1. Mean wet tissue mercury concentration in Lake Trout and Lake Whitefish from Kluane Lake, YT. Note the Subsistence Consumption Guideline for Mercury (0.2 ppm).

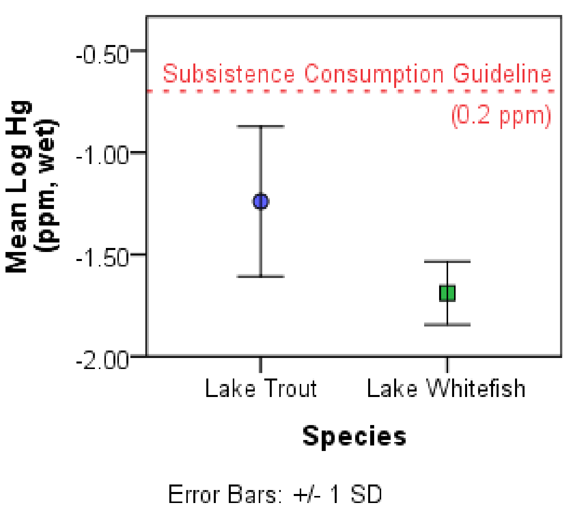


Figure 2. Lake Trout and Lake Whitefish wet tissue mercury concentration plotted against fork length. Note the Subsistence Consumption Guideline, shown with a red dotted line (0.2 ppm). The fork length data gap between approximately 700 mm and 950 mm is due to a total length-based conservation limit on Kluane Lake: Lake Trout with a total length between 650 and 1000 mm total length are not permitted to be kept by anglers. Lake Trout-specific linear regression is significant ($t(1,38) = 122.777$, $p < 0.001$; $\log [Hg]\ wet = -2.370 + 1.854 \cdot 10^{-3}(\text{Fork Length})$, $R^2 = 0.764$). Lake Whitefish-specific linear regression is not significant.

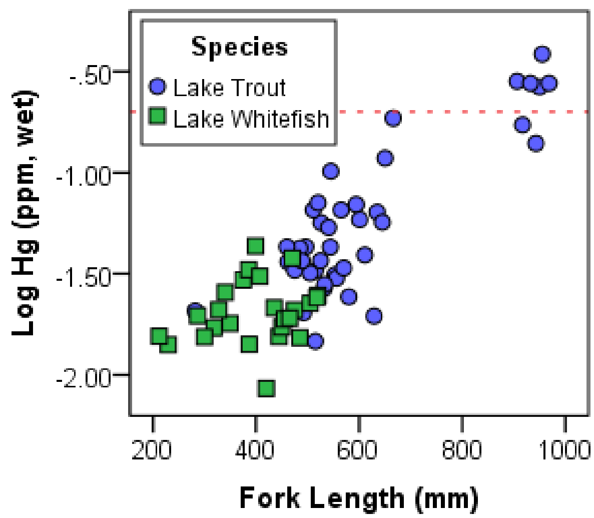
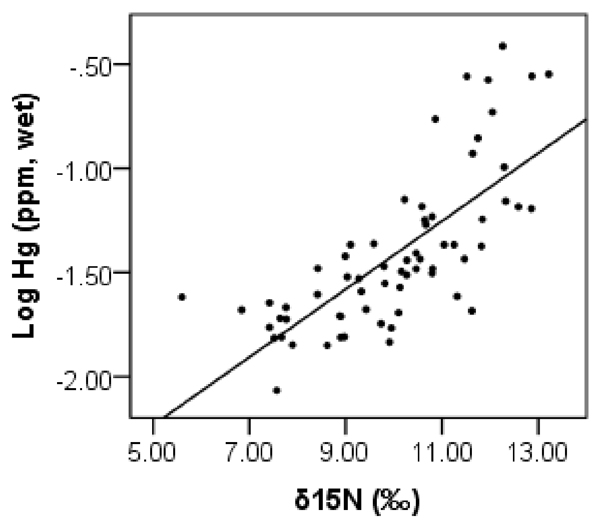


Figure 3. Relationship between log wet mercury and $\delta^{15}N$ (linear regression: $\text{Log [Hg] wet} = -3.048 + 0.163(\delta 15N)$, $R^2 = 0.542$; $t(1,63) = 74.647$, $p < 0.001$).



Analysis for fatty acids, micronutrients (Zn and Se), organochlorine pesticides, and persistent organic pollutants is underway.

Discussion and Conclusions

None of the Lake Whitefish sampled exceed the Subsistence Consumption Guideline for mercury (0.2 ppm wet weight). Some Lake Trout greater than 800 mm fork length have tissue mercury concentrations that exceed this guideline; however, mean Lake Trout tissue mercury concentration (0.086 ± 0.091 ppm) does not exceed this guideline. Large Lake Trout (>~650 mm) are not often consumed by the local community as smaller bodied fish are said to taste better, and conservation measures on Kluane Lake prohibit non-Aboriginal harvest of Lake Trout over 650 mm total length. This minimizes possible human exposure to Lake Trout in exceedance of the Subsistence Consumption Guideline (Barker et al. 2014). Mean tissue mercury concentration in Kluane Lake Trout is significantly lower than mercury concentrations reported from Lake Laberge and Kusawa Lake (Stern et al. 2013).

This research provides a sense of security and reassurance for Kluane First Nation and the communities surrounding Kluane Lake, as it shows the Lake Trout and Lake Whitefish are safe to eat. As this research is the first in-depth analysis of environmental contaminant and nutrient concentrations in Kluane Lake fish, it provides a strong baseline data set against which future monitoring can be compared.

Expected Project Completion Date:

April 2017

Project website (if applicable)

Please see included news and media links in Appendix I.

Acknowledgments

The research team would like to thank members of the Kluane First Nation, the Arctic Institute of Community-Based Research, and the Dän Keyi Renewable Resource Council, for their support, funding, logistics and organization. We would also like to thank the Kluane Lake Research Station for their support throughout the field season. Additionally, the research team gratefully acknowledges funds to support this project that were provided by Yukon Fish & Wildlife Enhancement Trust, the W. Garfield Weston Foundation, the Wildlife Conservation Society of Canada, the Northern Scientific Training Program, and the Arctic Institute of North America.

References:

Barker, O. E., Millar, N. P., & Foos, A. 2014. Lake trout and lake whitefish population assessment: Kluane Lake 2013. Yukon Fish and Wildlife Branch Report TR-14-04, Whitehorse.

Berti, P., Soueida, R., Kuhnlein, H. 2008. Dietary assessment of Indigenous Canadian Arctic women with a focus on pregnancy and lactation. *International Journal of Circumpolar Health* 67(4): 349-362.

Kidd, K. A., Schindler, D. W., Hesslein, R. H., Muir, D. C. G. 1998a. Effects of trophic position and lipid on organochlorine concentrations in fishes from subarctic lakes in Yukon Territory. *Can. J. Fish. Aquat. Sci.* 55: 869-881.

Lambden, J., Receveur, O., Marshall, J., Kuhnlein, H. 2006. Traditional and market food access in Arctic Canada is affected by economic factors. *International Journal of Circumpolar Health* 65(4): 331-340.

Northern Contaminants Program. 2014. NCP Blueprints-Strategic Long-term Plans for NCP Subprograms. Government of Canada. Online: http://www.science.gc.ca/default.asp?lang=En&n=7A442CC3-1

Stern, G. A., Roach, P., van Dijken, B., Burt, A. 2013. Trace Metals and Organohalogen Contaminants in Fish from Selected Yukon Lakes: A Temporal and Spatial Study. In: Synopsis of Research Conducted under the 2013-2014 Northern Contaminants Program. Aboriginal Affairs and Northern Development Canada. 472pp.

Van Oostdam, J., Donaldson, S., Feeley, M. and Tikhonov, C. 2009. Canadian Arctic Contaminants and Health Assessment Report: Human Health 2009. Ottawa Canada: Northern Contaminants Program, Ministry of Aboriginal Affairs and Northern Development. 184pp.

Willows, N. 2005. Determinants of Healthy Eating in Aboriginal Peoples in Canada: The Current State of Knowledge and Research Gaps. *Canadian Journal of Public Health* 96(3): S32-S36.

Appendix I: Media

Good News From Kluane Lake (Yukon News)
http://yukon-news.com/business/good-news-from-kluane-lake/

Mercury and the North's lake-bottom line (Your Yukon)
http://yukon-news.com/letters-opinions/mercury-and-the-norths-lake-bottom-line/

Aboriginal Youth secure their Traditional Foods in Partnership with University of Waterloo (AICBR)
http://www.aicbr.ca/latest-news/2016/3/30/aboriginal-youth-secure-their-traditional-foods-in-partnership-with-university-of-waterloo

First Nations students to help UW test Yukon fish (Waterloo Region Record)
http://www.therecord.com/news-story/6408238-first-nations-students-to-help-uw-test-yukon-fish/

Waterloo Biologist and First Nation examine mercury in fish (Waterloo Stories)
https://uwaterloo.ca/stories/waterloo-biologist-and-first-nation-examine-mercury-fish

Aboriginal youth partner with Waterloo as part of food security study (UWaterloo News)
https://uwaterloo.ca/news/news/aboriginal-youth-partner-waterloo-part-food-security-study

Western helps unlock secrets to food security (Western News)
http://news.westernu.ca/2016/04/western-helps-unlock-secrets-to-food-security/

Indigenous youth from Kluane First Nation to visit Western University (Western Media Relations)
http://mediarelations.uwo.ca/2016/03/29/indigenous-youth-from-the-kluane-first-nation-to-visit-western-university/

Environmental Monitoring and Research

Surveillance et recherche environnementales

Northern contaminants air monitoring: Organic pollutant measurement

Surveillance atmosphérique des contaminants du Nord : mesure des polluants organiques

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Abstract

The atmosphere is the most rapid pathway for organic pollutants to reach the remote Arctic. This project is a continuous monitoring program which has been measuring contaminants in Arctic air since 1992. Measuring how much organic pollutants are present in Arctic air over time will provide information on whether their air concentrations are decreasing, increasing or not changing over time; where these chemicals have come from; how much from which region and what climate conditions influence their movement to the Arctic. Results from this continuing project are used to negotiate and evaluate the effectiveness of international control agreements and to test atmospheric models that explain contaminant movement from

Résumé

L'atmosphère est la voie par laquelle les polluants organiques atteignent le plus rapidement les régions éloignées de l'Arctique. Ce projet est un programme de surveillance continue qui mesure les contaminants dans l'air arctique depuis 1992. La mesure de la quantité de polluants organiques présente dans l'air en Arctique au fil du temps permettra de déterminer si les concentrations atmosphériques de ces produits décroissent, augmentent ou demeurent stables dans le temps; d'où proviennent ces substances chimiques; quelle quantité est générée par quelle région; quelles conditions météorologiques ont une incidence sur le déplacement des contaminants vers l'Arctique.

sources in the South to the Arctic. In 2015/16, weekly sampling continued at the monitoring station of Alert, Nunavut, but only one out of four weekly samples were analyzed for routine trend analysis. The remaining samples were extracted and archived for future exploration and determination of emerging priority chemicals. Starting in 2006, we have extended the program to screen for emerging chemicals, such as current-use pesticides, brominated flame retardants and stain-repellent-related per and polyfluoroalkyl substances (PFASs), in Arctic air at Alert. Measured time trends of PFASs at Alert reflect the phase-out of perfluorooctanesulfonic acid (PFOS)-related products in North America and Europe; and the continual production and use of the fluorotelomer alcohols. A passive flowthrough sampler (FTS) specifically designed for use in cold environments has been deployed at Little Fox Lake, Yukon, since August 2011. Sampling at this site is continuous and ongoing.

Les résultats de ce projet en cours sont utilisés pour négocier des ententes internationales en matière de lutte contre ces contaminants, pour évaluer l'efficacité de celles-ci, et pour tester des modèles de l'atmosphère qui expliquent le déplacement des contaminants depuis les sources dans le Sud jusqu'en Arctique. En 2015-2016, on a poursuivi le prélèvement hebdomadaire d'échantillons au site de référence d'Alert au Nunavut, mais seulement un échantillon hebdomadaire sur quatre a été analysé de manière courante et à des fins de détermination des tendances. Les autres échantillons ont été soumis à une procédure d'extraction, puis ont été archivés en vue de l'examen ultérieur et du dosage des nouveaux produits chimiques prioritaires. À partir de 2006, nous avons élargi le programme pour étudier dans l'atmosphère de l'Arctique canadien, à Alert, les nouveaux produits chimiques, tels que les pesticides d'usage courant, les produits ignifuges bromés et les composés perfluoroalkyles et polyfluoroalkyles utilisés comme antitaches. Les tendances temporelles mesurées des composés perfluoroalkyles et polyfluoroalkyles à Alert reflètent l'élimination progressive des produits apparentés à l'acide perfluorooctane sulfonique en Amérique du Nord et en Europe, ainsi que la production et l'utilisation continuelles d'alcools fluorotélomériques. Un échantillonneur passif à circulation continue spécialement conçu pour être utilisé dans un environnement froid est installé au lac Little Fox, au Yukon, depuis août 2011. Des activités d'échantillonnage sont menées sur une base continue et permanente à ce site.

Key messages

- Stain-repellent-related chemicals were frequently detected in air at Alert
- Some of the stain-repellent-related chemicals which have been phased out in North America and Europe are declining in concentrations in Arctic air

Messages clés

- Des produits chimiques utilisés comme antitaches ont été fréquemment détectés dans l'air à Alert.
- Les concentrations de certains produits chimiques utilisés comme antitaches qui ont été progressivement éliminés en Amérique du Nord et en Europe sont en déclin dans l'air arctique.

- Some stain-repellent-related chemicals are increasing in concentration in Arctic air over time because they are still being produced or used
- The stain-repellent-related chemicals which tend to dissolve well in water seem to be carried to the Arctic mostly by ocean currents, and were transferred to the air by waves or bursting bubbles
- Stain-repellent related chemicals that do not dissolve as well in water seem to be carried to the Arctic over long distances through air currents and are released from the snow and ocean in warm seasons

- Les concentrations de certains produits chimiques utilisés comme antitaches augmentent au fil du temps parce qu'ils sont encore produits ou utilisés.
- Les produits chimiques utilisés comme antitaches qui tendent à bien se dissoudre dans l'eau semblent être transportés vers l'Arctique principalement par des courants océaniques, et ont été transférés à l'atmosphère par les vagues ou l'explosion de bulles.
- Les produits chimiques utilisés comme antitaches qui ne se dissolvent pas aussi bien dans l'eau semblent être transportés vers l'Arctique sur de longues distances par des courants aériens et sont dispersés depuis la neige et l'océan pendant les saisons chaudes.

Objectives

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

  a. continuing to measure the occurrence of selected organochlorines and polycyclic aromatic hydrocarbons in the Arctic atmosphere at Alert (measurements started in 1992).
  b. analyzing and reporting measurement from Alert to provide insight into pollutant trends and sources.

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

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

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

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

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

Introduction

Atmospheric measurements of persistent organic pollutants (POPs) have been conducted at Alert, Nunavut, since 1992. The atmosphere is the major and fastest route of transport for many priority pollutants to the remote Arctic. Monitoring for organic pollutant levels in Arctic air can be used for evaluating time trends of atmospheric contaminants, determining contaminant source regions, to evaluating global long-range transport models, and for assessing the effectiveness of national and international chemical control initiatives.

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

In this report, time trend results of neutral and ionic PFASs measured in air at Alert are reported. Their potential sources are discussed in terms of the relationship between measured PFAS concentrations and temperatures.

Activities in 2015-2016

Regular ground level atmospheric measurements of organochlorines (OCs) [polychlorinated biphenyls (PCBs), chlordane, dichlorodiphenyltrichloroethanes (DDTs), chlorobenzenes and selected herbicides], flame retardants (FRs) [14 polybrominated biphenyl ethers (PBDEs), 13 other brominated FRs and 2 highly chlorinated FRs] and polycyclic aromatic hydrocarbons (PAHs) (20 priority ones) are being made at Alert, Nunavut, using a custom-made super-high-volume air sampler (super-HiVol). Measurements involve routine weekly sample collection, extraction, analysis as well as archiving.

A separate high volume air sampler (PS-1 sampler), sampling with one glass fiber filter followed by a PUF-XAD sandwich, operates in parallel with the routine air monitoring sampler since 2006. Weekly integrated air samples have been collected to analyze for new and emerging chemicals, including PFASs and CUPs. Sampling occurred once per month from October to February and once every other week from March to September. The samples from the PS-1 sampler were extracted and split for the analysis of CUPs and PFASs. Results for measured PFASs in air at Alert are reported here.

A field audit was conducted in September 2016. Audit reports are currently being compiled by Airzone One Ltd.

An attempt to screen for organophosphate flame retardants (OPs) in the PS-1 filters has found relatively higher blank levels. To rectify this problem, a second separate PS-1 sampler has been installed and sampling with pre-baked filters (with no PUF-XAD sandwich) started in May 2015 for the analysis of OPs.

A flowthrough sampler (FTS) was installed at Little Fox Lake in August 2011 and started monthly-integrated sampling for the determination of selected OCs and FRs. Sampling at this location allows for the continual investigation of trans-Pacific transport of contaminants to the western Canadian Arctic.

An article including time series of FRs measured in air at Little Fox Lake has been published (Yu et al., 2015). PBDEs were found to show declining tendency (Aug 2011- Dec 2014) while conversely some new FRs were frequently detected in air at Little Fox Lake. In warm seasons, these chemicals tend to stem from potential sources in Northern Canada, the Pacific, and East Asia; while in cold seasons, they mainly come from the Pacific Rim.

Time trends for POPs at AMAP stations (including those from Alert) have been updated to the end of 2012 (Hung et al., in press). This study found that most POPs listed for control under the Stockholm Convention, e.g. PCBs, DDTs and chlordanes, are declining slowly in Arctic air, reflecting the reduction of direct emissions during the last two decades and increasing importance of emissions from environmental reservoirs (e.g. soil and oceans) and waste streams/stockpiles. Comparing to other AMAP stations, PBDEs do not decline in air at Alert but are declining in European Arctic air, which may be due to influence of local sources at Alert (e.g. the nearby military base and the laboratory) and the much higher historical usage of PBDEs in North America than Europe.

Air concentration data from Alert contributed to the UNEP Global Monitoring Plan (GMP) Second Report for the Stockholm Convention and the Stockholm Convention's Risk Profile for SCCPs and decaBDE.

Communications, Consultation and Capacity Building

Outreach and communication under this project is conducted in conjunction with that of the projects “Air Measurement of Mercury at Alert and Little Fox Lake” (P.I. Alexandra [Sandy] Steffen) and “Passive Air Sampling Network for Organic Pollutants and Mercury” (P.I.s Hayley Hung and Sandy Steffen).

We have set our main focus on the communication aspect of our program. Since Alert is isolated, not near any community and restricted by the military we have been challenged, in the past, to meet our capacity building and training expectations.

In FY2015/16, we continued to work with the Yukon College by giving a full web seminar to a class on environmental science (November 2015). We met with partners Bob Van Dijken and Derek Cooke to provide an update on the program and discussed ideas and plans to incorporate Traditional Knowledge (TK) in this proposal (October 2015 and at NCP meeting December 2015).

In June 2015, Sandy and Hayley went to the Yukon for the official transfer of the Little Fox Lake site. This was the official transfer of the site operations from the Yukon College to the Council of First Yukon Nations (CYFN). The transfer included a site visit by the local Yukon Contaminants Committee (YCC) members and our partner from the Ta’än Kwach’än Council. An elder from the Ta’än Kwach’än Council came to the site to provide the history of the location and to approve the transfer on behalf of the Ta’än Kwach’än community. A tour of the site and discussions about the research were provided to the whole group.

Data collected from Little Fox Lake (once interpreted) will be distributed to the CYFN and the Ta’än Kwach’än First Nation, in whose traditional territory the sampler site is located. The data generated can be used by CYFN in local and national issues, as required. The Ta’än Kwach’än can use the information to keep their community informed of local effects from airborne contaminants.

Sandy and Hayley also recorded a seminar for the ENVS100 online course as part of the Yukon College. Some technical challenges were encountered but overcome. The full recording of the presentation has been made and finalizing it to send to Nicolaus Gantner will be forthcoming.

Sandy, Hayley and Liisa Jantunen travelled to Iqaluit Jan 25-27, 2016, to conduct a half-day guest lecture with a half-day hands-on activity session to students in the Environmental Technology Program at the Nunavut Arctic College. They met with the NECC to discuss about their communication, capacity building and TK plans.

Traditional Knowledge Integration

In consultation with Derek Cooke (Ta’än Kwach’än Council), Bob Van Dijken (CYFN) and Pat Roach (INAC), we have engaged a Yukon student, Jamie Thomas, to potentially research on the integration of TK into the NCP air monitoring projects of POPs and mercury if funding permits in FY2016/17. Jamie visited the Downsview facility of ECCC in March 2016 with funding from Project M03 and discussed with Sandy and Hayley about this potential project. The project plan is to develop an outreach/communication/TK package which Jamie could bring to various First Nations communities and during these visits, she will bring back TK information that is best suited for integration into the air monitoring projects for POPs and mercury. We hope that Jamie will be able to undertake discussions with community members on wind and air and what it means to northerners. Outcomes of the project may be a video, presentation or written materials summarizing discussions and ideas.

Results

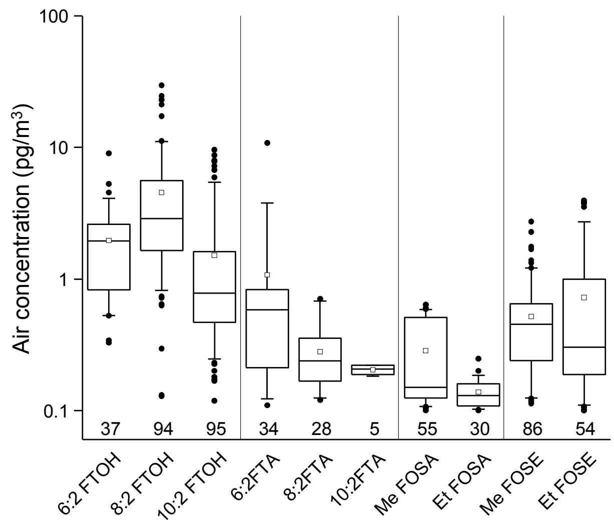
Per and Polyfluoroalkyl Substances (PFASs) in Air at Alert

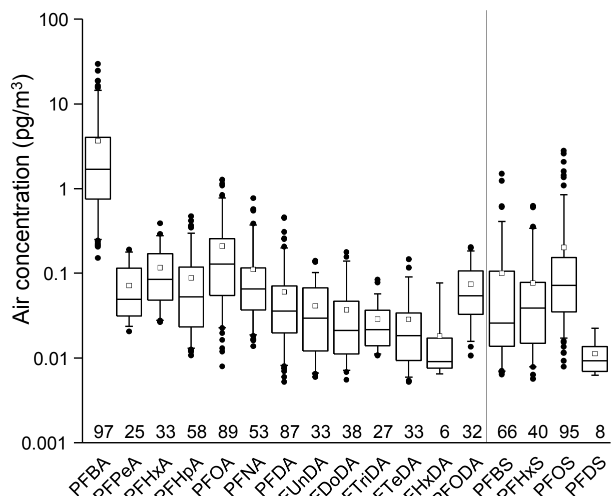
A total of 164 samples collected from August 2006 to February 2015 were analyzed for 27 PFASs. Results reported here represent the sum of PFASs on the GFF and PUF-XAD, which reflects both of gas and particle phase PFASs. The target analytes were i) 10 neutral (n) PFAS: 6:2, 8:2, 10:2 fluorotelomer alcohols (FTOHs), 6:2, 8:2, 10:2 fluorotelomer acrylates (FTAs), methyl (Me) and ethyl (Et)perfluorooctane sulfonamide (FOSAs), and Me and Et perfluorooctane sulfonamidoethanol (FOSEs), ii) 17 perfluoroalkyl acids (PFAAs): C4-14, C16, C18 perfluoroalkly carboxylic acids (PFCAs) [i.e. perfluorobutanoic acid (PFBA), perfluoro-n-pentanoic acid (PFPeA), perfluorohexanoic acid (PFHxA), perfluoroheptanoic acid (PFHpA), perfluorooctanoic acid (PFOA), perfluorononanoic acid (PFNA), perfluorodecanoic acid (PFDA), perfluoroundecanoic acid (PFUnDA), perfluorododecanoic acid (PFDoDA), perfluorotridecanoate acid (PFTriDA), perfluorotetradecanoic acid (PFTeDA), perfluorohexadecanoic acid (PFHxDA), perfluorooctadecanoic acid (PFODA)] and C4, C6, C8, C10 perfluoroalkane sulfonic acids (PFSAs) [i.e. perfluorobutane sulfonic acid (PFBS), perfluorohexane sulfonic acid (PFHxS), PFOS, perfluorodecane sulfonic acid (PFDS)].

Figure 1 summarizes the data in box-whisker plots. The 8:2 and 10:2 FTOH were the most frequently detected nPFASs with detection frequency (DF) of 94% and 95% respectively. Mean concentration of FTOHs (i.e. sum of 6:2, 8:2 and 10:2 FTOHs) at Alert was 6.5 pg/m^3 and accounted for 52% of total PFASs (sum of nPFAS and PFAAs). Among the FTOHs, 8:2 FTOH was the highest in concentration representing 66% of FTOHs followed by 10:2 FTOH (21%) and 6:2 FTOH (12%).

Detection for the FTAs, FOSAs and FOSEs were generally low with DF ranged from 5 to 34%, 30 to 55% and 54-86% respectively. Sum of FOSEs (i.e. Me- and Et FOSEs) were higher than sum of FOSAs (i.e. Me- and Et FOSAs) with concentrations (pg/m^3) of 0.85 and 0.28 respectively. FTA concentrations were low with sum of FTAs (i.e. 6:2, 8:2 and 10:2 FTAs) = 0.61 pg/m^3.

Fig 1. Box-whisker plots of nPFAS (top) and PFAAs (bottom) in air at Alert. The box is bounded by the 25th and 75th percentiles, whiskers indicate the 5th and 95th percentiles, dots are outliers of the 5th and 95th percentiles, squares indicate arithmetic means, and lines indicate medians. Values inside of the plots are detection frequencies. Detection frequency was defined as the percentage of samples with concentration of an analyte that was greater than the instrumental detection limit.





The most abundant PFAAs was PFBA which had DF of 97%, and accounted for 27% of the total PFASs. Mean concentration of PFBA in air at Alert was 3.4 pg/m^3. PFOA and PFOS were highly detected with DFs of 89% and 95% and mean concentrations of 0.18 and 0.19 pg/m^3, respectively. PFDA was also highly detected with DF of 87% and mean concentration of 0.051 pg/m^3. Other PFAAs with DF>50% were the PFBS (0.065 pg/m^3), PFHpA (0.053 pg/m^3) and PFNA (0.060 pg/m^3).

The temporal trends of the most detected PFASs at Alert were examined using the digital filtration method (Hung et al., 2005). Analyses were performed for 8:2- and 10:2 FTOH, Me- and EtFOSE (Figure 2), PFBA, PFOA, PFBS, and PFOS (Figure 3). MeFOSE and EtFOSE are reported to be PFOS precursors (i.e can transform to PFOS), showed declining trends with half-lives (t1/2) 11 and 1.6 years (y) respectively. 8:2 and 10:2 FTOH showed increasing trend with doubling times 4.2 and 5.1 years respectively (Figure 2). Increasing trends were found for PFAAs with doubling times of 2.5 y for PFBA, 3.7 y for PFOA, 2.6 y for PFBS and 2.9 y for PFOS.

Discussions and Conclusions

Comparisons with other measurements

The sum of FTOHs at Alert (6.5 pg/m^3) is consistent with those measured by Genualdi et al. (2010) at Alert with ∑FTOHs = 6.4 pg/m^3, and in air collected from the southern Atlantic ocean with ∑FTOH 9.3 pg/m^3 (Wang et al., 2015). ∑FTOH at Alert was lower than those measured previously in air at the North Atlantic

Fig 2. Trends of nPFASs in air at Alert. Negative t1/2 indicates doubling time (year). Positive t1/2 indicates half-life (year).

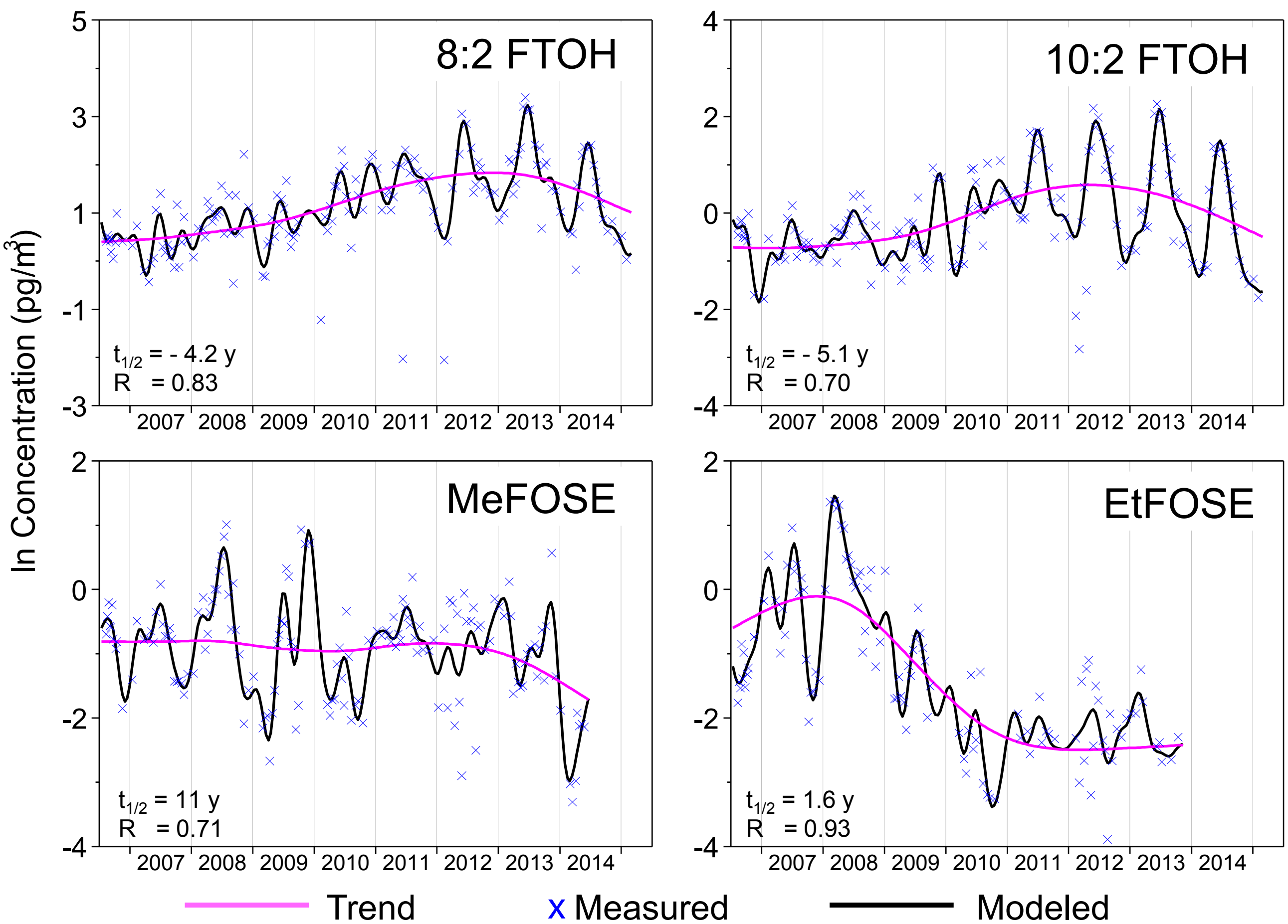
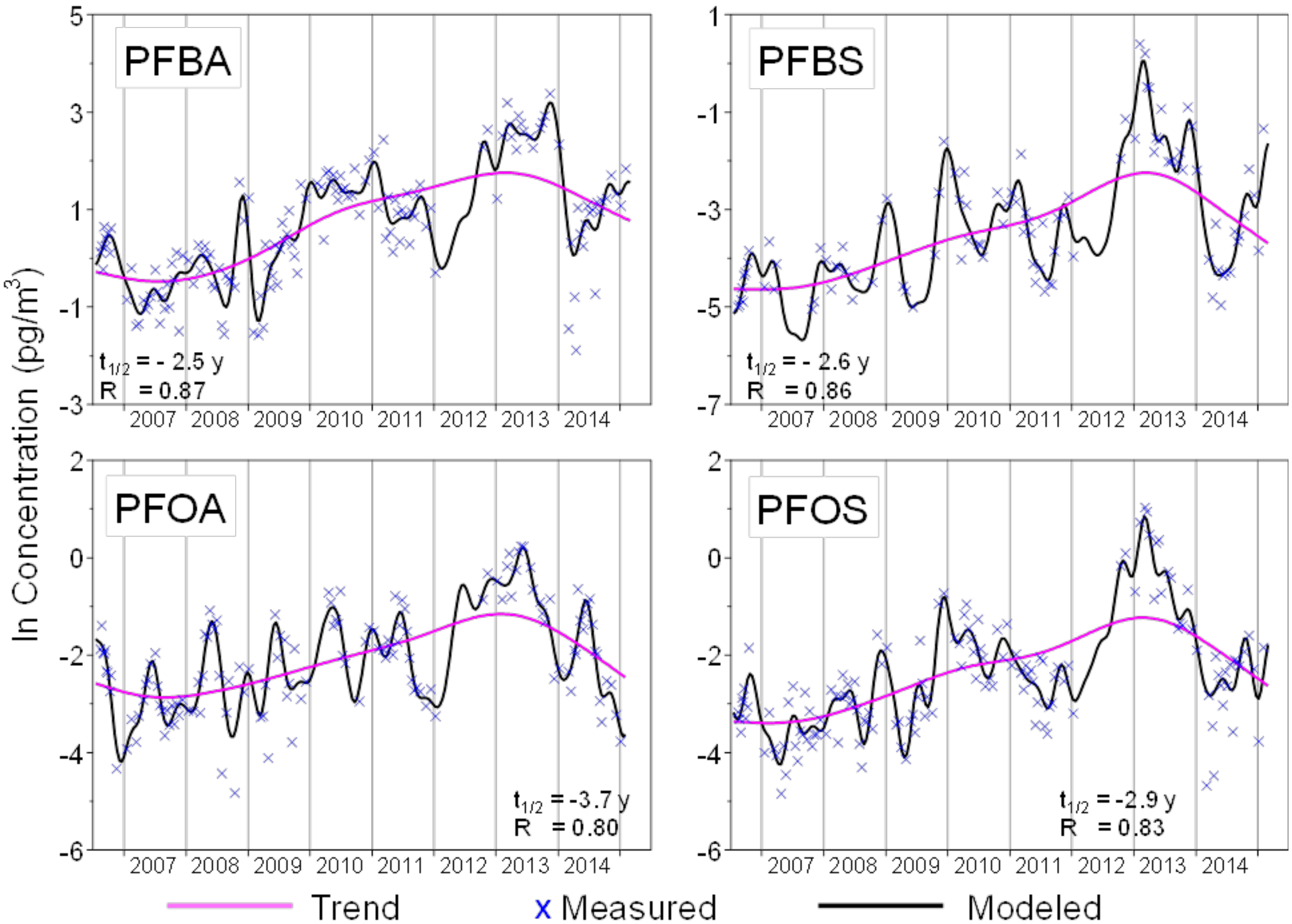


Fig 3. Trends of PFAAs in air at Alert. Negative t1/2 indicates doubling time (year). Positive t1/2 indicates half-life (year).



and Canadian Archipelago (∑FTOH, gas + particle = 24 pg/m³) (Shoeib et al., 2006), in the Antarctic Peninsula (∑FTOH, gas, 26 pg/m³), and in the Beaufort sea (∑FTOH = 69 pg/m³) (Ahrens et al. 2011).

Mean concentrations of PFOA and PFOS at Alert were 0.18 and 0.19 pg/m3 respectively, which are similar to those reported at Zeppelin, Norway, from 2006 to 2012 at 0.76 and 0.10 respectively (AMAP 2014). Genualdi et al. (2010) reported air concentrations of below detection limit for PFOA and 2.0 pg/m3 for PFOS in 2009.

Time Trends

Figures 2 and 3 show the time trends of selected PFASs in air at Alert. The declining trend of Me- and EtFOSE may reflect the phase-out of the production of PFOS-related products in North America and Europe since 2002. Our results are consistent to the global decline of FOSAs and FOSEs in air measured between 2006 and 2011 (Gawor et al., 2014). On the contrary, Bossi et al. (2016) reported no time trends for the FTOHs, FOSAs and FOSEs in air at Greenland collected from 2008 to 2013.

8:2- and 10:2 FTOHs showed increasing trends with doubling times ranged from 4.2 to 5.1 y, which reflects the continual production and used of these chemicals. PFBA, PFOA, PFBS, and PFOS were also increasing with doubling time ranging from 2.5 to 3.7 y. PFOAs, PFOS and their precursors are still being produced in Asia, and China has been reported to be the world's largest industrial contributor of PFOA (Li et al., 2015; Wang et al., 2014). Furthermore, the shifting from the long to short chain fluorochemical production may lead to the increasing trend of PFBA and PFBS in air at Alert (Wang et al., 2013).

Correlation between air concentration and temperature

Significant correlations ($p<0.05$) between air concentration and temperature were observed for 8:2-, 10:2 FTOHs and MeFOSE with higher concentrations observed in the warm season. However, scattering of the data were observed (R ranging from 0.23 to 0.49), implying that the presence of these compounds in Arctic air is probably due to both long-range transport and volatilization from snow or ocean. These compounds have low water solubility and tend to volatise. Net volatilization of FTOHs from snow and ocean to air has been demonstrated in North Sea (Xie et al., 2013), and from snow in Antarctic (Xie et al., 2015) and Ny-Ålesund (Wang et al., 2015). PFAAs were not correlated with temperature. PFAAs unlike other persistent organic pollutants, have high water solubility and low vapor pressure/Henry's constant, therefore transfer from ocean to air most often occurs by ejecting these pollutants through bursting bubbles and waves (McMurdo et al. 2008, Reth et al. 2011). Bursting bubbles and waves is likely to be the dominant pathway for PFAAs to be transferred to Arctic air while volatilization from snow surfaces could be less important.

Expected Project Completion Date

Ongoing

Acknowledgments

We would like to thank the Northern Contaminants Program (NCP) for supporting the atmospheric measurement at Alert and Little Fox Lake. ECCC's Chemicals Management Plan (CMP) co-funded the analysis of emerging contaminants in Arctic air samples. The authors would also like to thank the Canadian Forces Station (CFS) Alert for supporting sample collection.

References

Ahrens, L., Shoeib, M., del Vento, S., Codling, G., Halsall, C. 2011. Polyfluoroalkyl compounds in the Canadian Arctic atmosphere. *Environ. Chem.* 8: 399-406.

AMAP, 2014. *Trends in Stockholm Convention Persistent Organic Pollutants (POPs) in Arctic Air, Human media and Biota.* AMAP Technical Report No. 7 (2014). Olso, Norway: Arctic Monitoring and Assessment Programme (AMAP). Available from: http://www.amap.no/

Bossi, R.,Vorkamp, K., Skov, H. 2016. Concentrations of organochlorine pesticides, polybrominated diphenyl ethers and perfluorinated compounds in the atmosphere of North Greenland. *Environ. Pollut.* in press.

Gawor, A., Shunthirasingham, C., Hayward, S. J., Lei, Y. D., Gouin, T., Mmereki, B. T., Masamba, W., Ruepert, C., Castillo, L. E., Shoeib, M., Lee, S. C., Harner, T. and Wania, F. 2014. Neutral polyfluoroalkyl substances in the global atmosphere. *Environ. Sci.: Processes Impacts* 16: 404-413.

Genualdi, S., Lee, S. C., Shoeib, M., Gawor, A., Ahrens, L., Harner, T. 2010. Global pilot study of legacy emerging persistent organic pollutants using sorbentimpregnated polyurethane foam disk passive air samplers. *Environ. Sci. Technol.* 44: 5534-5539.

Hung H., Blanchard, P., Halsall, C. J., Bidleman, T. F., Stern, G. A., Fellin, P. 2005.

Temporal and spatial variabilities of atmospheric polychlorinated biphenyls (PCBs), organochlorine (OC) pesticides and polycyclic aromatic hydrocarbons (PAHs) in the Canadian Arctic: results from a decade of monitoring. *Sci. Tot. Environ.* 342:119–144.

Hung, H., Katsoyiannis, A. A., Brorström-Lundén, E., Olafsdottir, K., Aas, W., Breivik, K., Bohlin-Nizzetto, P., Sigurdsson, A., Hakola, H., Bossi, R., Skov, H., Sverko, E., Barresi, E., Fellin, P., Wilson, S. (in press) Temporal Trends of Persistent Organic Pollutants (POPs) in

Arctic Air: 20 Years of Monitoring under the Arctic Monitoring and Assessment Programme (AMAP). *Environ. Pollut.* Article in Press.

Li, L., Zhai, Z., Liu, J., Hu, J. 2015. Estimating industrial and domestic environmental releases of perfluorooctanoic acid and its salts in China from 2004 to 2012. *Chemosphere* 129: 100-109.

McMurdo, C. J., Ellis, D. A., Webster, E., Butler, J., Christensen, R. D., Reid, L. K. 2008. Aerosol enrichment of the surfactant PFO and mediation of the water– air transport of gaseous PFOA. Environ. Sci. Tech. 42: 3969-3974.

Piekarz, A. M., Primbs, T., Field, J. A., Barofsky, D. F., Simonich, S. 2007. Semivolatile fluorinated organic compounds in Asian and Western U. S. air masses. *Environ. Sci. Technol.* 41: 8248-8255.

Reth, M., Berger, U., Broman, D., Cousins, I. T., Nilsson, E. D., McLachlan, M. S. 2011. Water-to-air transfer of perfluorinated carboxylates and sulfonates in a sea spray simulator. *Environ. Chem.* 8: 381-388.

Shoeib, M., Harner, T., Vlahos, P. 2006. Perfluorinated chemicals in the arctic atmosphere. *Environ. Sci. Technol.* 40:7577-7583.

Shoeib, M., Harner, T., Webster, G. M., Lee, S. C. 2011. Indoor Sources of Poly- and Perfluorinated Compounds (PFCS) in Vancouver, Canada: Implications for Human Exposure. *Environ. Sci. Technol.* 45: 7999-8005.

Wang, Z., Cousins, I. T., Scheringer, M., Hungerbühler, K. 2013. Fluorinated alternatives to long-chain perfluoroalkyl carboxylic acids (PFCAs), perfluoroalkane sulfonic acids (PFSAs) and their potential precursors. *Environ. Int.* 60: 242-248.

Wang, Z., Cousins, I. T., Scheringer, M., Buck, R. C., Hungerbühler, K. 2014. Global emission inventories for C4–C14 perfluoroalkyl carboxylic acid (PFCA) homologues from 1951 to 2030, Part I: Production and emissions from quantifiable sources. *Environ. Int.* 70: 62-75.

Wang, Z., Xie, Z., Mi, W., Moller, A., Wolschke, H., Ebinghaus, R. 2015. Neutral Poly/Per-Fluoroalkyl Substances in Air from the Atlantic to the Southern Ocean and in Antarctic Snow. *Environ. Sci. Technol.* 49: 7770-7775.

Xie, Z., Wang, Z., Mi, W., Moller, A., Wolschke, H., Ebinghaus, R. 2015. Neutral Poly-/perfluoroalkyl Substances in Air and Snow from the Arctic. *Sci. Rep.* 5: 8912-8916.

Xie, Z., Zhao, Z., Moller, A., Wolschke, H., Ahrens, L., Sturm, R., Ebinghaus, R. 2013. Neutral poly- and perfluoroalkyl substances in air and seawater of the North Sea. *Environ. Sci. Pollut. Res.* 11: 7988-8000.

Yu, Y., Hung, H., Alexandrou, N., Roach, P., Nordin, K. 2015. Multiyear measurements of flame retardants and organochlorine pesticides in air in Canada's western sub-arctic. *Environ. Sci. Technol.* 49 (14): 8623 – 8630.

Mercury measurements at Alert, NU, and Little Fox Lake, YT

Mesures du mercure à Alert, au Nunavut, et au lac Little Fox, au Yukon

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Abstract

Mercury (Hg) is a priority pollutant of concern in Arctic regions. The Arctic receives Hg via long range transport from source regions, which are primarily from outside of Canada. While results from atmospheric Hg concentration measurements at Alert, Nunavut show a decreasing trend (-0.987% per year for 13 years), this is a slower decline than what is observed at more southern locations. In contrast, Hg concentrations at Little Fox Lake, Yukon show an increasing trend (+1.40% per year for 8 years). This is the first recorded increasing annual trend in total gaseous mercury (TGM) in Canada. At Alert, Hg continues to show a distinct seasonal decrease in gaseous elemental Hg (GEM) in the spring. Concurrently, seasonal

Résumé

Le mercure (Hg) est un polluant prioritaire qui demeure préoccupant dans les régions arctiques. L'Arctique reçoit des dépôts de mercure par le transport à grande distance en provenance des régions sources, qui sont pour la plupart en dehors du Canada. Bien que les résultats des mesures des concentrations atmosphériques de mercure prises à Alert, au Nunavut, démontrent une tendance à la baisse (-0,987 % par année sur une période de 13 ans), il s'agit d'un déclin plus lent que celui observé dans les régions plus au sud. En revanche, les concentrations de mercure au lac Little Fox, au Yukon, démontrent une tendance à la hausse (+1,40 % par année, sur une période de huit ans). Il s'agit de la première tendance annuelle à la hausse enregistrée pour

patterns in shorter-lived Hg species (reactive gaseous Hg, or RGM, and particle-bound Hg, PHg) continue to show a peak in PHg during early spring and a peak in RGM in late spring. The highest deposition of Hg seems to come from this springtime peak in PHg and RGM concentrations. A new method using stable isotopes is being studied to assess ways to further understand the sources of the Hg to this region and investigate processes that Hg goes through after deposition in the Arctic.

le mercure gazeux total (MGT) au Canada. À Alert, le mercure élémentaire gazeux (MEG) continue de connaître une chute saisonnière caractéristique au printemps. En parallèle, les profils saisonniers des espèces de mercure à plus courte durée de vie (mercure gazeux réactif, ou MGR, et mercure lié aux particules ou PHg) ont continué à démontrer un pic de mercure lié aux particules au début du printemps et un pic de MGR à la fin du printemps. Les dépôts les plus élevés de mercure semblent issus de ce pic printanier des concentrations de mercure lié aux particules et de MGR. Une nouvelle méthode employant des isotopes stables est à l'étude afin d'évaluer des façons de mieux comprendre les sources de mercure se retrouvant dans cette région et d'analyser les processus que le mercure subit après son dépôt dans l'Arctique.

Key messages

- Atmospheric mercury measurements have been collected at Alert, Nunavut since 1995 and at Little Fox Lake, Yukon since 2007
- Gaseous elemental mercury levels at Alert have decreased annually since 1995 to present and at Little Fox Lake have increased annually from 2007 to present
- Seasonal variability in atmospheric mercury continues to be reported at both Alert and Little Fox Lake
- The data collected as part of this program will be used as Canada's contribution to national policies and to the assessment of effectiveness of national and international emission reduction strategies

Messages clés

- On recueille des mesures du mercure atmosphérique à Alert, au Nunavut, depuis 1995 et au lac Little Fox, au Yukon, depuis 2007.
- Les niveaux de mercure élémentaire gazeux à Alert diminuent chaque année depuis 1995 et augmentent chaque année depuis 2007 au lac Little Fox.
- On rapporte toujours une variabilité saisonnière à Alert et au lac Little Fox.
- Les données recueillies dans le cadre du programme représenteront la contribution du Canada aux politiques nationales et à l'évaluation de l'efficacité des stratégies nationales et internationales de réduction des émissions de mercure.

Objectives

- Establish long-term baseline concentrations, patterns and trends of Hg in the Canadian high Arctic air at the Alert site. This information will be crucial in the development of Canadian strategies for national and international pollution control objectives such as those outlined in the Minamata Convention on Mercury.
- Use measurements of atmospheric Hg species, Hg in snow, and additional complementary data to understand the cycling of Hg in the atmosphere and its subsequent deposition from the atmosphere to the Arctic environment. Understanding these processes will help us predict the effect that changes in anthropogenic emissions and changes in the Arctic climate will have on Hg deposition.
- To assess the impact of Hg cycling and emissions from areas in the Pacific Rim and western Canada to the Canadian western Arctic using measurements at the Little Fox Lake site.

Introduction

The Canadian Mercury Science Assessment concluded that mercury (Hg) remains a risk to Canadian ecosystems and human health (Canada, 2016). The preamble to the Minamata Convention on Mercury declares that "The Parties to this Convention, note the particular vulnerabilities of Arctic ecosystems and indigenous communities *to mercury* [sic]…". Additionally, Hg continues to be a pollutant of concern by the Arctic Council. In this manner, the issue of Hg levels in the Arctic has been globally recognised as a priority. This project provides long term information on the temporal trends of Hg in the air and snow in the High Arctic, contributes to understanding the spatial variability of Hg in the air, and assesses how the behaviour of Hg in the atmosphere may impact the pristine Arctic.

Canadian anthropogenic emissions of Hg to the air have decreased 85% between 1990 and 2010. Ambient air levels have also decreased in Canada on average 18% (ranging between 10 and 26% over various time periods between 1995 and 2011) with Alert being on the lowest end of this trend. Interestingly, global emissions of anthropogenic Hg are not following the same pattern of decline and are increasing in some locations. This is important because 95% of the anthropogenic Hg deposited in Canada comes from sources outside of the country. In addition, with climate change occurring at a rapid pace in Arctic regions, changes in atmospheric dynamics and chemistry will likely have an impact on how pollutants such as Hg are transported through the atmosphere and deposited to this environment. Thus, monitoring of atmospheric Hg is required to evaluate both global and regional changes to the Hg cycle.

While European and North American emissions of atmospheric Hg have decreased since 1995, emissions in other regions such as Asia and Africa have increased (Streets *et al.*, 2011). Circulation patterns show that air masses originating in Asia can enter the Canadian Arctic (Durnford *et al.*, 2010) and thus the increase in Asian emissions are particularly important to the Canadian North. It has been established by modellers that the Little Fox Lake site in the Yukon is an ideal location to measure input from the Pacific Rim, and the data collected at both Little Fox Lake and Alert have been used to model source regions of Hg to these sites (Durnford et al., 2010).

The annual time series of GEM at Alert shows a repetitive distinct seasonal cycling of Hg. Alert is a coastal site near the Arctic Ocean and thus is subject to intense atmospheric chemical reactions in the Arctic springtime that convert Hg in the air so that it can more easily deposit to surfaces. Alert also reports increased levels of GEM in the summer season. Neither of these phenomena is reported inland at the high altitude site in the Yukon. It is known that the Arctic Ocean plays a strong role in the atmospheric transformation and deposition of Hg, thus the cycling of mercury in the Yukon interior differs from Alert. For the first time, a trend analysis on the Little Fox Lake Hg data was performed as a sufficient amount of data is available to render the results statistically significant.

The data collected by this NCP program serves to monitor long term and seasonal trends of Hg in the high- and sub-Arctic. It provides important information on the atmospheric transport, transformation and deposition processes of this priority pollutant throughout the Polar Regions. The data collected from this program is used by chemists, modellers and those influencing policy decisions on Hg.

Activities in 2015-2016

Research activities

Ground-based continuous atmospheric measurements of total gaseous mercury (TGM)[1], gaseous elemental mercury (GEM), reactive gaseous mercury (RGM) and particulate mercury (PHg) continued at Alert. Site visits for maintenance and calibration of all mercury instruments at Alert were made in April 2015, November 2015 and February 2016 on top of regular checks by the onsite operator and student. Continuous measurements of TGM at Little Fox Lake were also carried on through 2015-2016 and a technical site visit was made in October 2015. Contractors from Laberge Environmental visit the Little Fox Lake site on a weekly basis to check the instrument, download the data and perform minor repairs to the instrument on site.

Data from both sites for the year 2015 are reviewed monthly and have been quality controlled; after review and acceptance of the final product by the principle investigator, this data will be submitted to the Environment Canada Data Catalogue (ECDC) (http://donnees-data.intranet.ec.gc.ca:8080/geonetwork/home/eng) and the AMAP database. Data from previous years that had previously been submitted to the National Atmospheric Chemistry (NAtChem) database will be migrating to the ECDC in 2016[2]. Metadata from this program have also been updated in the Polar Data Catalogue (PDC); the existing link from the PDC record to the NAtChem database will be updated to the ECDC once the data have migrated.

Filter and snow samples were collected for Hg and lead (Pb) stable isotopic analysis in collaboration with the University of Toronto. Most of the Hg samples have been analyzed for the Hg particulate and all years for Pb particulate and snow samples. Filter samples were not collected in 2015 but some snow samples were collected. Filter samples were reinstated in March 2016. In addition to Hg isotopes, filter and snow samples were also collected for other trace metals (*i.e.,* Pb, Cu, Zn, Ni) and Pb isotopes in order to potentially aid with interpretation of Hg isotope data. This year passive air samplers for Hg isotopes were deployed in spring 2016.

Snow samples continued to be collected at Alert both weekly (from the ground) and on a per event basis (from a Teflon table). In addition, snow samples from over the sea ice to inland were also collected. All snow samples collected up to the end of 2014 and most from 2015 have been analyzed at the Water Science and Technology Branch in Burlington, Ontario.

1 TGM at Alert is considered to be almost entirely GEM at Alert.

2 The delays continue at ECCC in getting the final data onto the new national database. The data is available to anyone upon request until the database has been finalized.

Capacity Building

As in previous years, the NCP atmospheric organic pollutants and Hg monitoring projects have joined forces for communication and capacity building activities because they are closely related in terms of goals, facilities and technical support. Hayley, Sandy and Liisa travelled to Iqaluit in February 2016 to give a presentation and a hands-on demonstration at the Nunavut Arctic College. This trip was very successful and we had an excellent day with the students from the Environmental Technology Program. We spent the morning in the classroom discussing Hg and POPs monitoring in the Arctic and then spent the afternoon in the laboratory with the students explain how to sample and run some instrumentation.

Hayley and Sandy continued to work with the Yukon College by giving a remote full web-ex seminar to an environmental science class in November 2015. They have also recorded a seminar for the ENVS100 online course as part of the Yukon College. Some technical challenges were encountered but overcome and the full recording of the presentation has been made and needs to be finalized and sent to Nicolaus Gantner. As well, when in Kuujjuaq for the M03 project, Hayley and Sandy connected with the local high school science teachers and gave a class lecture on Hg and POPs in the Arctic to students in grades 10 and 11.

Communications

In June 2015, Sandy and Hayley went to the Yukon for the official transfer of the Little Fox Lake site. This was the official transfer of the site operations from the Yukon College to the Council of First Yukon Nations (CYFN). The transfer included a site visit by some of the local Yukon Contaminants Committee (YCC) members and our partner from the Ta'än Kwach'än Council. An elder from the Ta'än Kwach'än Council came to the site to provide the history of the location and to approve the transfer on behalf of the Ta'än Kwach'än community. A tour of the site and discussions about the research were provided to the whole group. In September, Hayley and Sandy visited Kuujjuaq to discuss the passive air sampling program by meeting with the Kativik Regional Government Administration. In November 2015, Sandy and Geoff visited Whitehorse and met with some members of the YCC to discuss current research activities and started to discuss plans for the forthcoming year. In January, Hayley, Liisa and Sandy met with the NECC members to discuss the ongoing projects and progress.

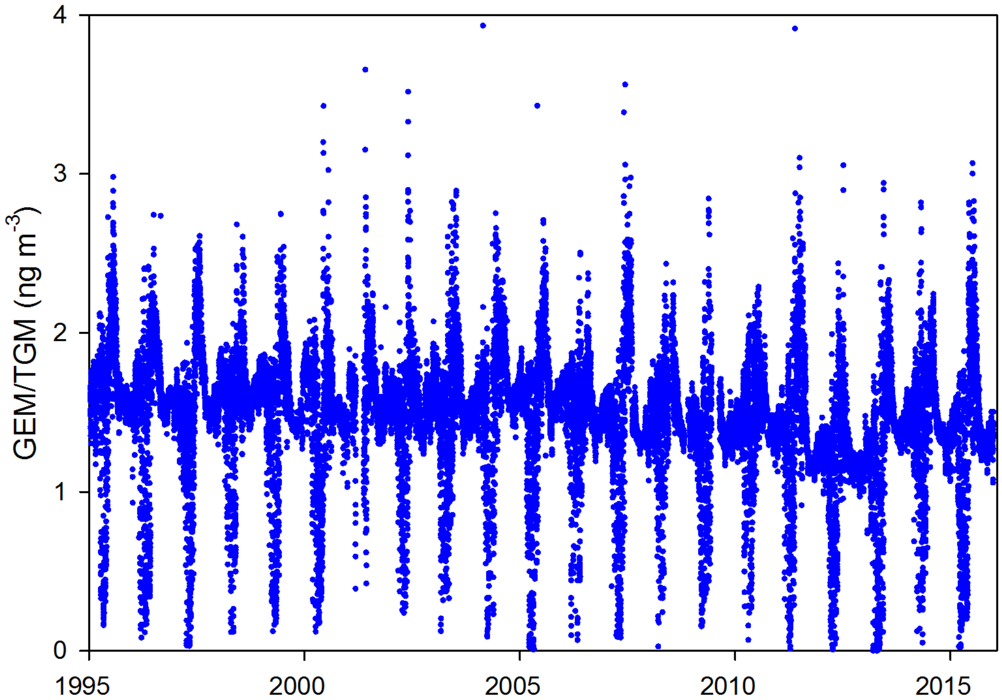
Traditional Knowledge

At this time, we are working on how best to incorporate traditional knowledge into our long term measurements at Alert and Little Fox Lake. While in Whitehorse, Sandy and Geoff met with Derek Cooke (Ta'än Kwach'än Council) and Bob VanDijken Council of First Yukon Nations (CYFN) and began discussions about engaging a Yukon student to research ideas on how to integrate traditional knowledge into the NCP air monitoring program. A further discussion happened in Vancouver where a plan was developed. Sandy and Hayley met with a potential student from the Yukon in March in Toronto and discussed options and a plan for this project. This plan was included in proposed work under the M03 project proposal and we await a decision on the success of this proposal.

Results

Figure 1 shows the total gaseous mercury (TGM) 6 hour averages for Alert (top) from 1995 to 2015 and for Little Fox Lake (bottom) from 2007 to 2015. We have 20 years of this data from Alert and 8 years of data from Little Fox Lake.

Figure 1: Time series of total gaseous mercury (TGM) from both Alert (top) and Little Fox Lake (bottom) up to the end of 2015. Data presented in 6 hour averages.



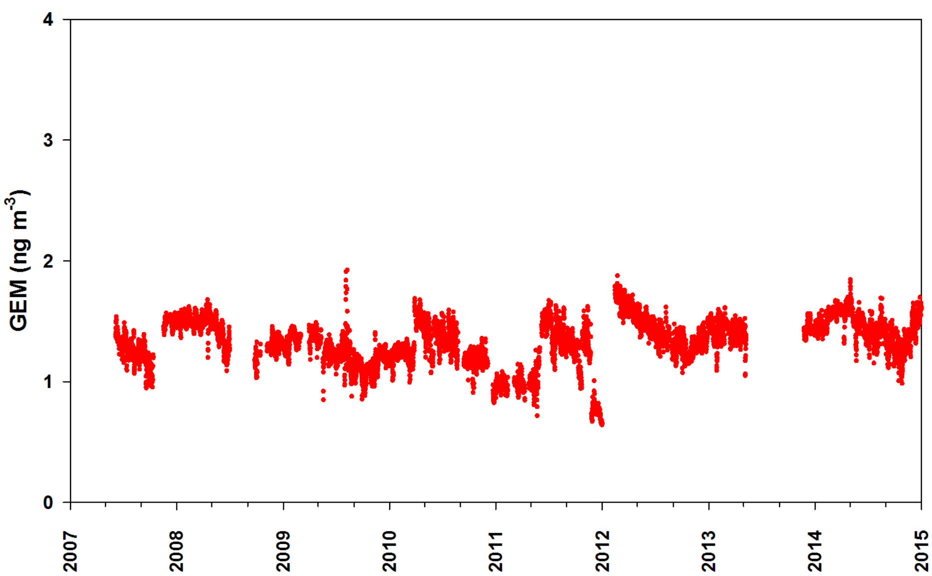


Figure 2 shows the seasonal variation for the Little Fox Lake (top) and Alert (bottom) data as box and whisker plots. Monthly and annual trend analyses were done for the Alert data from 1995 to 2013 and for Little Fox Lake from 2007 to 2014.

Figure 2: Monthly box and whisker plots of total gaseous mercury (TGM) at Little Fox Lake (top) and Alert (bottom). Data presented are daily averaged with days that contained more than 80% data completeness for that day.

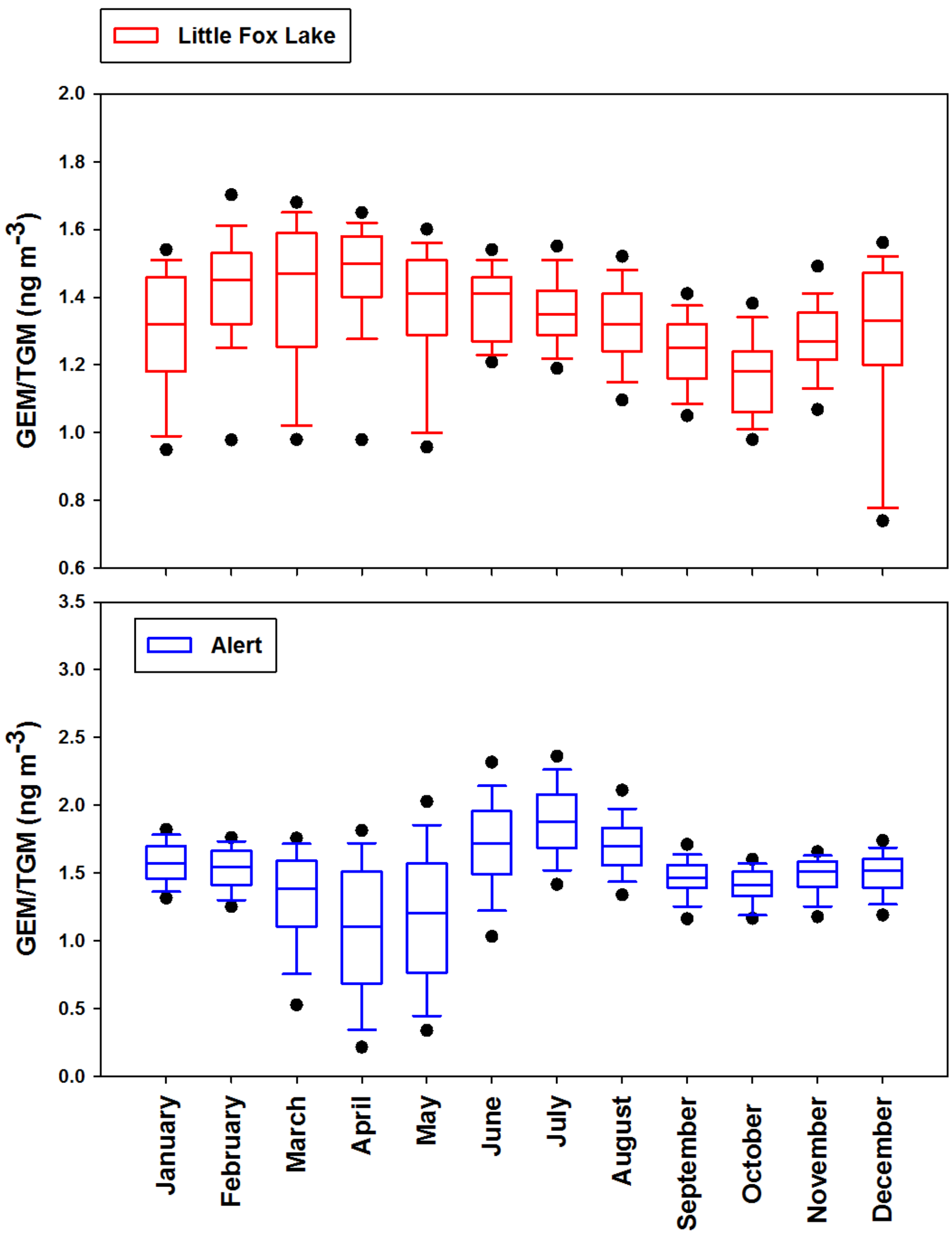


Figure 3: Monthly trends calculated from the TGM data collected at Alert (top) and Little Fox Lake (bottom). Boxes above zero represent an increasing trend and below zero represent a decreasing trend for a given month.

The monthly trend analyses are shown in Figure 3.

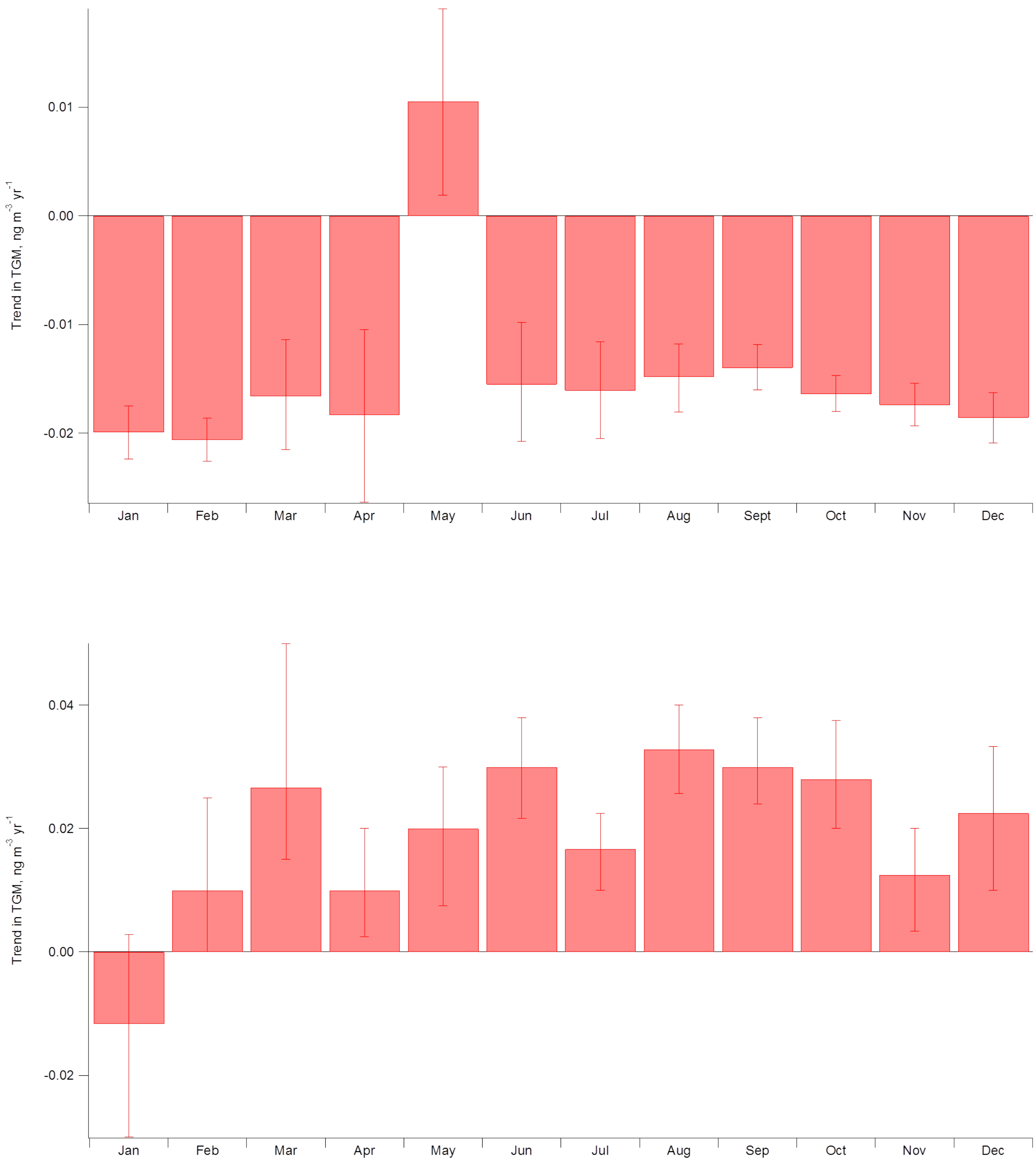


Figure 4: Atmospheric mercury speciation data from Alert up to the end of 2015. Data is presented in 6 hourly averages. Blue represents gaseous elemental mercury (GEM), pink represents reactive gaseous mercury (RGM) and green represents particulate mercury (PHg).

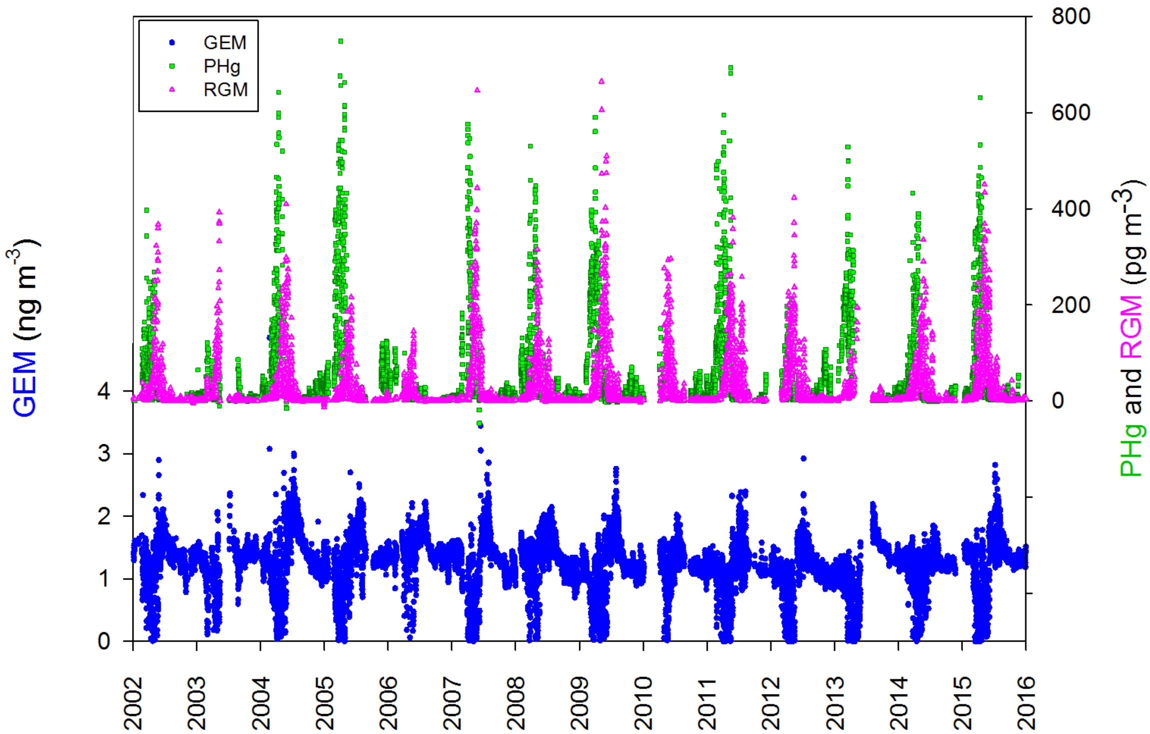


Figure 4 shows the long term mercury speciation data from Alert including gaseous elemental mercury (GEM), reactive gaseous mercury (RGM) and particulate mercury (PHg) from Alert from 2002 to 2015.

Figure 5: Mercury isotopes in snow and aerosols collected at Alert from March to July for years 2011, 2013, 2014 and 2015. Mercury mass dependent fractionation (MDF) (δ202Hg) is plotted versus Hg mass independent fractionation (MIF) (Δ199Hg). Also plotted is data from two other studies that measured snow in the Artic in Barrow, Alaska, USA (Sherman et al., 2012; Sherman et al., 2010).

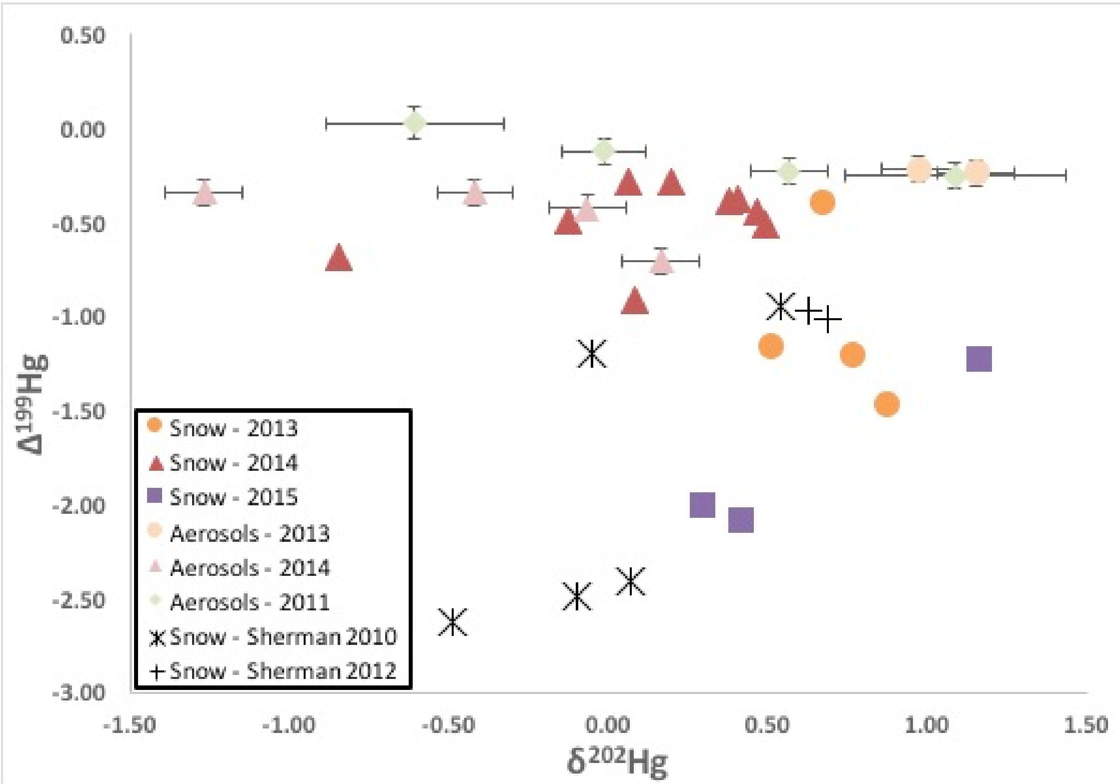


Figure 5 shows initial results from the Hg isotope snow and particle study. A discussion of these results follows.

Discussion and Conclusions

Data collection was again the primary focus of this year. Figure 1 shows the quality controlled data[3] from both Alert and Little Fox Lake up to the end of 2015. The patterns from the GEM data at Alert continue to demonstrate the strong seasonal variability in the Hg levels at this site. As well, the data from Little Fox Lake show a distinct seasonal cycle. Figure 2 shows the monthly box and whisker plots TGM at Little Fox Lake (top) and Alert (bottom). The top graph shows higher levels of Hg in the winter and spring months from December to May with some periodic low concentrations. TGM levels are lower from June to November and have less variability with few very low concentrations. This pattern is in keeping with elevated Hg levels emitted in winter months from elevated heating use, likely from long range transport. The lower levels are likely an indication of local ambient air concentration or long range transport. The monthly trends from Alert are consistent with data presented in earlier synopsis reports. Figure 3 shows the monthly trends calculated from the TGM data collected at Alert (top) and Little Fox Lake (bottom). Boxes above zero represent an increasing trend and below zero represent a decreasing trend for a given month. The Alert data shown in Figure 3 describes trends from 1995 to 2013 and is consistent with trends that were published on earlier data (Cole et al., 2014). The Little Fox Lake trends have been calculated from data collected between 2007

3 2015 data is preliminarily quality controlled but is not the final data set

and 2014. This data shows that from March to December, levels of Hg at Little Fox Lake are increasing (January and February trends were not statistically significant). It is easy to suggest that this increase is a reflection of the increases in Hg emissions from Asia but it is not as straightforward because other factors impact the Hg levels measured at this site, primarily local and regional forest fires. Further investigation into this interesting trend result will be undertaken this next year. Figure 4 shows the Hg speciation data from Alert up to the end of 2015. This figure shows that there remains a consistent pattern in the speciation data with time.

Hg isotopes in snow and aerosols have been measured at Alert to assess the feasibility of making Hg isotope measurements and to assess if Hg isotopes can help to understand and distinguish the various Hg sources, transport pathways and transformations in the Arctic. Preliminary Hg isotope data in snow and aerosols (shown in Figure 5) from Alert show a large range in both mass dependent fractionation (MDF) (3‰) and mass independent fractionation (MIF) (2‰), well outside analytical uncertainty. MDF is found all through nature, occurs in both scientific (equilibrium and kinetic) processes and is reported as δ202Hg. In contrast, Hg MIF signatures are only produced in a subset of transformations where different transformations have unique Hg MIF signatures that can be distinguished from one another. Hg MIF is reported using ΔxxxHg nomenclature, where xxx is the isotope of interest and is the deviation from MDF. Results from the Alert snow and aerosol samples have Hg MIF signatures (Δ199Hg/Δ201Hg) consistent with photochemical reduction in either aqueous or solid surface reactions. This supports quantitative conversion of Hg0 to Hg2+ in the atmosphere and that this Hg2+ is the main source of Hg to the snow in the Arctic spring. This means that the Hg collected at Alert in these samples has gone through changes consistent with light interactions and that this is the main source of Hg in the snow during this time period and is not coming from elsewhere.

Overall, this year focused on the continued collection of data and a preliminary look at the Little Fox Lake Hg trends. With these interesting results, we will continue to investigate the trends at Little Fox Lake. A more in depth investigation into ongoing measurements at Alert for air and snow are planned for the upcoming year.

Expected Project Completion Date

ongoing

Acknowledgements

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References

Environment and Climate Change Canada (ECCC). 2016. Canadian Mercury Science Assessment, Summary of Key Results. Toronto: Environment and Climate Change Canada, 1-38 pp.

Cole, A. S., Steffen, A., Eckley, C. S., Narayan, J., Pilote, M., Tordon, R., Graydon, J. A., St Louis, V. L., Xu, X., and Branfireun, B. 2014. A Survey of Mercury in Air and Precipitation across Canada: Patterns and Trends. *Atmos.* 5: 635-668

Durnford, D., Dastoor, A., Figueras-Nieto, D., and Ryjkov, A. 2010. Long range transport of mercury to the Arctic and across Canada. *Atmos. Chem. and Phys.* 10: 6063-6086.

Streets, D. G., Devane, M. K., Lu, Z., Sunderland, E. M., and Jacob, D. J. 2011. All-time releases of mercury to the atmosphere from human activities, *Environ. Sci. Tech.* 45: 10485-10491.

Sherman, L. S., Blum, J. D., Johnson, K. P., Keeler, G. J., Barres, J. A., and Douglas, T. A. 2010. Mass-independent fractionation of mercury isotopes in Arctic snow driven by sunlight. *Nat. Geosci.* 3: 173-177.

Sherman, L. S., Blum, J. D., Douglas, T. A., and Steffen, A. 2012. Frost flowers growing in the Arctic ocean-atmosphere-sea ice-snow interface: 2. Mercury exhange between the atmopshere, snow and frost flowers. *Jour. of Geophys. Res. D: Atmos.* 117.

Passive Air Sampling Network for Organic Pollutants and Mercury

Réseau d'échantillonnage atmosphérique passif de mesure des polluants organiques et du mercure

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Abstract

This project measures pollutants, namely persistent organic pollutants (POPs) and mercury, in the air at multiple locations across Canada's North. When POPs and mercury enter the ecosystem, they may affect the health of northerners. Currently, there are few locations in Canada's Arctic where these pollutants are being measured. Pollutants are carried through the air from more southerly regions to the Arctic, and expanding the number of locations where they are measured will provide more information about where they come from and how they are changing over

Résumé

Ce projet vise à mesurer les polluants atmosphériques, dont les polluants organiques persistants (POP) et le mercure, dans différents sites du Nord canadien. Lorsqu'ils entrent dans l'écosystème, les polluants organiques persistants et le mercure peuvent influer sur l'état de santé des résidants du Nord. Actuellement, ces polluants sont mesurés à quelques endroits de l'Arctique canadien. Ils sont transportés dans l'air à partir de régions du sud de l'Arctique. En augmentant le nombre de sites de mesure, on obtiendra un plus grand nombre de données sur l'origine des polluants et sur la manière dont

time. To increase the geographical coverage and to obtain a more comprehensive picture of the levels of pollutants, passive sampling methods are used. Passive air samplers (PASs) are a low-cost, low-maintenance way to monitor air pollutants and therefore ideally suited to the Arctic environment. This method also provides opportunities for involving students or other interested persons in sample collection, enhancing communication between the project team and local communities as well as creating training opportunities for Northern students. The project will gather data over 3-4 years, eventually producing air concentrations of multiple pollutants at a network of sites across the North. Passive air samplers and sampling material were sent to seven sites across the North to start air sampling in October 2014. Some issues were encountered resulting in the delayed starts but most sites are in full operation and we continue to work on resolving the issues to get all sites up and running. Laboratory and initial tests for developing a passive mercury air sampler were completed and a scientific paper reporting progress on this work has been published. Project Principal Investigators visited Iqaluit (Nunavut), Whitehorse (Yukon) and Kuujjuaq (Nunavik) to discuss with the respective Regional Contaminants Committees and community leaders about the project plans and site selections. They also conducted communication/ capacity building activities, including lectures at the Nunavut Arctic College and the Jaanimmarik School in Kuujjuaq; and a webinar at the Yukon College.

ils évoluent au fil du temps. Afin d'accroître la couverture géographique des contaminants et d'obtenir ainsi une meilleure vue d'ensemble des concentrations de polluants, on utilise des méthodes d'échantillonnage passif. Les échantillonneurs atmosphériques passifs sont peu coûteux, constituent un moyen exigeant peu d'entretien de surveiller les polluants atmosphériques et, par conséquent, sont bien adaptés au milieu arctique. La simplicité de la méthode favorise également la participation d'étudiants et d'autres personnes intéressées au prélèvement d'échantillons, améliore la communication entre l'équipe de projet et les collectivités locales et crée des occasions de formation pour les étudiants du Nord. Le projet recueillera des données sur trois à quatre ans, et permettra de compiler les concentrations atmosphériques de nombreux polluants au sein d'un réseau de sites disséminés dans le Nord. En octobre 2014, on a envoyé des échantillonneurs atmosphériques passifs de polluants organiques persistants et du matériel d'échantillonnage vers sept sites du Nord afin d'entamer le processus d'échantillonnage atmosphérique. On a éprouvé certains problèmes, qui ont retardé les débuts, mais la plupart des sites sont maintenant opérationnels, et nous continuons de travailler à la résolution des problèmes afin de mettre en œuvre l'ensemble des sites. Les essais en laboratoire et les essais initiaux en vue de mettre au point un échantillonneur atmosphérique passif pouvant mesurer le mercure ont été effectués, et un article scientifique faisant état de ce travail a été publié. Les directeurs du projet se sont rendus à Iqaluit (Nunavut), à Whitehorse (Yukon) et à Kuujuaq (Nunavik) afin de discuter avec les comités régionaux des contaminants et les dirigeants des collectivités des plans du choix des sites pour le projet. Ils ont également tenu des activités axées sur la communication et le renforcement des capacités, dont des conférences au Collège de l'Arctique du Nunavut et à l'École Jaanimmarik à Kuujjuaq, ainsi qu'un webinaire au Collège du Yukon.

Key messages

In 2015/16, the project team continued to focus on coordinating the installation of passive air sampling sites and collection of first samples, as well as communication, consultation and capacity building:

- Passive air sampling equipment has been sent to seven arctic sites and most stations were in operation since October 2014.
- Project Principal Investigators visited Iqaluit (Nunavut), Whitehorse (Yukon) and Kuujjuaq (Nunavik) to discuss with the respective Regional Contaminants Committees and community leaders about the science activities and communication/outreach plans under this project. They also conducted communication/capacity building activities, including giving lectures at the Nunavut Arctic College and the Jaanimmarik School in Kuujjuaq ;and a webinar at the Yukon College
- Prototypes of the mercury passive air samplers are currently being tested at Alert (Nunavut) and Little Fox Lake (Yukon) to compare with the automated active mercury sampling systems there. Once they are fully tested, they will be used at the seven passive air sampling sites to measure air concentrations of mercury.

Messages clés

En 2015-2016, l'équipe du projet a continué de se concentrer sur la coordination des installations des sites d'échantillonnage atmosphérique passif, de même que sur la communication, les consultations et le renforcement des capacités.

- On a envoyé de l'équipement d'échantillonnage atmosphérique passif à sept différents sites dans l'Arctique et la plupart des stations étaient opérationnelles en octobre 2014.
- Les directeurs du projet se sont rendus à Iqaluit (Nunavut), à Whitehorse (Yukon) et à Kuujjuaq (Nunavik) afin de discuter avec les comités régionaux des contaminants et les dirigeants des collectivités respectifs des activités scientifiques ainsi que des plans de communication et de sensibilisation liés au projet. Ils ont également tenu des activités axées sur la communication et le renforcement des capacités, dont des conférences au Collège de l'Arctique du Nunavut et à l'École Jaanimmarik à Kuujjuaq, ainsi qu'un webinaire au Collège du Yukon.
- Les prototypes d'échantillonneurs atmosphériques passifs pouvant mesurer le mercure sont en cours d'essai à Alert (Nunavut) et au lac Little Fox (Yukon) afin de faire la comparaison avec les systèmes d'échantillonnage du mercure automatisés actifs qui s'y trouvent. Une fois qu'ils seront totalement éprouvés, ils seront utilisés sur les sept sites d'échantillonnage atmosphérique passif afin de mesurer les concentrations atmosphériques de mercure.

Objectives

Short-term objectives of this project are:

1. Expand the geographic coverage of the air monitoring program by developing, installing and operating passive air sampling devices capable of operating remotely under extreme conditions at up to seven new locations across all Arctic regions. Separate devices will be deployed for POPs and mercury.

2. Determine latitudinal gradients in air concentrations from which empirical estimates of characteristic travel distances (CTDs) of pollutants can be made.

3. Engage with and train Northern residents, likely affiliated with local colleges, for the deployment of samplers and collection of samples in order to provide training opportunities for northern students and provide local information on pollutants to northern communities.

4. Provide spatially-distributed concentration data for this under-represented region to atmospheric modellers, to assist in model validation and improvement.

Long-term objectives of this project are:

1. Provide key data to evaluate the overall effectiveness of the provisions outlined in the Stockholm Convention, the CLRTAP Protocols on POPs and Heavy Metals and the Minamata Convention.

2. Complement active monitoring at Alert and Little Fox Lake to provide a more geographically complete picture of atmospheric contamination and assess global transport pathways and sources.

3. Track long-term trends in pollutants to evaluate the effect of global and regional environmental changes at multiple Arctic locations.

Introduction

This new project aims at measuring POPs and mercury in Arctic air using passive air sampling methods that will provide scientific information on the spatial distribution and input of these contaminants to the Arctic environment. For the last two decades, air monitoring programs were limited to continuous monitoring of POPs and mercury at Alert and Little Fox Lake and POPs at a few satellite stations for 1-2 years. Expanding the spatial distribution of air monitoring within the Canadian Arctic would be extremely valuable for further constraining atmospheric models of pollutant transport, chemistry and deposition, since current validation data is so sparse. This project aims to achieve this objective using passive air sampling methods which are low-cost, low-maintenance and easy to deploy at multiple locations.

It builds upon the two NCP core air monitoring projects for POPs and mercury in air (M01 and M02), as well as the Global Atmospheric Passive Sampling (GAPS) network, which conducts air monitoring of POPs at 50+ sites worldwide. There are currently eight Arctic sites operating under GAPS with three in the Canadian Arctic region (i.e. Little Fox Lake, Alert, and Coral Harbour). Our additional sites would expand coverage and develop an Arctic network of passive air samplers. The other 50+ sites under GAPS will provide reference in terms of levels and context for investigating long-range atmospheric transport and spatial distributions on a global scale. The team will collaborate with the GAPS network to deploy both the XAD-based (one-year integrated sampling) and PUF-disk-based (3-month integrated sampling) PAS at 7 Arctic sites. The PUF-PAS will provide seasonal air concentration data for POPs while the XAD-PAS will be able to capture more volatile and polar chemicals [e.g. per- and polyfluoroalkyl substances (PFASs)] and is ideal for sampling in locations with relatively low air concentrations of organic contaminants, such as the Arctic.

In 2014-15, the PASs for POPs measurements were sent out to 7 sampling sites (Iqaluit, Inuvik, Cambridge Bay, Fort Resolution, Kuujjuaq, Nain and Northwest River) and most of these sites were in operation since October 2014. The samples will be sent back to Environment and Climate Change Canada (ECCC) where they will be analyzed for priority chemicals. Results for legacy chemicals, e.g. organochlorines (OCs), and flame retardants (FRs), will be available for dissemination back to the school and participating communities. Results will be put into context with historical global results from the GAPS program.

The team initiated the development of the mercury PAS, which is composed of a small cylindrical container for activated carbon inserted into a diffusion tube of the commercial Radiello type PAS. The team has successfully acquired an ECCC Grants and Contribution funding for FY2014/15 and FY2015/16 to continue this sampler development. In October 2014, team member Prof. Frank Wania (University of Toronto) received funding from an NSERC Strategic Grant that will provide the team with funding for 3 years to continue the development, laboratory and field testing for this device.

Activities in 2015-2016

Initiation of Passive Air Sampling Sites

Sampling at most of the seven sites started in winter 2014/15. The Kuujjuaq sampling site is on Category 1 land which required the Land-holding Corporation of Kuujjuaq for approval of site use. The approval was granted in December 2014 but the ground was frozen and it was not possible to install the post which holds the samplers. The samplers were finally installed on June 6th, 2015. Rodd Laing (Nunatsiavut Government) has made arrangements to install the Northwest River site by local colleagues but communication has been lost and the station was not installed. A site has now been selected and will be installed in early 2016. At the Cambridge Bay station, the first sample deployed has not been collected for more than 1 year because of staff changeover. The samplers were first installed at the Upper Air Station (UAS). Intense development (including a quarry and building of new roads) close to the UAS has started in summer 2015 which was unexpected. A new operator, Angulalik (Angut) Pedersen (Canadian High Arctic Research Station), has now been identified. He will assist with finding a new and more suitable station for sampling in early 2016 and the samplers will be moved. PIs Hayley Hung and Sandy Steffen are planning to visit Cambridge Bay in September 2016 and will perform an inspection of the site. For the other stations, some delays were encountered due to staff changeover, poor weather conditions and/or damage to the samplers, but sampling is currently ongoing. Some errors regarding sample deployment schedules were also encountered during the first year of sampling. We are in continuous communication with the various sampling sites to ensure that these problems are resolved in the fiscal year of 2016/17.

Mercury PAS Development

A prototype of the mercury passive sampler was developed. The sampler consists of a stainless steel mesh cylinder filled with activated carbon placed in a commercially produced radial diffusive barrier and housed in a PET external windshield, which doubles as a storage and transport container. Indoor and outdoor experiments were performed, in which multiple samplers were deployed for increasing periods of time ranging from a few days to a year alongside a Tekran mercury vapour analyser that continuously recorded gaseous elemental mercury (GEM) concentrations. A paper was published reporting these results (McLagan et al., 2016). The initial results show that these PASs may be suitable for monitoring ambient air concentrations, depending on their performance under a wider range of environmental conditions. To that end, they are currently being tested at Alert and Little Fox Lake, as well as at multiple air monitoring sites around the world where automated active mercury sampling systems are in operation.

Communications and Capacity Building

Hayley Hung and Sandy Steffen visited Kuujjuaq between Sep 30 and Oct 2, 2015. Guided by operator Monica Nashak, Hayley and Sandy inspected the passive air sampling station. Hayley and Sandy also met with Michael Barrett at the Kativik Regional Government to discuss about the project. They gave a seminar about air monitoring of POPs and mercury in the Arctic under NCP to the Jaanimmarik School Grade 10-11 science class and the seminar was well received. The science teachers are now in contact with operator Véronique Gilbert to potentially bring the students out to visit the site and observe how samples are changed. Unfortunately we were unable to meet with Elena Labranche (Nunavik Nutrition and Health Committee) who had to travel to another community during our visit.

Hayley Hung and Alexandra Steffen visited Iqaluit in January 2016 to conduct a half-day lecture and half-day activity session to the students of the Environmental Technology Program at the Nunavut Arctic College. While in Iqaluit, they met with the Nunavut Environmental Contaminants Committee (NECC) to discuss about communication/ capacity building activities related to this project.

Hayley and Sandy attended the hand-over ceremony of the Little Fox Lake station in June 2015 which was attended by representatives of the Ta'än Kwach'än Council. Little Fox Lake is located in the Ta'än Kwach'än First Nations' traditional territory. The PIs gave a tour of the site, showing how the instruments are used for air measurements of POPs and mercury. A student webminar at the Yukon College (with Instructor Larry Gray) was conducted remotely on November 26th, 2015. A short video was compiled for Yukon College's Environmental Science online course for 2016 (ENVS100) showcasing air monitoring of POPs and mercury under NCP, with special focus on the measurements at Little Fox Lake.

Two instructors from the Nunavut Arctic College (Jason Carpenter and Daniel Martin) visited Hayley's and Sandy's laboratory in Toronto and Liisa Jantunen's laboratory in Egbert in Feb 2016. The potential for future laboratory training/exchange activities so that Northern students/ operators can be trained in the Toronto/Egbert laboratories was discussed. We have also discussed about how to improve the annual seminar and hands-on session at the college.

At Fort Resolution, operators Rosie Bjornson and Shawn Mckay trained youths, including Nicole McKay and Kathleen Fordy (DKFN Aquatics Coordinator trainees), to collect PAS samples. They are also planning to take local students to the site and train them on the sample changing procedure.

Signage and notification have been provided to site operators to make sure that the communities are aware of the presence of the samplers to ensure that they are secure and would not be subjected to contamination (e.g. smoke or vehicles exhaust) and destruction (e.g. used as targets during hunting).

Traditional Knowledge Integration

Regional Contaminants Committee (RCC) representatives and community members contributed traditional/local knowledge of preferred site locations to ensure samples collected will be regionally representative and are not subjected to local emission influences (e.g. landfills, incinerators, mines, highway traffic etc.).

In consultation with Derek Cooke (Ta'än Kwach'än Council), Bob Van Dijken (CYFN) and Pat Roach (INAC), we have engaged a Yukon student, Jamie Thomas, to potentially research on the integration of TK into the NCP air monitoring projects of POPs and mercury if funding permits in FY2016/17. Jamie visited the Downsview facility of ECCC in March 2016 and discussed with Sandy and Hayley about this potential project. The project plan is to develop an outreach/communication/TK package which Jamie could bring to various First Nations communities and during these visits, she will bring back TK information that is best suited for integration into the air monitoring projects for POPs and mercury. We hope that Jamie will be able to undertake discussions with community members on wind and air and what it means to northerners. Outcomes of the project may be a video, presentation or written materials summarizing discussions and ideas.

Results

Initiation of Passive Air Sampling Sites

PAS sampling equipment was sent to seven Arctic sites. Figure 1 shows the site map and photos of the stations. Table 1 shows the locations of the sites. Some of the samples from 2014/2015 were collected and are currently undergoing extraction and analysis at the Organics Analysis Laboratory (ECCC) in Toronto.

Mercury PAS Development

Test deployment of the mercury PASs started in April 2015 at Alert (Figure 2), followed by Little Fox Lake in October 2015 (Figure 3), for comparison of results with the active monitoring at these sites. These samplers are also deployed at a number of sites worldwide under the NSERC Strategic Grant project with Prof. Wania to test their feasibility under various environmental conditions. Once the performance of the mercury PAS has been fully characterized, they will be deployed to the seven passive sampling sites.

Discussion and Conclusions

In 2015/16, the team focused on initiating the POPs passive air sampling sites and ensuring that the samples are collected and delivered to the laboratory. First samples have been received at the OAL. Results will be disseminated after sample and data analysis.

Figure 1. Site Map and Photos for Passive Air Sampling Stations in the Canadian Arctic. In Fort Resolution, Kathleen Fordy (DKFN Aquatics Coordinator trainee) making a sample change. In Nain, Rodd Laing (Nunatsiavut Government) with youth Jonathan Lidd.

Table 1. Site Location (Note that for Northwest River exact latitude and longitude are not yet available. The team will verify the exact location when the sampler is installed.)

Name	Location (Lat/Long)
Inuvik	68° 21.417′ N, 133° 42.832′W
Cambridge Bay	69°7.844′N, 105°3.395′W
Fort Resolution	61°10′ N, 113°45′W
Kuujjuaq	58° 14.6′ N, 68°21′W
Iqaluit	63°44′ 27.5″N, 68°27′56.7″W
Nain	56° 31′ 30.9″N, 61°43′ 29.3″ W
Northwest River	53°31.5′ N, 60°8.5′W (estimated)

Figure 2. Mercury passive air samplers at Alert

Figure 3. Mercury passive air samplers at Little Fox Lake

Expected Project Completion Date

Ongoing

Acknowledgments

The team would like to acknowledge NCP (INAC) for funding the passive air sampling network. The continued support of the 5 RCCs, northern community members and associations of the passive air sampling initiative is greatly appreciated. Initial seed funding for the development of the mercury PAS was provided by NCP (INAC) in fiscal year 2013/14. Since then further development and field testing of the sampler is supported by an Environment and Climate Change Canada Grants and Contribution agreement and an NSERC Strategic Grant to the University of Toronto.

References

McLagan, D. S., Mitchell, C. P. J., Huang, H., Lei, Y. D., Cole, A. S., Steffen, A., Hung, H., Wania, F. 2016. A high precision passive air sampler for gaseous elemental mercury. Environ. Sci. Tech. Letters. 3: 24–29.

Temporal Trends of Persistent Organic Pollutants and Metals in Ringed Seals from the Canadian Arctic

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

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Abstract

The objective of this project is to determine changes in concentrations of legacy contaminants, such as PCBs and other persistent organic pollutants (POPs), and mercury in ringed seals. All sampling is done with the help of hunter and trapper committees in each community who are supplied with sampling kits and instructions. The sampling effort in 2015 was very successful at all four sites: Sachs Harbour, Resolute, Arviat and Nain. During the past year, we specifically

Résumé

Ce projet a pour but de déterminer les changements quant aux concentrations d'anciens contaminants, comme les BPC et d'autres polluants organiques persistants (POP), et le mercure, chez les phoques annelés. Tout l'échantillonnage est effectué avec l'aide de comités de chasseurs et de trappeurs dans chacune des collectivités visées, auxquelles on remet des trousses d'échantillonnage et des instructions à cet égard. L'effort d'échantillonnage mené

assessed the spatial and temporal trends of polychlorinated naphthalenes (PCNs) and brominated flame retardants (BFRs) in blubber of seals collected between 1998 and 2014 in the central archipelago (mainly at Resolute), Hudson Bay (Arviat and Inukjuaq) and the southern Beaufort Sea region (Sachs Harbour, Ulukhaktuk) as well as perfluoroalkyl substances in liver samples. Perfluorooctane sulfonate (PFOS) concentrations have declined in seals from Sachs Harbour (2011-2014) but increased in Western Hudson Bay over the same period and remained stable in Lancaster Sound. PCN levels ranged from 1 to 6 ng/g l.w. across locations and have declined in seals from 2011 to 2014. Flame retardants results indicated that the highest ΣPBDE concentrations were found in seals in Nain, Inukjuaq, and Arviat and the lowest levels in seals from Lancaster Sound. A significant decreasing trend in PBDEs since 2008 has been observed in seals from East Baffin. Blubber concentrations of newer BFRs, bis-(tribromophenoxy)-ethane (BTBPE) and hexabromocyclododecane (HBCDD), were also found to have significantly increased at several sites during the past decade. The increases of some flame retardants in ringed seals and levels of PFASs suggest their continuous inputs in the Canadian Arctic environment.

en 2015 a remporté un grand succès sur l'ensemble des quatre sites : Sachs Harbour, Resolute, Arviat et Nain. Au cours de la dernière année, nous avons évalué précisément les tendances spatiales et temporelles des naphtalènes polychlorés et des produits ignifuges bromés dans le pannicule adipeux de phoques recueillis entre 1998 et 2014 dans la partie centrale de l'archipel (principalement à Resolute), la baie d'Hudson (Arviat et Inukjuaq) et la région du sud de la mer de Beaufort (Sachs Harbour, Ulukhaktuk), ainsi que des substances perfluoroalkyliques dans des échantillons de foie. Les concentrations de sulfonate de perfluorooctane (SPFO) ont baissé chez les phoques de Sachs Harbour (2011-2014), mais augmenté dans l'ouest de la baie d'Hudson au cours de la même période et sont demeurées stables dans le détroit de Lancaster. Les niveaux de naphtalènes polychlorés variaient de 1 à 6 ng/g en poids lipide entre les différents emplacements et ont diminué chez les phoques de 2011 à 2014. Les résultats liés aux produits ignifuges indiquaient que les concentrations de ΣPBDE les plus élevées se retrouvaient chez les phoques de Nain, d'Inukjuaq et d'Arviat et les plus faibles niveaux, chez les phoques du détroit de Lancaster. Une forte tendance à la baisse des PBDE depuis 2008 a été observée chez les phoques de l'est de l'île de Baffin. Il s'est également avéré que les concentrations dans le pannicule adipeux des nouveaux produits ignifuges bromés, le bis-(tribromophénoxy)-éthane (BTBPE) et l'hexabromocyclododécane (HBCDD), avaient considérablement augmenté sur plusieurs sites au cours de la dernière décennie. Les augmentations de certains produits ignifuges chez les phoques annelés et les concentrations de composés perfluoroalkyles et polyfluoroalkyles (PFAS) portent à croire à leurs apports continus dans l'environnement arctique canadien.

Key messages

- Polychlorinated naphthalenes (PCNs) are more prominent contaminants in seals than previously determined based on new results using improved analytical techniques
- PCN concentrations in ringed seal blubber have declined over the period 2011-2014
- Concentrations of existing and emerging flame retardants are increasing in some ringed seal populations
- PFOS concentrations have declined in recent years at Sachs Harbour but appear to be on the increase in the Western Hudson Bay seals

Messages clés

- Les naphtalènes polychlorés (NPC) sont des contaminants plus importants chez les phoques que ce que l'on avait déterminé initialement, selon les nouveaux résultats employant des techniques d'analyse améliorées.
- Les concentrations de NPC dans le pannicule adipeux des phoques annelés ont diminué pendant la période de 2011 à 2014.
- Les concentrations de produits ignifuges existants et nouveaux sont à la hausse chez certaines populations de phoques annelés.
- Les concentrations de SPFO ont décliné au cours des dernières années à Sachs Harbour, mais semblent à la hausse chez les phoques de l'ouest de la baie d'Hudson.

Objectives

1. Continue to determine temporal trends of POPs, mercury, and other metals as well as emerging organic chemicals of potential concern in ringed seals using annual collections at four sites.
2. Provide and discuss the information on levels and temporal trends of these contaminants to each participating community and to the Nunavut Environmental Contaminants Committee, the NWT Environmental Contaminants Committee and the Nunatsiavut Health and Environment Research Committee.
3. Present results and organize sessions on northern contaminants at national and international meetings such as ArcticNet and the Society of Environmental Toxicology and Chemistry (SETAC).

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, Kwan et al. 1999; Muir, Fisk et al. 2001; Muir, Kwan et al. 2003). Results for POPs and heavy metals including mercury are available going back to the 1980s, and earlier in some cases.

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

Our 2014-15 report focused on trends of mercury and cadmium as well as legacy POPs. In this report we have analyzed trends of polychlorinated naphthalenes (PCN), polybrominated diphenyl ethers (PBDEs) and other emerging flame retardants (e.g., hexabromocyclododecane, HBCDD and Bis-(tribromophenoxy)-ethane (BTBPE)) as well as perfluoroalkyl substances (PFAS) in ringed seals.

Activities in 2015-2016

Sample collection: In 2015 ringed seal samples were successfully collected by hunters in the communities of Sachs Harbour (n=15), Resolute Bay (n=18), Arviat (n=25) and Nain (n=18). 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°C and then shipped frozen to Burlington for processing. Large subsamples of all tissues were archived in walk-in freezers at -35°C in sealed plastic bags (double bagged).

In 2015 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 sent to the Hunters and Trappers committee offices of each community in April 2016 for the communication and consultations of the coming year.

Data were provided to the Arctic Monitoring and Assessment Program (AMAP) for the assessment of temporal trends of POPs listed under the Stockholm Convention and to the NCP Secretariat for a a study on trends of indicator POPs.

Chemical analyses: Analyses of OCPs and PCBs in the 2014 and 2015 samples was contracted to ALSGlobal (Burlington ON). Results for 2014 and 2015 are pending. Extraction and cleanup procedures followed the same general procedure as in previous years. Blubber samples (1 g) were mixed with anhydrous sodium sulphate, spiked with 13C12-PCB-133, and Soxhlet extracted overnight with dichloromethane (DCM). Half of the extract was removed for archiving and lipid determination. The other half was cleaned by gel permeation chromatography to remove lipids and reduced to a 1mL final volume in DCM. The extract was split for PCBs (0.5 mL), OCPs (0.05 mL) and BFR/toxaphene determination (0.45mL). A suite of 13C labeled PCBs was added to the PCB extract for target analyte quantification and retention time references. The PCB fraction was chromatographed on an acid/silica gel column and then analysed by gas chromatography-low resolution mass spectrometry (GC-LRMS) for 94 PCB congeners or co-eluting congener groups. A suite of deuterated and 13C-labeled OCPs was added to the OCP extracts and they were then analyzed directly by GC-high resolution mass spectrometry (GC-HRMS) for 39 OCPs and related chlorinated byproducts such as hexachlorobutadiene and pentachloroanisole. All data were recovery corrected for extraction and clean up losses relative to 13C12 PCB-133 response. The suite of OCPs and PCBs analyzed was identical previous suite analyzed by the National Laboratory for Environmental Testing (NLET) organics lab. PBDEs and other BFRs as well as toxaphene and endosulfan isomers were analyzed on the remaining extract using GC-negative ion LRMS by the NLET organics lab.

PCNs were also determined by ALS Global by GC-HRMS on the PCB extracts following an additional cleanup on alumina. The cleaned extracts were concentrated to small volume (40 µL in toluene) prior to the addition of a 5 µL solution of 13C- labeled PCN extraction standards. These final extracts were analyzed by GC-HRMS for 68 of the 75 possible PCN congeners. PCN concentrations were previously quantified by NLET (archived samples and 1998-2008). Comparisons in analyses and results are indicating that GC-low resolution MS analyses by NLET are up to an order of magnitude lower in concentration than PCN concentrations quantified using GC-HRMS. These discrepancies will carefully be considered for future assessment of temporal trends.

Seal liver was analyzed for a suite of PFASs in the Muir labs at Environment Canada (Burlington) as described by Butt et al.(2008) with method modifications described in Mueller et al.(2011). Instrumental analysis was performed by liquid chromatography-tandem MS (LC-MS/MS)(Butt et al. 2008)

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

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

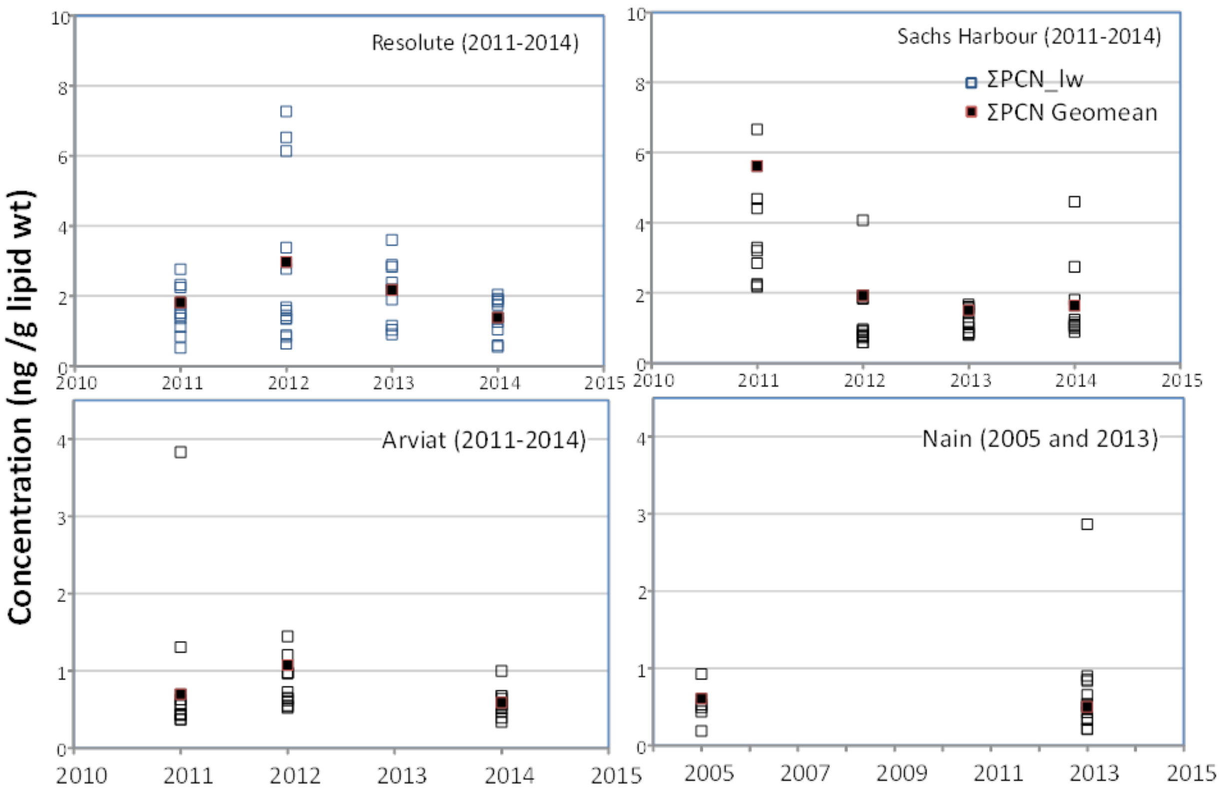
Quality assurance and statistical analysis: Both NLET labs and ALSGlobal are certified by certified by Canadian Standards Association and are participating annually in the NCP Interlab comparisons. The Muir lab at Environment Canada Burlington participated in the NCP Interlab 2015-16 comparison for PFASs and for mercury. 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, Wang et al. 2014; 2015).

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 were first tested for normality using the Shapiro-Wilk test. All contaminants data were log_{10} transformed to give coefficients of skewness and kurtosis <2 and geometric means (back transformed log data) were calculated. Linear regression analysis was used to assess the relationships between chemical concentrations and length, girth, blubber thickness, and stable isotope ratios. Significant model components for temporal trends were conducted using SAS 9.4 and SAS/STAT 13.1. Percentage of annual increases in contaminant concentrations were analyzed using the Arctic Monitoring and Assessment Programme (AMAP) PIA application (Bignert 2007).

Results and Discussion

Sample collection and hunter observations: In 2015 the requested information on gender, girth, length, and blubber thickness was provided for all harvested animals except for three. The identification of the gender of the seals by hunters in the field was in agreement with results for DNA. 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.

Figure 1. Total polychlorinated naphthalenes (ΣPCN) concentrations (ng/g l.w.) in ringed seal blubber from 2011 to 2014 (except for Nain 2005 and 2013). All analyses by GC-high resolution mass spectrometry.



Trends of PCN: Geometric mean concentrations of ΣPCNs ranged from 0.50 to 5.6 ng/g l.w. across the 4 sampling locations, with the highest levels recorded in seals from Sachs Harbour and Resolute in 2011 and 2012 (Figure 1). Mean concentrations declined from 2012 to 2014 except at Nain (Figure 1).Tetra- and pentachloro- PCN congeners predominated, representing 89-94% of ΣPCN These mean concentrations are about 10x higher than for the same locations sampled over the period 2000-2010 and reported in the Canadian Arctic Contaminants Assessment Report (Muir, Kurt-Karakus et al. 2013).The previous PCN data were determined by low-resolution mass spectrometry and were based on fewer congeners.

Figure 2. Average concentrations of flame retardants (PBDEs, ng/g lipid weight) in blubber of ringed seals collected across the Arctic pre-regulation (2000-2009) and post-regulation (2010-2013) of the substances.

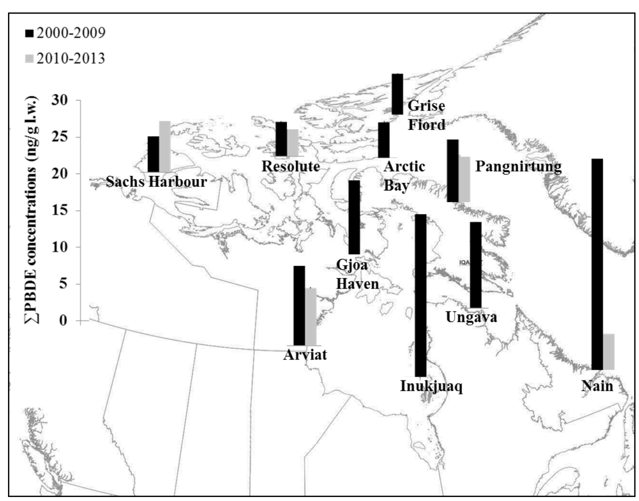
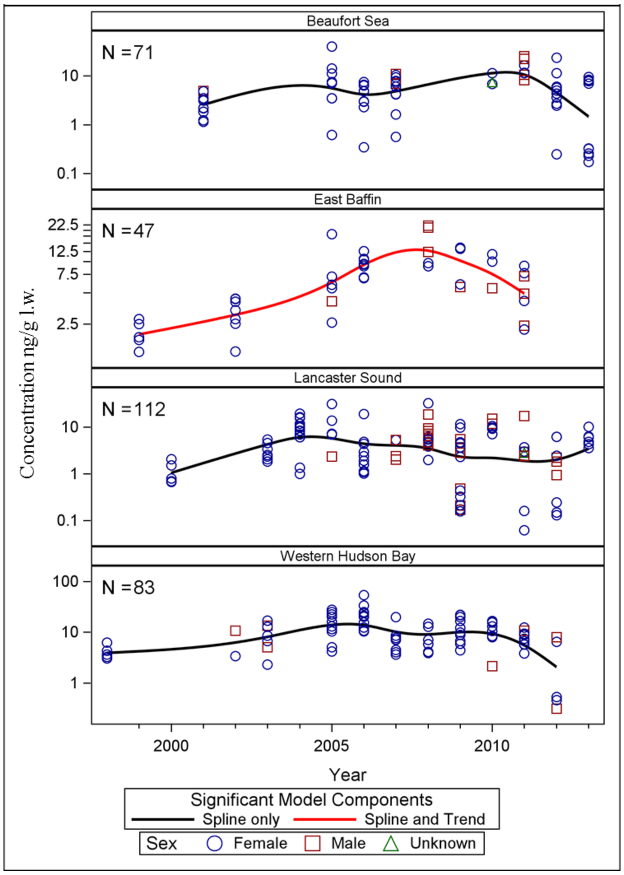


Figure 3. Temporal trends of PBDEs in blubber female and juvenile ringed seals collected in Beaufort Sea (Sachs Harbour), Lancaster Sound (Resolute Bay), Western Hudson Bay (Arviat) and, East Baffin (Pangnirtung). Red lines indicate that spline and trend were statistically significant; black lines indicate that only the spline was significant.



Trends of BFRs: The highest ΣPBDE concentrations (sum of 13 congeners) were found in seals in Nain (Labrador) as well as Inukjuaq and Arviat (Hudson Bay) (Figure 2). The lowest mean concentrations were found in seals from Lancaster Sound. BDE-47 and -99 were the predominant congener quantified in ringed seals. The most frequently detected non-PBDE flame retardants were 1,2-bis(2,4,6-tribromophenoxy)-ethane (BTBPE; 13% of samples analyzed for this chemical) and hexabromocyclododecane (α-HBCDD; 29%). ΣPBDEs have significantly increased from 1999 to 2011 in the regions of East Baffin with a peak recorded in 2008 (Figure 3). Significant fluctuations in PBDE blubber concentrations were observed in Beaufort Sea, Lancaster Sound and W. Hudson Bay since 2000 (Figure 3). Concentrations of α-HBCDD have significantly increased in Beaufort and Lancaster with peaks in concentrations found in 2011 and 2010, respectively (Figure 4). HBCDD levels in seals from W. Hudson Bay have fluctuated since 2006. Significant increasing trends were also found for BTBPE at two locations (Figure 4). The increases of BFR in blubber of ringed seals suggest their continuous inputs in the Canadian Arctic environment and warrant further surveillance and research on the effects of these substances in northern wildlife.

Recent measurements (2010-2014) show mean PFOS levels in seal livers from all four locations ranged from 5 to 30 ng/g w.w. Concentrations in seals from Lancaster Sound and Hudson Bay declined during the period of the mid-2000s to 2011 but have increased since then (Figure 5). Levels in animals from the southern Beaufort Sea (Sachs Harbour) increased from 2006 to 2011 but have undergone a rapid decline since 2012. Results for East Baffin (Pangnirtung) where only a limited number of samples have been analysed, show a slow decline of PFOS from the early 2000s. The trends for perfluoroalkyl carboxylic acids generally show a similar temporal pattern as PFOS concentrations with indications of recent increases.

The analyses for short chain chlorinated paraffins (SCCPs) are still pending for 2013-2015 as the National Laboratory for Environmental Testing has had trouble with the GC-HRMS analyses. We are looking into alternate labs to conduct the analyses in order to produce all SCCP results in this coming year.

Figure 4. Statistically significant temporal trends of non-PBDE flame retardants in Canadian Arctic ringed seals. A) HBCDD in blubber of female and juvenile male ringed seals collected at Beaufort, Lancaster Sound, and East Baffin, and B) for BTBPE for the same locations. Red lines indicate that spline and trend were statistically significant; dashed lines indicate that the trend is significant; continuous black lines indicate that only the spline was significant.

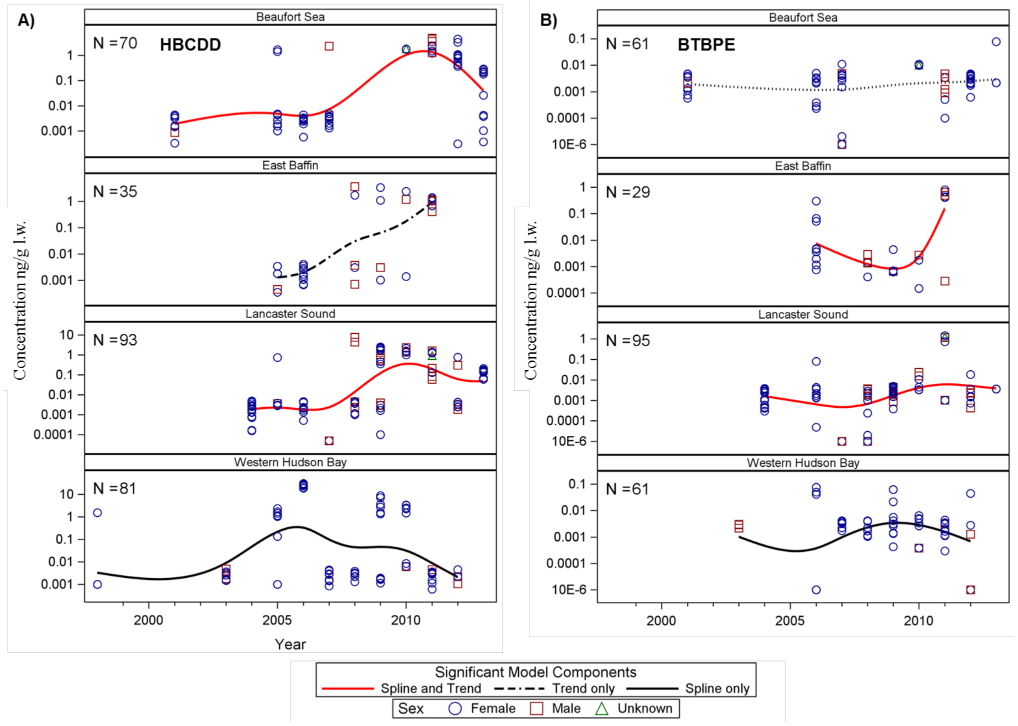
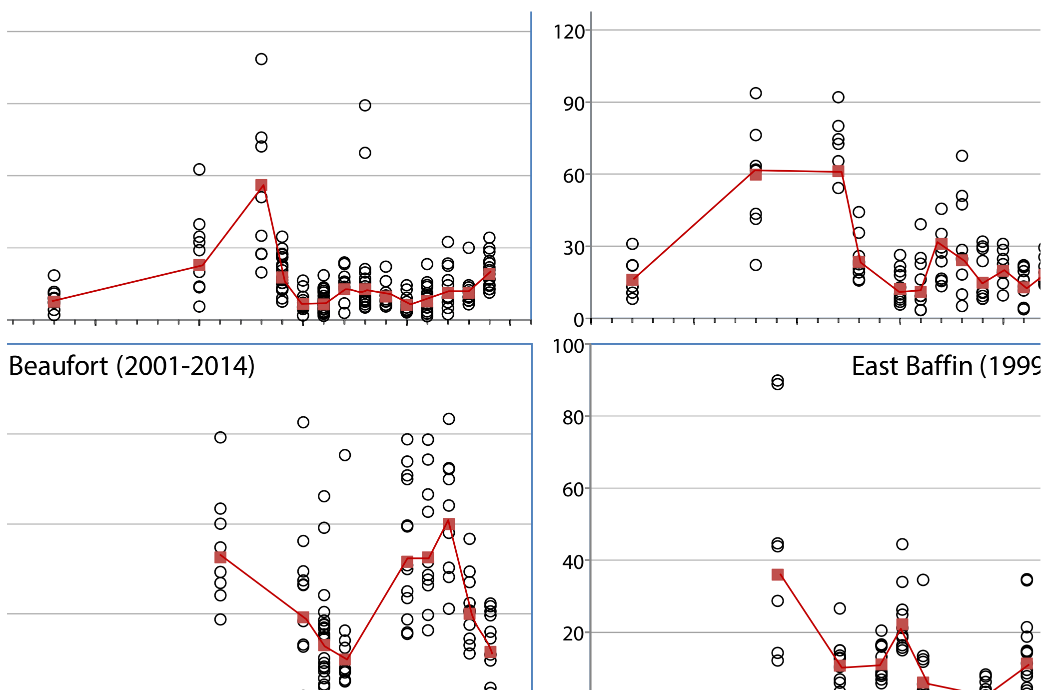


Figure 5. Perfluoroctane sulfonate (PFOS) concentrations (ng/g w.w.) in liver of ringed seals. The open circles represent the individual data points, the red circles are the geometric means.



Conclusions

This study has provided new information on the spatial trends of PCNs and temporal trends of PBDEs, and emerging flame retardants, as well as PFOS, in ringed seals from the Canadian Arctic. PCNs have decreased in the past year at several locations. However, further retrospective analyses are needed, along with continued monitoring of these substances in future years in order to enable adequate analyses of temporal trends. The increasing trends for PBDE and some emerging flame retardants in seals from the Beaufort Sea and the East Baffin raise questions about continuous sources and transport of these contaminants to Arctic environments. The relatively stable levels of PFOS and recent minor increases suggest continuous input of these substances.

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References

Bignert, A. 2007. PIA statistical application developed for use by the Arctic Monitoring and Assessment Programme. (available from www.amap.no). Oslo, No, Arctic Monitoring and Assessment Programme: 13

Butt, C. M., S. A. Mabury, et al. 2008. Spatial Trends Of Perfluoroalkyl Compounds In Ringed Seals (Phoca Hispida) From The Canadian Arctic. *Environ. Toxicol. Chem.* 27: 542-553.

Muir, D., A. Fisk, et al. 2001. Temporal trends of persistent organic pollutants and metals in ringed seals from the Canadian Arctic. In S. Kalhok (ed.), *Synopsis of research conducted under the 2000-2001 Northern Contaminants Program.* Ottawa: Indian and Northern Affairs Canada, pp. 208-214.

Muir, D., M. Kwan, et al. 2003. Temporal trends of persistent organic pollutants and metals in ringed seals from the Canadian Arctic. *Synopsis of research conducted under the 2001-2002 and 2002-2003 Northern Contaminants Program.* Ottawa: Indian and Northern Affairs Canada. pp. 318-327.

Muir, D., M. Kwan, et al. 1999. Spatial trends and pathways of POPs and metals in fish, shellfish and marine mammals of Northern Labrador and Nunavik. *Synopsis of Research Conducted Under the 1998/99 Northern Contaminants Program.* Ottawa: Indian and Northern Affairs Canada. pp. 165-171.

Muir, D. and L. Lockhart. 1994. Contaminant trends in freshwater and marine fish. *Synopsis of research conducted under the 1993/1994 Northern Contaminants Program. Environmental Studies Report, No. 72.* Ottawa: Indian and Northern Affairs Canada, 264-271.

Muir, D. C. G. 1996. Spatial and temporal trends of organochlorines in Arctic marine mammals. In Murray and R. G. Shearer (eds.), *Synopsis of Research Conducted Under the 1994/95 Northern Contaminants Program, Environmental Studies No. 73.* Ottawa: Indian and Northern Affairs Canada, pp. 135-146.

Muir, D. C. G. 1997. Spatial and temporal trends of PCBs, organochlorine pesticides,and chlorinated dioxin/furans in arctic marine mammals. *Synopsis of Research Conducted Under the 1995/96 and 1996/97 Northern Contaminants Program, Environmental Studies No. 74.* Ottawa: Indian and Northern Affairs Canada. pp. 215-221.

Muir, D. C. G., P. Kurt-Karakus, et al. 2013. Occurrence and Trends in the Biological Environment. Chapter 4. In D. C. G. Muir, P. Kurt-Karakas and J. E. Stow (eds.), *Persistent Organic Pollutants in Canada's North.* Ottawa: Aboriginal Affairs and Northern Development Canada, pp 273-422.

Muir, D. C. G., X. Wang, et al. 2015. Temporal trends of persistent organic pollutants and metals in ringed seals from the Canadian Arctic. *Synopsis of research conducted under the 2014-2015, Northern Contaminants Program.* Ottawa: Aboriginal Affairs and Northern Development Canada, pp. 189-198.

Muir, D. C. G., X. Wang, et al. 2014. Temporal trends of persistent organic pollutants and metals in ringed seals from the Canadian Arctic. *Synopsis of research conducted under the 2013-2014 Northern Contaminants Program.* Ottawa: Aboriginal Affairs and Northern Development Canada, pp 187-194.

Müller, C. E., A. O. De Silva, et al. 2011. Biomagnification of Perfluorinated Compounds in a Remote Terrestrial Food Chain: Lichen-Caribou-Wolf. *Environ. Sci. Technol.* 45: 8665-8673.

NLET. 2002. Standard Operating Procedure for the Analysis of Total and Dissolved Trace Metals in Water by In-bottle Digestion and Inductively Coupled Plasma-Mass Spectrometry and Inductively Coupled Plasma-Optical Emission Spectrometry. *SOP 02-2002.* Burlington ON: National Laboratory for Environmental Testing, NWRI.

US Environmental Protection Agency. 2007. Method 7473. *Mercury in Solids and Solutions By Thermal Decomposition, Amalgamation, and Atomic Absorption Spectrophotometry.* Washington, DC.

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

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

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Abstract

The polar bear (*Ursus maritimus*) is the top predator of the arctic marine ecosystem and food web. Starting in 2007 and ongoing in 2015-2016, on a biennial or annual basis, this project assesses longer-term temporal trends and changes of NCP priority persistent (legacy and emerging) organic and elemental pollutants (POPs) in polar bears from the southern and western Hudson Bay (Nunavut) subpopulations. For emerging POPs that are currently banned or regulated (e.g. under the treaty of the Stockholm Convention on POPs), including tetra- to octa-brominated diphenyl

Résumé

L'ours blanc (*Ursus maritimus*) est le superprédateur de l'écosystème et du réseau alimentaire marins de l'Arctique. Le projet, qui a débuté en 2007 et qui s'est poursuivi en 2015-2016, évalue sur une base annuelle ou bisannuelle les tendances et les variations temporales à long terme qui caractérisent les polluants organiques persistants (POP) prioritaires (anciens et émergents) du Plan de lutte contre les contaminants dans le Nord (PLCN) et que l'on retrouve dans les tissus des ours blancs des sous-populations du sud et de l'ouest de la baie d'Hudson

ethers (PBDEs), both subpopulations have shown decreasing levels of sum (S) PBDE concentrations from 2009 to 2014. Although quantifiable in the low ppb (lipid weight) up until 2013, hexabromocyclododecane (HBCDD) was not detectable in 2013 or 2014 bear fat samples. Over the period of 2007 to 2015, PFOS and SPFCA concentrations (wet weight) were consistently high (ppm or greater levels) with no obvious increasing or decreasing trends. Short-chain chlorinated paraffins (SCCPs) were in 2014 fat samples at mean SSCCP levels of high ppb concentrations. Hexachlorobutadiene (HCBD), β-endosulfan, endosulfan sulfonate, pentachorophenol (PCP), pentachloroanisole (PCA) and o,p'- and p,p'-dicofol isomers were consistently not detected. Consistent with previous years, legacy POPs (i.e., PCBs, CHLs, DDTs and ClBzs) remained at similar concentrations, although SPCB and SCHL concentrations (ppm lipid weight) remained at the greatest levels compared to all other POPs measured. Total Hg concentrations (wet weight) in liver were also unchanged from 2002 to 2015. To more clearly reveal temporal trends, POP concentration variance is being examined as a function of factors such as age, sex, body condition, time of collection, lipid content, and diet and food web structure (via carbon and nitrogen stable isotope ratios and fatty acid profiles). In addition to assessing temporal trends for Hudson Bay bears, this information is used to inform indigenous and northerners/northern communities about POP levels and how contaminant levels in marine wildlife affect their culturally and traditionally important country foods.

(Nunavut). Pour les nouveaux polluants organiques persistants qui sont actuellement bannis ou réglementés (p. ex. en vertu du traité de la Convention de Stockholm sur les polluants organiques persistants), y compris les tétra-bromodiphényléthers au octa-bromodiphényléthers (PBDE), les deux sous-populations ont affiché des tendances à la baisse de la somme des concentrations (S) de PBDE de 2009 à 2014. Bien que quantifiable en quelques ppb (poids lipide) jusqu'en 2013, l'hexabromocyclododécane (HBCDD) n'était pas détectable dans les échantillons de graisse d'ours en 2013 ou en 2014. Au cours de la période de 2007 à 2015, les concentrations de SPFO et d'SAPFC (poids humide) étaient invariablement élevées (ppm ou niveaux supérieurs), sans tendance à la hausse ou à la baisse évidente. Des paraffines chlorées à chaîne courte (PCCC) se trouvaient dans les échantillons de graisse prélevés en 2014 à des niveaux de SPCCC moyens de concentrations en ppm élevées. L'hexachlorobutadiène (HCBD), le β-endosulfane, le sulfate d'endosulfane, le pentachlorophénol (PCP), le pentachloroanisole (PCA) et le dicofol (somme des isomères et o,p'- et p,p') étaient systématiquement non détectés. Comme dans les années précédentes, les polluants organiques persistants anciens (c.à-d. les BPC, les chlordanes (CHL), les dichlorodiphényltrichloréthanes (DDT) et les chlorobenzènes (CIBz) se sont maintenus à des concentrations similaires, quoique les concentrations de SBPC et de SCHL (ppm poids lipide) sont demeurées aux niveaux supérieurs comparativement à tous les autres polluants organiques persistants mesurés. Les concentrations de mercure total (poids humide) dans le foie sont également demeurées inchangées de 2002 à 2015. Afin d'identifier plus clairement les tendances temporelles, on évalue les variations des concentrations des polluants organiques persistants en fonction de facteurs tels que l'âge, le sexe, l'état corporel, le moment de la collecte des données, la teneur en lipides, l'alimentation et la structure du réseau trophique (par l'intermédiaire des ratios d'isotopes stables du carbone et de l'azote et des profils d'acides gras). En plus d'évaluer les tendances temporelles relatives aux ours de la baie d'Hudson, ces données servent à informer les Autochtones et les résidants du Nord ainsi que les collectivités du Nord au sujet des niveaux de polluants organiques persistants et des répercussions des niveaux de contaminants dans la faune marine sur les aliments prélevés dans la nature importants d'un point de vue culturel et traditionnel.

Key messages

- As of 2014, for western Hudson Bay bears, generally the mean levels for ΣPCBs, ΣDDTs, ΣCHLs, α-HCH, β-HCH and ΣClBzs (in fat) were similar to those in samples going back to 2001. ΣPCBs and ΣCHLs continued to remain high at ppm (lipid weight) concentrations.
- Trends for mean ΣPBDE concentrations (in fat) increased from 1991 to late 2000s for western Hudson Bay bears, but then showed a decreasing trend from 2010-2014. Temporal trends were similar for southern Hudson Bay bears (2007-2008 to 2014 period), although the southern subpopulation maintained consistently greater ΣPBDE levels than the western subpopulation.
- Mean HBCDD levels were consistently at low ppb levels in western Hudson Bay bear fat over the years 2001 to 2013, and similarly from 2007-2008 to 2013 for southern Hudson Bay bears. However, as of 2014 HBCDD was not detected for all bear samples.
- Over the period of 2007-2015, mean PFAS concentrations (wet weight) in liver were consistently comprised mostly of PFOS and ΣPFCAs (low levels of PFOA but mostly C_9, C_{10} and C11 PFCAs). PFOS was consistently higher than ΣPFCAs, and PFOS was consistently at ppm levels but at greater levels in southern Hudson Bay versus western Hudson Bay bears. There was no obvious increasing or decreasing trends for ΣPFCAs and PFOS for both subpopulations over the 2007-2015 period.
- In the liver of bears from both subpopulations, mean THg concentrations

Messages clés

- En 2014, pour les ours de l'ouest de la baie d'Husdon, en général, les niveaux moyens de ΣBPC, de ΣDDT, de ΣCHL, de α-HCH, de β-HCH et de ΣClBz (dans la graisse) étaient similaires à ceux des échantillons remontant à 2001. Les concentrations de ΣBPC et de ΣCHL sont demeurées élevées en ppm (poids lipide).
- Les tendances des concentrations moyennes de ΣPBDE (dans la graisse) ont augmenté entre 1991 et la fin des années 2000 pour les ours de l'ouest de la baie d'Hudson, puis ont affiché une tendance à la baisse de 2010 à 2014. Les tendances temporelles ont été semblables pour les ours du sud de la baie d'Hudson (période de 2007-2008 à 2014), bien que la sous-population du sud ait maintenu des niveaux de ΣPBDE invariablement supérieurs à ceux de la population de l'ouest.
- Le HBCCD se retrouvait invariablement à de faibles concentrations moyennes en ppm dans la graisse des ours de l'ouest de la baie d'Hudson au cours des années 2001 à 2013, et on peut en dire autant pour la période de 2007-2008 à 2013 pour les ours du sud de la baie d'Hudson. Toutefois, en 2014, on n'a pas détecté d'HBCCD dans tous les échantillons prélevés sur les ours.
- Au cours de la période de 2007 à 2015, les concentrations moyennes d'APFA (poids humide) dans le foie étaient invariablement composées surtout de SPFO et d'ΣAPFC (faibles concentrations d'APFO, mais essentiellement des APFC C_9, C_{10} et $_{C11}$. Le SPFO se retrouvait invariablement en concentrations plus élevées que les ΣAPFC,

(wet weight) from 2002 to 2015 were constant, and slightly greater in bears from western versus southern Hudson Bay.

et le SPFO était invariablement détecté à des niveaux de ppm, mais à des niveaux plus élevés chez les ours du sud de la baie d'Hudson par rapport à ceux de l'ouest de la baie d'Hudson. Il n'y avait aucune tendance à la hausse ou à la baisse évidente relativement aux ΣAPFC et au SPFO pour les deux sous-populations au cours de la période de 2007 à 2015.

- Dans le foie des ours provenant des deux sous-populations, les concentrations moyennes de mercure total (poids humide) entre 2002 et 2015 ont été constantes, et légèrement supérieures chez les ours de l'ouest par rapport à ceux du sud de la baie d'Hudson.

Objectives

- To continue monitoring with increased resolution, the (retrospective) temporal trends and changes of legacy and emerging POPs in polar bears in Hudson Bay. POPs analyzed will be those outlined in the NCP priorities, including those currently under review for regulatory action (e.g. Stockholm Convention on POPs).
- To use carbon and nitrogen stable isotopes and fatty acid profiles as ecological tracers, in order to examine the influence of diet/food web structure, trophic level, sex, age, time of collection and lipid content as confounding factors on POP temporal trends in Hudson Bay polar bears.
- To provide information to Hudson Bay communities and indigenous peoples participating in the study, and other northern communities, on POP levels, changes and fate in polar bears.
- To archive the remaining polar bear tissue samples that were collected in Environment and Climate Change Canada's National Wildlife Specimen Bank (EC-NWSB), NWRC, Carleton University (Ottawa).

Introduction

Mercury (Hg) and a growing array of chlorinated, brominated and fluorinated POPs, have proven to be anthropogenic contaminants that have been transported to the (Canadian) Arctic and accumulate in biota (Haider et al. 2015; Letcher et al. 2010; Morris et al. 2016). These bioaccumulative POPs (and/or their precursors and/or degradation products) and Hg are transported mainly via global atmospheric and/or oceanic pathways and processes that result in deposition in the Arctic, and are found in Arctic endothermic top predators, and in particular in polar bears. Most known legacy and emerging POPs are lipophilic to some degree, and because lipids constitute an important energetic factor in polar marine biota, POPs are bioaccumulated and in some cases biomagnified in the long Arctic marine food chains. Polar bears are distributed throughout the circumpolar region, have unquestionable importance to indigenous and northern peoples both culturally and economically, and thus are an important sentinel or monitoring species for legacy and emerging POPs and Hg. The levels of POPs are generally the greatest in the polar bear as compared to other Arctic wildlife, and thus polar bears are an ideal wildlife receptor for the biomonitoring of spatial and temporal trends, distribution, dynamics, fate, biomagnification and potential effects of Hg and legacy and emerging POPs (Braune et al. 2015; Letcher et al. 2010, 2015a, 2015b, 2015c; McKinney al. 2011a, 2011b; Riget et al. 2016; Routti et al. 2011). This is despite the high ability of polar bears to bio-transform POPs compounds via hepatic enzymatic processes and thus excrete these compounds (Letcher et al. 2010; Letcher et al. 2014a, 2014b, 2014c).

Consistent with previous monitoring years, POPs are being determined in Hudson Bay polar bears that are contaminant priorities for the NCP, and are listed or under consideration by or nominated for addition to the POPs Stockholm Convention. This includes chemicals that have recently or are currently being reviewed by the POP Review Committee (POPRC), e.g., Penta-/Octa-BDEs (added to Annex A in 2009), DecaBDE (BDE-209), short-chained chlorinated paraffins (SCCPs), hexabromocyclododecane (HBCDD) (added to Annex A in 2014), pentachlorophenol (PCP) and pentachloroanisole (PCA), and isomers of dicofol. Other POPs being monitored in (Hudson Bay) polar bears and consistent with previous monitoring years are a suite per-/poly-fluoroalkyl substances (PFASs) such as perfluorinated carboxylates (PFCAs) and perfluorinated sulfonates (PFSAs) and precursors and new PFAS such as perfluorooctane ethylcyclohexyl sulfonate (PFEtCHxS) and shorter chain PFAAs and precursors (Boisvert et al., 2015a, 2015b; Letcher et al. 2014a, 2014b, 2015a, 2015b, 2015c, 2015d, 2015e).

This work continues to integrate and better understand the influence of climate change in POP dynamics and trends in Hudson Bay, which has been shown to be particularly affected by Arctic warming. Arctic ecosystems face multiple challenges at local and regional scales, among them changes and the potential stress of changes in climate and exposure to anthropogenic chemical contaminants proven to be POPs (Bechshøft et al. 2013; Dietz et al. 2015a, 2015b, 2016; Ferguson et al. 2015; Letcher et al. 2010; McKinney et al., 2015; Pavlova et al. 2015). More recently the warming of the Arctic has been signaled by loss of multi-year sea ice and thawing of permafrost and accelerated coastal erosion. The significance of the conversion of ice to water is that it affects physical and biogeochemical pathways of POPs and other contaminants. This can result in an alteration of animal behaviour such as habitat use and diet as well as ecosystem structure including the introduction of new species and loss of existing species of biota. Research in this ongoing project has shown that Arctic warming and changes in sea-ice means change in POP and Hg exposure for polar bears from the Hudson Bay and East Greenland subpopulations (McKinney et al., 2010, 2011a, 2011b, 2015; Routti et al. 2012).

Activities in 2015-2016

NCP Projects:

Field Sampling: In September 2014, we successfully applied for a 2015 Nunavut Wildlife Research Permit (NWRP) for polar bear sample collections during the 2015 harvests by communities in Hudson Bay and Baffin Bay. In December 2014, the 2015 NWRP was approved/signed/validated by the Nunavut Department of Environment (NDE). The 2014 and 2015 NWRPs were prepared and evaluated in collaboration with communities via the NDE (Wildlife Management Research: M. Dyck). As per the 2014 and 2015 NWRPs, the following Hunters and Trappers Organizations (HTOs) and associated hunters as well as Nunavut Conservation Officers (COs) (Hudson Bay and Baffin Bay communities and polar bear management zones) have been or are participants in this project (updated by M. Dyck (GN-NDE)): Western Hudson Bay (Keewatin Region): Joe Savikataaq Jr. (CO) - Arviat; Johanne Coutu-Autut and Daniel Kaludjak - Rankin Inlet; currently there is no CO - Whale Cove. Southern Hudson Bay (Qikiqtaaluk Region): Daniel Qavvik - Sanikiluaq. Baffin Bay (Qikiqtaaluk Region): Bruce Jerry Hainu – Clyde River; George Koonoo – Pond Inlet.

As per the valid and approved 2014 and 2015 NWRPs, in 2015 community hunters and COs collected polar bear fat, liver and/or muscle sample sets during harvests spanning very late 2014/early 2015, from n=22 western Hudson Bay (Arviat (n=9; 9 males and 4 females), Rankin Inlet (n=7; n=6 males and n=1 females) and Whale Cove (n=6; n=5 males and n=1 female)) and from southern Hudson Bay (Sanikiluaq (n=20; n=14 males and n=6 females) Hudson Bay bears (adults and subadults). Also, opportunistic collections of fat, liver and/or muscle sample sets were made from a total of n=22 bears from northern Baffin Island/Bay (Clyde River (n=6; n=4 males and n=2 females) and Pond Inlet (n=16; n=11 males and n=5 females). All of these samples were collected by local hunters in participating communities via interaction with local HTOs and COs. All samples were sent from these communities to NDE offices in Igloolik where they were documented and processed. Subsample sets that were prepared for these bears were shipped on October 17, 2015 to R. Letcher at NWRC in Ottawa. In November 2015 all polar bear sub-samples received by NWRC were processed, and for the Hudson Bay bear sample portions were taken for POP (fat, liver), element/metal (liver), FA (fat) and SI (muscle) analysis. Remaining sample portions are currently stored and archived in ECCC's National Wildlife Specimen Bank (EC-NWSB) at NWRC (Ottawa) for future considerations (e.g. future retrospective monitoring of new/emerging POPs).

Sample Analysis: Since NWRC only received and processed the bear sub-samples in late 2015, POP and Hg, ecological tracer and age analysis could only be started in mid-December 2015. By the end of March 2016, all aforementioned analyses were underway, nearing completion or completed via the NWRC-Organic Contaminants Research Laboratory (OCRL), NWRC-Lab Services or NLET (EC-Burlington). Age determinations (via bear teeth) for all harvested bears from 2009 to 2014 were completed in early 2015 via a formal NCP-supported Environment Contract to Matson's Laboratories (Matson's Laboratory LLC, 8140 Flagler Road Missoula MT 59802, U.S.A.; http://www.matsonslab/com). For available teeth collected from bears in 2015, Matson's Laboratory will carry out the age analysis along with 2016 collected teeth. All 2015-collected fat samples for a suite of FAs (i.e., a suite of 37 saturated and polyunsaturated, C_6-C_{24} fatty acids) have been analyzed by NWRC-Lab Services. Analysis of SIs of nitrogen and carbon in 2015 and 2016 collected muscle samples will be completed by the end of 2016 via the lab of Dr. Aaron Fisk at the Great Lakes Institute for Environmental Research (GLIER), University of Windsor.

Capacity building: Dr. Letcher had previously established with the NDE an Agreement of Cooperation and Contribution (ACC), which embodies this research and monitoring EC-NDE partnership. In 2015-2016, this project cooperated in building capacity and expertise in scientific sampling during the 2015 harvests in Hudson Bay and Baffin Bay. The participating communities and HTOs were directly involved and led in the organization and collection of fat, liver and muscle samples. As detailed in the valid 2014 and 2015 NWRPs, and in cooperation with M. Dyck and M. Harte at the NDE, as was necessary, Dr. Letcher arranged and sent directly to NDE a supplementary number of sampling kits that coincides with the number of bears required for these management zones and within the allowable hunting quota for communities involved (Hudson Bay and Baffin Bay).

For the hunters in each community, and via the HTOs, each sampling kit contained simple and easy to read sampling instructions in both English and Inuktitut. In 2015, electronic copies of the sampling instructions were also sent to the Nunavut Environmental Contaminants Committee (NECC; Co-Chairs Romani Makkik (also the Nunavut IRA) and Lilianne Kydd), and in direct response to the recommendations made in the NECC social-cultural review of the 2015-2016 project year. Two files were forwarded in 2014 to the NECC, "Polar bear Sampling Instructions-English-2011.doc" and "Polar bear Sampling Instructions-Inuktitut-2011.doc", and we noted that these specific bilingual instructions have been provided to hunters every year since 2008. As we noted in the 2015-2016 mid-year status report in September 2015, which was then circulated to and reviewed by the NECC, all polar bear harvests completed in 2015 were carried out by local hunters in the participating Nunavut communities (i.e., Arviat, Whale Cove, Rankin Inlet, Sanikiluaq, Pond Inlet and Clyde River). For these regional 2015 sample collections, the participating project team members in the NDE continued to provide training to members of the HTOs that were involved. Hunters were compensated for the sampling. In terms of other capacity building, new graduate students, Mr. Gabriel Boisvert and Ms. Adelle Strobel (MSc students, Carleton U., Ottawa; supervised by R. Letcher) were recruited and began graduate work in Sept. 2014 and Jan. 2015, respectively, on established and newly detected PFAS and organophosphate ester (flame retardant and plasticizer chemicals) contaminants and their bioaccumulation and metabolism in ringed seals and polar bears.

Communications: As detailed in the NCP Project Statistics and Information, as of March 2016, publications included 11 papers and reviews in peer-reviewed journals (published, accepted or submitted), 1 reports, 1 book chapter as well as 13 oral and poster presentations at conferences or workshops. For example, presentations were made at the ArcticNet (ASM2015) / NCP Results Workshop held on Dec. 6-9, 2015, in Vancouver, BC. Another Arctic –polar bear based presentation was also made at the 2015 DIOXIN conference in Sao Paulo, Brazil in August 2015. In 2015-2016, numerous papers were published reported on the effects of contaminants in exposed polar bears (e.g. Bechshøft et al. 2016; Desforges et al. 2015; Dietz et al. 2015a, 2015b; Gabrielsen et al. 2015a, 2015b; Levin et al. 2015; Pedersen et al. 2015; Scheuhammer et al. 2015; Sonne et al. 2015)

With the completion of presentations and posters at workshops and conferences, and journal publications and reports, electronic copies continued to be provided to NDE project partners that also fulfill the reporting obligations of the 2014 and 2015 NWRPs, and also to the NECC for edification and further distribution as deemed necessary. Whenever it was necessary, in 2015 the PI responded to any inquires or concerns of the participating communities and the NECC, e.g. questions after the social-cultural review of the initial 2015-2016 proposal.

The PI was committed to travel to at least one Nunavut community in 2015-2016. In late Sept. 2015, Letcher travelled to Igloolik to interface with NDE partners (e.g., M. Dyck and M. Harte). Letcher also travelled to Iqaluit to participate in the Wildlife Contaminants Workshop (WCW) 2015 held over 4 days in late Sept./early Oct. 2015 at the Nunavut Research Institute (NRI) at Nunavut Arctic College in Iqaluit. Letcher lectured on contaminants and effects in polar bears as part of the WCW 2015 to students enrolled in the NRI-Environmental Technology Program (ETP). Overall, the WCW 2015 provided contaminants knowledge to the students in the context of ecosystem and wildlife health within the ETP. The WCW 2015 also provided an opportunity for Letcher (and on behalf of his NCP research team) to present scientific results in a northern context and to northerners. Most of the communication of ongoing research in the north ends up being the responsibility of workers closest to the field and communities (i.e. conservation officers, local research coordinators, etc.). Thus, the ETP is an ideal example of critical training programs for students who subsequently will go on to such frontline research positions in Nunavut. Letcher also gave a joint community presentation (with D. Muir) at the NRI while in Iqaluit during the WCW 2015.

In 2015, Letcher and Dyck at NDE initiated the preparation of a “polar bear - contaminant fact sheet”, which is intended for circulation to interested individuals and communities, and will be written in very plain language for easy understanding, and as per the recommendation of the NECC. As we responded to the NECC, the NDE requires that for all bears harvested, that a hunter kill return sheets be completed and submitted. On the kill sheets, the hunters have the opportunity to provide and generally made observational comments. Since we only received and processed 2015 bear samples in late November 2015, we intend to provide them to the NECC in 2016.

The Stockholm Convention’s POPRC is reviewing and assessing several NCP priority chemicals for addition to the POP convention annexes. Among these POPs, are Deca-BDE

(BDE-209), and SCCPs. PCNs and PCP/PCA were added to the Convention at COP7 in May 2015. The last POPRC11 meeting was in October 2015 in Rome, Italy. New Arctic information of high priority POPs, including for polar bears, is needed to adequately make risk nomination recommendations to the POP Convention Annexes. Letcher continued to communicate and discuss POPRC data needs for these priority chemicals within ECCC, INAC and with ICC Senior Policy Advisor, Eva Kruemmel (as she attends/participates in the POPRC committee meetings). In December 2014, new POP data and temporal trends for Southern (2007 – 2013) and Western (1991-2013) Hudson Bay polar bears was prepared and provided to the AMAP POPs Experts Group (led by Mr. Simon Wilson and Dr. Frank Riget). The data has been converted to *.amp files to feed into a larger database to carry out Power Analysis of the data in an identical manner as for other NCP priority wildlife and fish monitoring sentinels and other Arctic compartments (e.g. air), in preparation for a new round of AMAP POP temporal trend assessment reports to be completed in the 2016 time frame.

Traditional knowledge integration: It can be a challenge to incorporate traditional knowledge (TK) on an annual basis into an ongoing contaminants monitoring program, and in particular for polar bears. However, as in past sampling for this core monitoring project, the 2015 collection of samples was carried out exclusively by hunters in the participating Hudson Bay and Baffin Bay communities and in coordination with the PI (Letcher) and involved agencies in Nunavut. This project worked within the guidelines of the allowable hunting quotas for each of the HTOs and communities. This project continued to seek any TK that could be provided in the information provided by the hunters such as ecological information on behavior (e.g. observations of unusual dietary events other than ringed seal predation), body condition and population numbers as provided to wildlife COs and biologists. It should be noted that polar bears are consuming country food at similar trophic levels as people in the communities. The inclusion of TK continues to be vitally important in understanding contaminant variations and changing trends (diet and habitant), despite the link to shared resources (e.g. contaminant exposure from seal). This supports a two-way integration of knowledge.

Other Related Projects on Polar Bears:

In 2015, Letcher started collaborations with Dr. Evan Richardson, Dr. Andy Derocher and their Postdoctoral Fellow Dr. Thea Bechshøft, all located at the University of Alberta in Edmonton. Letcher provided legacy POP and brominated flame retardant data for n=31 polar bear fat biopsies collected from western Hudson Bay bears over the years of 2004-2010. These POP data are being used in a multi-disciplinary project investigating linkages and inter-individual variability and heritability on relation to diet, disease, body condition, contaminants, stress (e.g. climate change) and genetics (e.g. DNA and RNA nucleotide polymorphisms) in Hudson Bay polar bears. In 2015-2016, Letcher forged a formal collaboration with Dr. Aaron Fisk at the University of Windsor in Windsor, ON to examine temporal shifts in diet and food web structure in relations to POPs in polar bears from Hudson Bay.

Letcher contributed to and is a coauthor on a published ArcticNet (IRIS I) chapter in the ArcticNet Western & Central Arctic Assessment (IRIS 1), i.e. chapter 4 - Arctic Change: Impacts on Marine Ecosystems. Letcher is also a coauthor of a soon to be published chapter entitled “Polar bear (Ursus maritimus) circumpolar health assessment in relation to chemical pollutants and climate change” in the book “Pole to Pole: Polar Environmental Research during the International Polar Year 2007 – 2009”.

Dr. Letcher continued to be the Canadian component with a Danish led group in maintaining an International Arctic Research Station for Contaminant Stress in Wildlife. The station was named “AURORAE” and was established in March 2011 in Scoresby Sound, East Greenland, which is a biodiversity hot spot for Arctic wildlife including polar bears, marine mammals (seals and beluga whales), terrestrial mammals (Arctic fox and muskox) and seabirds.

Letcher continued in 2015-2016 to collaborate, communicate, integrate and publish with polar bear/Arctic wildlife scientists from Denmark (Drs R. Dietz, C. Sonne, B. Stryishaven), Norway (Dr. B. Jenssen), the U.S.A. (Drs M. Levin, S. de Guise). Collaborative studies on Greenland polar bears were mostly concluded with Dr. Bjarne Styrishave (U. of Copenhagen) on the effects of complex contaminant mixtures isolated from various polar bear tissues and compartments (collected in 2011) and screening them through a human H295R cell line to examine the effects on steriodogenic activity catalyzed by the CYP17 enzyme. In another collaborative project with Dr. Styrishaven, work was recently completed and published that examined brain-region-specific PFASs in relation to neurochemical biomarker responses in (East Greenland) polar bears. Also, Letcher collaborated with Dr. Bjorn Jenssen at the Norwegian Science and Technology University (Trondheim, Norway) and completed, a study examining thyroidogenic contaminants in relation to thyroid hormones in East Greenland polar bears. A PhD student in this collaboration, Kristen Møller Gabrielsen, successfully defended her PhD thesis in 2015, and two journal papers were recently published or submitted for publication from this PhD thesis work. Letcher also continued to collaborate and published a paper with former PhD student Dr. Melissa McKinney and Danish researchers Drs. Dietz and Sonne in examining long-term changes in fatty acid profiles and diet shifts in relation to contaminants in East Greenland polar bears.

Results

Recent data was generated for legacy and (re) emerging POPs (including newly screened POPs, e.g. SCCPs, PCNs, organophosphate esters (OPEs) and α-endosulfan) in the tissues of polar bears (fat or liver) from Hudson Bay subpopulations, and on samples collected in the 2014 monitoring year. Data is in the process of completion for 2015-collected samples. Some priority POPs that were screened in the same fat samples collected in 2013 and 2014 were not detectable with any frequency. For 2014 samples, hexachlorobutadiene (HCBD), β-endosulfan and endosulfan sulfonate were not detected, whereas α-endosulfan is quantifiable at very high sample frequency but at low ppb concentrations (lipid weight). For 60 polar bear fat samples from 2013-2015 sample collections, pentachlorophenol (PCP) was only detectable (sub-ppb levels) in 40% of the fat samples but was not quantifiable. o,p'- and p,p'-dicofol isomers and pentachloroanisole (PCA) were not detected in any of the same samples.

Western Hudson Bay fat samples collected in 2012-2013 had also been screened for several Dechlorane Plus (DP)-like, norbornene derivatives, as well as for syn- and anti-DP FRs that are structurally related to Mirex (Dechlorane) and Photomirex (Photo-Dechlorane). Syn- and anti-DP were not detectable in any of these samples. However, DP-602 and DP-603 were quantifiable and at levels of 2.5 ± 2.4 and 0.3 ± 0.2 ng•g^{-1} (lipid weight), respectively.

In 2013 and 2014 collected fat samples, low to sub ppb (ww) concentrations of the OPE triester contaminants, tris(2-chloroethyl)phosphate (TCEP), tris(2-chloroisopropyl)phosphate (TCIPP), tributyl phosphate (TNBP), triphenyl phosphate (TPHP) and/or tris(2-butoxyethyl) phosphate (TBOEP) were found. For both Western and Southern Hudson Bay bears, TCIPP and TBOEP were at the highest levels at 1.2 ± 0.7 and 3.8 ± 2.1 ng•g^{-1} (wet weight), respectively. Regardless, for all Hudson Bay bears the mean ΣOPE concentrations in fat has been consistently very low compared to other emerging POPs, and exceedingly low compared to legacy POPs.

The suite of 24 SCCP congeners screened for 2014-collected fat samples were of chain lengths of C_{10}-C_{13}, and for each chain length SCCP grouping they contained 5 to 10 chlorine atoms. There was 100% frequency of sample detection for all the quantifiable SCCPs. The mean Σ24SCCP concentrations were 175 ± 100 ng•g^{-1} and 160 ± 84 ng•g^{-1}(wet weight) for Western and southern Hudson Bay bears, respectively, and were among the most concentrated POPs and comparable to e.g. ΣHCH, ΣDDT and ΣClBz concentrations, for bears from both subpopulations.

A suite of 75 mono- to hepta-chloro-PCN congeners were determined in bear fat samples from 2014. There was a very high frequency percentage of detection for 27 of the PCN congeners in the sub-sets of n=5 adult male and female bears from each of the two subpopulations. The mean S27PCN concentrations in the 2014 samples were 17.6 ± 8.5 ng·g^{-1} and 27.1 ± 17 ng·g^{-1} (wet weight) for western and southern Hudson Bay bears, respectively, and somewhat lower than SPBDE and BB-153 concentrations for the same year (Figure 1). Tetra- to hexa-chlorinated congeners accounted for >95% of the S27PCN concentrations, and with penta-chlorinated congeners accounting for >80% of the S27PCN concentrations.

Over the period of 2007 to 2015, in liver samples the PFCAs were mostly C_9-C_{11} congeners with the PFNA (C9) dominating. In addition to PFOS, the C6 PFSA and several "Pre-FOS" precursors were quantifiable e.g. N-EtFOSA and FOSA at low ppb levels, which are ultimate precursors to PFOS. The C4 perfluorobutane sulfonamide (FBSA) in polar bear liver was quantifiable, although no corresponding perfluorobutane sulfonic acid (PFBS) was detectable in any liver sample. Perfluorobutane carboxylic acid (PFBA) was measureable at low ppb levels (wet weight) with almost 100% frequency in all western and southern Hudson Bay bear livers. Furthermore, the cyclic analogue of PFOS, PFEtCHxS was quantifiable in all Hudson Bay bear liver samples.

With respect to temporal trends, and although uncorrected for e.g. age, sex and diet, from 1991 to 2014 the most concentrated BFRs were the mean ΣPBDE (BDE-47, -99, -100 and -153 consistently accounted for 90% of the ΣPBDEs) concentrations, which increased up until 2009 and then began a general decline progressing to 2014 in Western Hudson Bay bears (Figure 1). The same decreasing trend occurred between 2007 and 2014 in Southern Hudson Bay bears (Figure 1).

Starting in 2007 and until 2013, analysis of fat samples from Hudson Bay bears showed that BDE-209 and 22 non-PBDE replacement FRs were not detectable at all or infrequently, whereas HBCDD and BB-153 were quantifiable (Figure 2). However, in 2014 samples the same 22 non-PBDE replacement FRs whereas HBCDD was no longer not detectable in any southern or western Hudson Bay fat sample (Figure 1).

Even though the concentrations were not corrected for e.g. age, sex and diet, between 2007 and 2015, the mean concentrations of ΣPFCAs and PFOS in Hudson Bay polar bear liver was continually very high at high ppb and ppm levels (wet weight), respectively (Figure 2). These mean ΣPFCA and PFOS concentrations were comparable to ΣPCB and ΣCHL concentrations in fat tissue for all years (Figure 2). However, mean PFOS and ΣPFCA levels appeared to be neither increasing nor decreasing and there was no clear trend over the period of 2007-2015 (Figure 2).

In the liver of bears from both subpopulations, mean THg concentrations (wet weight) from 2002 to 2015 were constant (ranging from approximately 10 to 25 μg•g^{-1}, and slightly greater in bears from western versus southern Hudson Bay (Figure 3).

Discussion and Conclusions

The overall picture of the legacy and emerging POPs in both southern and western Hudson Bay bears shows that with the exception of the major PFASs (mean ΣPFCA and PFOS in liver), mean ΣSCCP, ΣPCN, ΣPBDE and BB-153 concentrations, all other recently screened POPs (e.g. mean ΣOPEs, α-endosulfan, HBCDD and ΣDP-like substances) were generally at much lower concentrations in fat tissue compared with the legacy POPs (mean ΣPCB, ΣCHL, ΣHCH, ΣDDT and ΣClBz). Also, some priority POPs that were screened in the same fat samples collected as recently as 2013-2015 were not detectable with any frequency (e.g. β-endosulfan, endosulfan sulfate, HCBD, PCP, PCA and dicofol isomers). Low level new and emerging POPs should continue to be monitoring in Canadian polar bears.

Figure 1

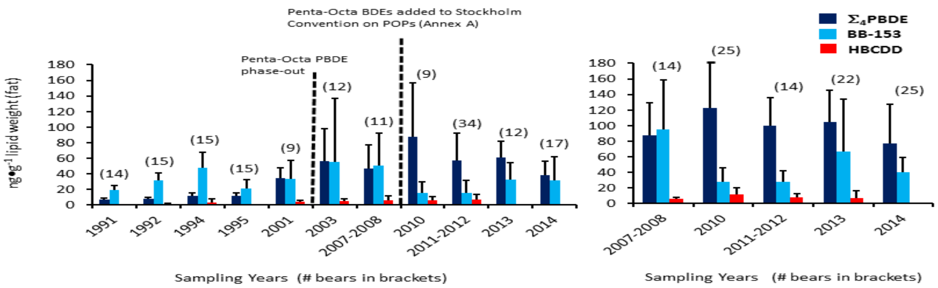


Figure 2

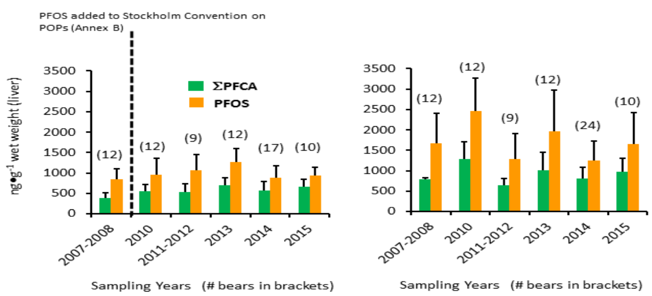
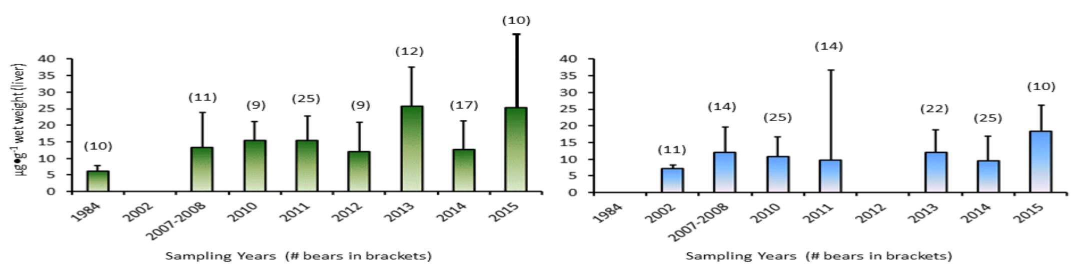


Figure 3



To our knowledge, the (low ppb concentration) detection of C_4 perfluorobutane sulfonamide (FBSA) in polar bear liver is a first for any Arctic wildlife sample, although no corresponding perfluorobutane sulfonic acid (PFBS) was detectable in any liver sample. Perfluorobutane carboxylic acid (PFBA) was measureable at low ppb levels with almost 100% frequency in all western and southern Hudson Bay bear livers. Furthermore, the cyclic analogue of PFOS, PFEtCHxS was quantifiable in all Hudson Bay bear liver samples. To our knowledge this is the first report detecting PFEtCHxS or FBSA in any Arctic sample. PFEtCHxS, FBSA and PFBA are representative of new and replacement PFASs currently being produced and used and continued monitoring in polar bears is warranted.

With respect to temporal trends, and although uncorrected for e.g. age, sex and diet, from 1991 to 2014 the mean concentrations for the the most concentrated BFRs, and ΣPBDEs increased up until 2009 and then began a general decline progressing to 2014 in Western Hudson Bay bears (Figure 1). The same downward trend occurred between 2007 and 2014 in Southern Hudson Bay bears (Figure 1). This is consistent with the PentaBDE and OctaBDE production phase out in the early 2000s and addition of these formulations to Annex A of the Stockholm Convention in 2009.

BDE-47, -99, -100 and -153 consistently accounted for 90% of the ΣPBDE concentration. The lack of BDE-209 is likely due to a combination of low exposure and uptake in the polar bear via the diet and also due to rapid metabolism and debromination. Polar bears possess a high ability, compared to other Arctic mammalian and avian wildlife, to bio-transform compounds via liver enzymatic processes including the debromination of BDE-209 and decabromodiphenyl ethane (DBDPE) (McKinney et al. 2011c).

PFOS and ΣPFCA levels appeared to be neither increasing nor decreasing and there was no clear trend for the period of 2007-2015 (Figure 2), despite C8 chemistry's phase-out around 2002 by the major worldwide producer at the time, the 3M Company. This stresses the importance of PFCAs and PFOS and their precursors as sources, which are transported to the Arctic and/or degraded in bears and/or their prey/food web (Letcher et al. 2014c; Boisvert et al. 2015a, 2015b).

In the liver of bears from both subpopulations, mean THg concentrations (wet weight) from 2002 to 2015 were essentially constant, but slightly greater in bears from Western versus Southern Hudson Bay (Figure 3). As we reported in Rush et al. (2008), in liver of southern or Western Hudson Bay bears collected in 2002 and as far back as 1984, mean THg concentrations were less than 10 μg•g-1 wet weight. Thus, over the longer time period from of 1984, increases occurred after 2002 and remained constant until 2015 in Hudson Bay bears. The Minamata Convention on Hg was officially adopted and opened for signatures in October, 2013, and thus THg annual monitoring is warranted for Hudson Bay polar bears.

Clearly, POP and Hg exposure for Hudson Bay polar bears continues to increase in complexity, which is also being shown to be true for other circumpolar subpopulations such as for bears from East Greenland. Several high priority POPs under consideration for addition to the POPs Stockholm Convention annexes (being reviewed by the POPRC that recommends POPs for addition to the Stockholm Convention Annexes) are being detected and/or are quantifiable (in some cases at high levels) in tissue from recently harvested Hudson Bay polar bears, e.g. SCCPs, and PFASs including replacements such as shorter chain perfluoroalkyl acids and sulfonamide precursors. These new emerging POPs require further annual monitoring and selective retrospective temporal examination to understand longer-term trends, sources, fate and exposure to polar bears.

Expected Project Completion Date

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

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References

Bechshøft, T.Ø., Sonne, C., Jakobsen, J., Rigét, F.F., Born, E.W., Letcher, R.J., Jenssen, B.M., Dietz, R. 2016. Vitamins A and E in liver, kidney, and whole blood of East Greenland polar bears sampled 1994-2008: Reference values and temporal trends *Polar Biol.* 39: 743-754.

Bechshøft, T.Ø., Sonne, C., Rigét, F.F., Letcher, R.J., Novak, M.A., Henchey, E., Meyer, J.S., Eulaers, I., Jaspers, V.L.B., Covaci, A., Dietz, R. 2013. Polar bear stress hormone cortisol fluctuates with the North Atlantic Oscillation climate index. *Polar Biol.* 36: 1525–1529.

Boisvert, G., Letcher, R.J., Dietz, R., Sonne, C., Born, E.W. 2015a. *POSTER: Novel and established perfluoroalkyl substances in East Greenland ringed seals and polar bear liver and fat samples and predator to prey bioaccumulation and biomagnification.* ASM/NCP 2015, December 7-11, Vancouver, BC, Canada

Boisvert, G., Letcher, R.J., Dyck, M., Dietz, R., Sonne, C., Born, E.W. 2015b. *POSTER: A comparison of bioaccumulative perfluorinated sulfonic and carboxylic acids and precursors in recent liver samples of polar bears from East Greenland (2012) and two subpopulations from Hudson Bay, Canada (2011-2012).* 36th Annual SETAC North American Meeting (SETAC), Nov. 1-5, Salt Lake City, UT, U.S.A.

Braune, B., Chételat, J., Amyot, M., Brown, T., Evans, M., Fisk, A., Gaden, A., Girard, C., Hare, A., Kirk, J., Lehnherr, I., Letcher, R.J., Loseto, L., Macdonald, R., McMeans, B., Muir, D. 2015. Mercury in the marine environment of the Canadian Arctic: A review of recent data. *Sci. Total Environ.* 509–510: 67-90.

Desforges, J.-P., Sonne, C., Levin, M., Siebert, U., Eulaers, I., Letcher, R.J., Dietz, R. 2015. *ORAL: Immunotoxic effects of environmental pollutants in marine mammals.* 21st Biennial Conference on the Biology of Marine Mammals. Dec. 13-18, San Francisco, CA, U.S.A.

Dietz, R., Gustavson, K., Sonne, C., Desforges, J.-P., Riget, F.F., McKinney, M.A., Letcher, R.J.. 2015a. Physiologically-based pharmacokinetics modelling of immune, reproductive and carcinogenic effects from contaminant exposure in polar bears (Ursus maritimus) across the Arctic. Environ. Res. 140: 45-55.

Dietz, R., Gustavson, K., Sonne, C., Desforges, J.-P., Rigét, F.F., Pavlova, V., McKinney, M.A., Letcher, R.J. 2015b. ORAL: Effects of contaminant exposure in polar bears (Ursus maritimus) across the Arctic, over the last three decades. 21st Biennial Conf. on the Biology of Marine Mammals. Dec. 13-18, San Francisco, CA, U.S.A.

Dietz, R., Sonne, C., Letcher, R.J., Jenssen, B.M. 2016. Polar bear circumpolar health assessment in relation to chemical pollutants and climate change. In: R. Kallenborn (eds.) *From Pole to Pole: Polar Environmental Research during the International Polar Year 2007 – 2009* Heidelberg, Germany: Springer-Verlag, in press.

Ferguson, S.H., Archambault, P., Matley, J., Robert, D., Darnis, G., Geoffroy, M., Suzuki, K., Falardeau, M., Harwood, L.A., Slavik, D., Grant, C., Link, H., Asselin, N.C., Reist, J.D., MacPhee, A., Majewski, A.R., Sawatzky, C.D., Atchison, S., Loseto, L.L., Letcher, R.J., Macdonald, R.W. 2015. Chapter 4 - Arctic Change: Impacts on Marine Ecosystems and Contaminants . In G. Stern and A. Gaden (eds.) ArcticNet, *From Science to Policy in the Western and Central Canadian Arctic: IRIS of Climate Change and Modernization.* ArcticNet, pp. 201-254.

Gabrielsen, K.M., Krokstada, J.S., Villanger, G.D., Blair, D.A.D., Obregond, M.-J., Sonne, C., Dietz, R., Letcher, R.J., Jenssen, B.M. 2015a. Thyroid hormones and deiodinase activity in plasma and tissues in relation to high levels of organohalogen contaminants in East Greenland polar bears. *Environ. Res.* 136: 413-423.

Gabrielsen, K.M., Krokstad, J.S., Villanger, G.D., Blair, D.A.D., Obregon, M.S., Ciesielski, T.M., Sonne, C., Dietz, R., Letcher, R.J., Jenssen, B.M. 2015b. *ORAL: Thyroid-disruptive effects of organohalogenated compounds in plasma and tissues of polar bears.* 18th Pollutant Responses in Marine Organisms (PRIMO 18) Conference, May 24-27, Trondheim, Norway.

Haider, W., Pröbstl-Haider, U., Steinberg, P., Singh, R., Letcher, R.J. 2015. R.J. Letcher sub-section, Environment: Physical properties, Arctic warming, biodiversity, contaminants - Arctic warming is the major driver in a changing Arctic. Elsevier Virtual Special Issue, "*The Arctic: a virtual special issue of multidisciplinary research*"

Letcher, R.J., Bustnes, J.-O., Dietz, R., Jenssen, B.M, Jørgensen, E.H., *et al.* 2010. Exposure and Effects assessment of persistent organic pollutants in Arctic wildlife and fish. *Sci. Total Environ.* 408(15): 2995-3043.

Letcher, R.J., Dyck, M., Sverko, E., Reiner, E., Blair, D.A.D., Chu, S.G., Shen, L. 2014a. *POSTER: New and emerging persistent organic pollutants and the changing exposure profile in polar bears (Ursus maritimus) from Hudson Bay.* Arctic Change 2014 conference / ArcticNet Meeting, December 8-12, Ottawa, ON

Letcher, R.J., Muir, D.C.G. 2014b. *Invited session joint speakers: New Chemicals in wildlife and fish and future research on persistent organic pollutants in a changing Arctic.* Arctic Change 2014 conference / ArcticNet Meeting, December 8-12, Ottawa, ON, Canada

Letcher, R.J., Chu, S.G., McKinney, M.A., Tomy, G.T., Dietz, R., Sonne, C. 2014c. Comparative hepatic *in vitro* depletion and metabolite formation of major perfluorooctane sulfonate precursors in polar bear, ringed seal and beluga whale. *Chemosphere* 112: 225-231.

Letcher, R.J. *et al.* 2015a. Temporal/spatial trends of contaminants in Canadian polar bears: Part III. In: *Synopsis of research conducted under the 2014/2015, Northern Contaminants Program.* Ottawa: INAC. Ottawa, Canada.

Letcher, R.J., Dyck, M., Sverko, E., Reiner, E., Blair, D.A.D., Chu, S.G., Shen, L. 2015b. (Re) Emerging persistent organic pollutants (POPs), exposure, fate and temporal changes in polar bears (*Ursus maritimus*) from a POP hotspot in the Canadian Arctic, Hudson Bay. 35th International Symposium on Halogenated Persistent Organic Pollutants (DIOXIN 2015), *Organohalogen Compounds*, 77.

Letcher, R.J., Dyck, M., Sverko, E., Reiner, E., Blair, D.A.D., Chu, S.G., Shen, L. 2015c. *POSTER: (Re)Emerging persistent organic pollutants (POPs), exposure, fate and temporal changes in polar bears (Ursus maritimus) from a POP hotspot in the Canadian Arctic, Hudson Bay.* ArcticNet Meeting/ Northern Contaminant Program Workshop 2015 (ASM/NCP 2015), December 7-11, Vancouver, BC, Canada

Letcher, R.J., Dyck, M., Fisk, A.T., Boisvert, G. 2015d. *POSTER*: Established and novel per- and poly-fluoroalkyl substance exposure, fate and temporal changes in relation to diet in polar bears from Canadian Arctic subpopulations in Hudson Bay. ASM/NCP 2015, December 7-11, Vancouver, BC, Canada

Letcher, R.J., Dyck, M., Fisk, A.T., Boisvert, G. 2015e. *POSTER: Established and novel per- and poly-fluoroalkyl substance exposure, fate and temporal changes in relation to diet in polar bears from Canadian Arctic subpopulations in Hudson Bay.* 36th Annual Society of Environmental Toxicology and Chemistry North American Meeting (SETAC), Nov. 1-5, Salt Lake City, UT, U.S.A.

Levin, M., Desforges, J.-P., Gebhard, E., Dietz, R., Sonne, C., Bossi, R., Letcher, R.J., Gabrielsen, K., Jenssen, B.M., De Guise, S. 2015. *POSTER: Immunomodulatory effects of in vitro and in vivo exposure to PCBs and perfluorinated compounds in East Greenland ringed seals.* 25th Annual Society of Environmental Toxicology and Chemistry European Meeting (SETAC-Europe), May 3-7, Barcelona, Spain.

McKinney, M.A., Stirling, I., Lunn, N.J., Peacock, E., Letcher, R.J. 2010. The role of diet in the temporal patterns and trends (1991-2007) of brominated flame retardants and organochlorines in western Hudson Bay polar bears. *Sci. Total Environ.* 408: 6210-6222.

McKinney, M.A., Letcher, R.J., Aars, J., Born, E.W., Branigan, M., Dietz, R., Evans, T.J., Gabrielsen, G.W., Peacock, E. 2011a. Regional contamination versus regional diet differences: Understanding geographic variation in brominated and chlorinated contaminant levels in polar bears. *Environ. Sci. Technol.* 45: 896-902.

McKinney, M.A., Letcher, R.J., Aars, J., Born, E.W., Branigan, M., Dietz, R,. Evans, T.J., Gabrielsen, G.W., Peacock, E., Sonne, C. 2011b. Flame retardants and legacy contaminants in polar bears from Alaska, Canada, East Greenland and Svalbard, 2005-2008. *Environ. Int.* 37: 365-374.

McKinney, M.A., Dietz, R., Sonne, C., De Guise, S., Skirnisson, K., Karlsson, K., Steingrímsson, E., Letcher, R.J. 2011c. Comparative hepatic microsomal biotransformation of selected polybrominated diphenyl ether, including decabromodiphenyl ether, and decabromodiphenyl ethane flame retardants in arctic marine-feeding mammals. *Environ. Toxicol. Chem.* 30: 1506-1514.

McKinney, M.A., Pedro, S., Dietz, R., Sonne, C., Fisk, A.T., Letcher, R.J. 2015. Ecological impacts of global climate change on persistent organic pollutant and mercury pathways and exposures in arctic marine ecosystems: A review of initial findings. *Current Zool.* 61(4): 617-628.

Morris, A.D., Muir, D.C.G., Solomon, K.R.S., Letcher, R.J., McKinney, M.A., Fisk, A.T., McMeans, B., Teixeira, C., Wang, X., Duric, M. 2016. Current use pesticides in seawater and their bioaccumulation behavior in polar bear-ringed seal food chains of the Canadian Arctic. *Environ. Toxicol. Chem.* In press.

Pavlova, V., Grimm, V., Dietz, R., Sonne, C., Vorkamp, K., Rigét, F.F., Letcher, R.J., Gustavson, K., Desforges, J.-P., Nabe-Nielsen, J. 2016. Modeling population-level consequences of PCB exposure in East Greenland polar bears. *Arch. Environ. Contam. Toxicol.* 70: 143-154.

Pedersen, K.E., Basu, N., Letcher, R.J., Sonne, C., Dietz, R., Styrishave, B. 2015. Brain region-specific perfluoroalkylated sulfonic and carboxylic acid accumulation and neurochemical biomarker responses in East Greenland polar bears (*Ursus maritimus*). *Environ. Res.* 138: 22-31.

Rigét, F.F., Vorkamp, K., Bossi, R., Sonne, C., Letcher, R.J., Dietz, R. 2016. 20 years of monitoring of persistent organic pollutants in Greenland biota: A review. *Environ. Pollut.* In press.

Routti, H., Letcher, R.J., Born, E.W., Branigan, M., Dietz, R., Evans, T.J., Fisk, A.T., Peacock, E., Sonne, C. 2011. Spatial and temporal trends of selected trace elements in liver tissue from polar bears (*Ursus maritimus*) from Alaska, Canada and Greenland. *J. Environ. Monit.* 13: 2260-2267.

Routti, H., Letcher, R.J., Born, E.W., Branigan, M., Dietz, R., Evans, T.J., McKinney, M.A., Peacock, E., Sonne, C. 2012. Influence of carbon and lipid sources on variation of mercury and other trace elements in polar bears (*Ursus maritimus*). *Environ. Toxicol. Chem.* 31: 2739–2747.

Rush, S.A., Borgå, K., Dietz, R., Evans, T.J., Muir, D.C.G., Letcher, R.J., Norstrom, R.J., Fisk, A.T. 2008. Geographic distribution of select elements in the livers of polar bears (*Ursus maritimus*) from Greenland, Canada and the United States. *Environ. Pollut.* 153: 618-626.

Scheuhammer, A., Braune, B., Chan, L.H.M., Frouin, H., Krey, A., Letcher, R.J., Loseto, L., *et al.* 2015. Biological effects of mercury in Canadian Arctic fish and wildlife: A review. *Sci. Total Environ.* 509–510: 91-103.

Sonne, C., Dyck, M., Rigét, F.F., Beck-Jensen, J.-E., Hyldstrup, L., Letcher, R.J., Gustavson, K, Gilbert, T., Dietz, R. 2015. Penile density and globally used chemicals in Canadian and Greenland polar bears. *Environ. Res.* 137: 287-291.

Update on Mercury Levels in Hendrickson Island and Sanikiluaq Beluga

Mise à jour sur les concentrations de mercure chez les bélugas de l'île Hendrickson et de Sanikiluaq

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Abstract

Samples of liver, kidney, muscle and muktuk of beluga whales collected in 2015 were analyzed for total mercury and selenium. Levels of mercury remained similar to ranges established in previous years. Of the organs analyzed in this study, liver typically had the highest concentrations of mercury, followed by kidney, muscle and muktuk. For example, the mean concentration of total mercury in 27 liver samples of beluga from Hendrickson Island in 2015 was 26.41 ± 20.82 $\mu g \cdot g^{-1}$ while that of muktuk from the same animals was 0.44 ± 0.22 $\mu g \cdot g^{-1}$. Data from these samples were added to the growing database on concentrations of these elements in organs of arctic marine mammals. The database now contains information on over 1377 arctic beluga from several locations over the period from 1977 to 2015. Mercury content varies among species, among individual animals, and among organs within an animal. This variation makes rigorous detection of differences among animals, places and times statistically

Résumé

On a analysé les concentrations de mercure total et de sélénium dans des échantillons de foie, de reins, de muscles et de muktuk du béluga prélevés en 2015. Les concentrations de mercure sont semblables aux plages du paramètre établies au cours des dernières années. Parmi les organes analysés dans le cadre de cette étude, le foie est celui qui, en général, présente les plus fortes concentrations de mercure, suivi des reins, des muscles et du muktuk. Par exemple, la concentration moyenne de mercure total dans 27 échantillons de foie prélevés en 2015 chez des bélugas de l'île Hendrickson s'élevait à 26,41 ± 20,82 µg g^{-1}, alors que celle dans le muktuk des mêmes animaux s'élevait à 0,44 ± 0,22 μg^{-1}. Les données provenant de ces échantillons ont été ajoutées à la base de données croissante sur la présence de ces éléments dans les organes et les tissus des mammifères marins de l'Arctique. La base de données contient maintenant de l'information sur plus de 1 377 bélugas de

difficult. Detection of differences among samples is further complicated by the fact that mercury accumulates with age so that older animals usually have higher levels than younger ones from the same location. Consequently comparison of mercury levels among different groups of beluga requires adjustment for differing ages, and as a result, accurate age data are essential. The additional samples obtained each year improve the chances of detecting differences if they are real and reduce the chances of reporting apparent differences if they are not real. Usually the chemical analyses are completed prior to the age determinations and so there is a lag in interpretation of the data.

l'Arctique capturés à plusieurs endroits au cours de la période allant de 1977 à 2015. Le contenu en mercure varie entre les espèces, entre les individus et entre les organes d'un animal. Vu cette variation, la détection rigoureuse de différences entre les animaux, les lieux et les périodes est difficile sur le plan statistique. Le fait que le mercure s'accumule au fil du temps dans l'organisme des animaux, ce qui fait que les individus âgés présentent habituellement des niveaux plus élevés que les jeunes animaux d'un même lieu, vient compliquer davantage la détection de différences entre les échantillons. Par conséquent, la comparaison des niveaux de mercure chez les différents groupes de bélugas demande un rajustement du fait des différences d'âges, et ainsi, des données précises sur l'âge sont essentielles. Les échantillons additionnels prélevés chaque année améliorent les chances de détecter des différences si elles sont réelles et réduisent les chances de signaler des différences apparentes si elles ne sont pas réelles. Habituellement, les analyses chimiques se font avant la détermination de l'âge, ce qui entraîne un délai dans l'interprétation des données.

Key messages

- New data were obtained on total mercury in organs of beluga from Hendrickson Island, Sanikiluaq.
- The mean level of mercury in 2015 liver samples from the HI animals was 26.41 ± 20.82 $\mu g \cdot g^{-1}$. The mean age of these same whales was 26.3 ± 7.6 years. Mercury in muscle was lower than that in liver with a mean concentration of 1.26 ± 0.80 $\mu g \cdot g^{-1}$.
- In spite of the lower values in HI muscle, all of them still exceeded 0.5 $\mu g \cdot g^{-1}$, the concentration long used to regulate the sale of commercial fish in Canada.
- Of the three organs analyzed in the HI animals, muktuk contained the lowest levels of total mercury with a mean 0.44 ± 0.22 $\mu g \cdot g^{-1}$. Thirty percent of the samples (8 of 27) exceeded 0.5 $\mu g \cdot g^{-1}$.
- Unlike liver, total mercury in muscle and muktuk is equivalent to MeHg (i.e. THg =

Messages clés

- De nouvelles données ont été obtenues sur les concentrations de mercure total dans les organes et les tissus de bélugas de l'île Hendrickson et de Sanikiluaq.
- La concentration moyenne de mercure mesurée dans les échantillons de foie prélevés en 2015 chez des animaux de l'île Hendrickson était de 26,41 ± 20,82 $\mu g \cdot g^{-1}$. L'âge moyen de ces mêmes baleines était de 26,3 ± 7,6 ans. Les concentrations de mercure étaient plus faibles dans les muscles que celles dans le foie, la moyenne de ces concentrations étant de 1,26 ± 0,80 $\mu g \cdot g^{-1}$.
- Même si les valeurs étaient plus faibles dans les muscles des bélugas de l'île Hendrickson, elles demeuraient toutes supérieures à 0,5 µg·g-1, soit la concentration de référence utilisée depuis longtemps pour réglementer la vente d'espèces commerciales de poissons au Canada.

MeHg). MeHg is the form of mercury that bioaccumulates and is toxic.

- The mean mercury concentration in SK liver samples was 7.72 ± 9.67 $\mu g \cdot g^{-1}$. Muscle levels were lower, with a mean of 0.60 ± 0.27 $\mu g \cdot g^{-1}$, and mercury levels in muktuk were even lower with a mean concentration of 0.18 ± 0.10 $\mu g \cdot g^{-1}$.

- Parmi les trois organes analysés chez les animaux de l'île Hendrickson, c'est le muktuk qui renfermait les plus faibles concentrations de mercure total, soit en moyenne 0,44 ± 0.22 $\mu g \cdot g^{-1}$. Trente pour cent des échantillons (8 des 27) dépassaient 0,5 $\mu g \cdot g^{-1}$.

- Dans le muktuk et dans les muscles, le mercure total (HgT) est équivalent au méthylmercure (MeHg) [c'est-à-dire que HgT = MeHg], contrairement à ce que l'on observe dans le cas du foie. Le MeHg est une forme de mercure qui est bioaccumulable et toxique.

- La concentration moyenne de mercure dans les échantillons de foie provenant de Sanikiluaq était de 7,72 ± 9,67 $\mu g \cdot g^{-1}$. Les concentrations dans les muscles étaient plus faibles, la moyenne étant de 0,60 ± 0,27 $\mu g \cdot g^{-1}$, et les niveaux de mercure dans le muktuk étaient encore plus faibles, la concentration moyenne se chiffrant à 0,18 ± 0.10 $\mu g \cdot g^{-1}$.

Objectives

- To provide incremental information on concentrations of mercury and selenium in organs of beluga from selected locations in the Canadian Arctic

- To present new data in the context of previous data from the same species and locations

- To maintain a database of this information that will enable the more rigorous assessment of temporal and spatial changes of mercury in these animals

Introduction

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

The levels of mercury in several organs of marine mammals from the Canadian Arctic have been relatively high (Wagemann et al. 1996; Lockhart et al. 2005; Loseto et al. 2015), exceeding levels in commercial fish analyzed by the Canadian Food Inspection Agency. Health Canada has published an updated evaluation of the risks of mercury in fish for human health (Health Canada, 2007) but Health Canada did not address consumption of marine mammals. One table (Appendix III, Health Canada 2007) lists species of fish for which at least some individuals have levels over 0.5 $\mu g \cdot g^{-1}$. If the marine mammal organs reported here were to be included in the Health Canada tables, they would fall in this group with levels over 0.5 $\mu g \cdot g^{-1}$. However, mercury in fish is almost all in the toxic form of methylmercury; in marine mammals that is not the case. Recent analyses have shown that marine mammals organs vary in the way they store mercury; in liver, kidney and brain only about one quarter of the mercury is methylmercury but in muscle, most of it is methylmercury (Lemes et al, 2011).

Mercury has increased in air over the North Atlantic (Slemr and Langer, 1992) and mercury has been measured in air and in snow in the Arctic (Lu et al., 2001). Sediment core studies in arctic lakes (Hermanson, 1993; Lockhart et al., 1998) have suggested that mercury inputs have increased over the past few decades but those studies do not discriminate between inputs due to imported mercury transported by the air and inputs due to mercury already in watersheds and mobilized by, for example, climate warming. Mercury has increased in teeth from modern beluga from the Mackenzie Delta but not in teeth of walrus from Igloolik (Outridge et al., 2002). Previously, Outridge et al. (2000) showed that mercury in teeth correlates with those in liver, kidney, muscle and muktuk, and so trends in teeth were likely mirrored by trends in other organs. It is not clear what proportion of the mercury supporting these increases derives from mercury already present in the Arctic or from mercury imported into the Arctic from elsewhere.

Several recent studies have suggested that decreased ice cover has resulted in altered feeding behaviour in some arctic marine mammal populations (Stern and Macdonald, 2005; Gaden et al., 2009; Gaden and Stern, 2010) and that this may influence intakes of mercury. Loseto et al. (2015) reviewed over three decades of Hg to evaluate trend drivers. Neither the diet nor trends in Hg emissions explained beluga Hg trends. Rather a strong fit with the Pacific Decadal Oscillation (lagged by 8yrs) provided the best fit with beluga Hg. These findings suggest that beluga Hg trends may reflect distant drivers of climate variability that likely altered dietary exposure in their large home range.

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

Activities in 2015-2016

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

In the 2015 animal tissues, total Hg (THg) was analysed at the Centre for Earth Observation Science (CEOS) at the University of Manitoba. THg is measured by Combustion Atomic Absorption Spectroscopy (C-AAS) on a Teledyne Leeman HYDRA IIc. Samples are directly combusted in an oxygen-fed oven, followed by gold trap amalgamation and detection by AAS. Detection limits are 0.04 ng Hg (absolute; most beluga tissues have several thousand ng of Hg per 0.01 g of sample). QA/QC is accomplished using certified reference materials (CRM) from the National Research Council (NRC) Canada, using dogfish muscle (DORM-3), dogfish liver (DOLT-3) and lobster hepatopancreas (TORT-2). Recoveries are 90-110% of established values, and precision is better than 8% RSD for each of the CRM.

Beluga ages were estimated using the standard approach of counting growth layer groups in dentine and cementum. Alongside this approach novel methods using aspartic acid we tried and tested in beluga eyeballs at FWI. The lab at FWI is currently evaluating the feasibility and application of this new method for beluga age estimation (Pleskach et al., accepted). Hendrickson Island beluga liver and muscle tissues were analyzed for stable isotopes at the FWI (Rosenberg et al., 2015), and beluga blubber samples were extracted and processed for fatty acids.

Results

New samples of beluga were obtained and analyzed in 2015

- Muscle, liver and muktuk samples and ages of 27 beluga from Hendrickson Island.
- Muscle, liver and muktuk samples and ages of 10 beluga from Sanikiluaq.
- As in previous years we had no success with the collection Pangnirtung samples.

The ages and mean concentrations (μg·g-1 wet weight) of mercury in liver, muscle and muktuk are listed in Table 1.

Hendrickson Island 2015

Collections from Hendrickson Island are one of the most extensive with 454 samples from 19 collections taken every year since 1993 with the exception of a gap between 1996 and 2001. The mean level of mercury in liver samples in 2015 was 26.41 ± 20.82 μg·g-1 (Table 1). The mean age of these same whales is 26.3 ± 9.6 years. Mercury in muscle was lower than that in liver with a mean concentration of 1.36 ± 0.80 μg·g-1. In spite of the lower values in muscle, all of them still exceeded 0.5 μg·g-1, the concentration long used to regulate the sale of commercial fish in Canada. Of the 3 organs analyzed, muktuk contained the lowest levels of total mercury with a mean 0.44 ± 0.22 μg·g-1. Thirty percent of the samples (8 of 27) exceeded 0.5 μg·g-1. Unlike liver, total mercury in muscle and muktuk is equivalent to MeHg (i.e. THg = MeHg). MeHg is the form of mercury that bioaccumulates and is toxic. Retrospective data is reported by Stern et al. in the 2013 NCP synopsis report and in Loseto et al. (2015).

Sanikiluaq

Ten samples were analyzed from Sanikiluaq in 2015. Total mercury levels found in the three organs analyzed are listed in Table 1. Mean mercury in liver was 7.72 ± 9.67 $\mu g \cdot g^{-1}$, Muscle levels were lower, with a mean of 0.60 ± 0.27 $\mu g \cdot g^{-1}$ and mercury levels in muktuk were lower with a mean of 0.18 ± 0.10 $\mu g \cdot g^{-1}$. As previously reported, mercury concentrations in Sanikiluaq animal tissues (actually all eastern Arctic beluga) are significantly lower than has been measured in the western Arctic animals.

Discussion and Conclusions

Levels of total mercury in arctic beluga organs remain high when compared with fish commonly consumed by people. Of the three organs analyzed, liver contains the highest mercury concentrations, followed by muscle and muktuk. Even with the lowest concentrations in muktuk, many of them still exceed 0.5 μg·g-1, the concentration long used to regulate the sale of fish for human consumption. These results

Table 1. Age data and concentrations of total mercury in organs of beluga (M+F) from HI and SK. Concentrations are shown in $\mu g \cdot g^{-1}$ wet weight followed by standard deviations.

Location	Year	Age	Liver	Muscle	Muktuk
Hendrickson	2015	26.3 (9.6)	26.41 (20.82)	1.26 (0.80)	0.44 (0.22)
Sanikiluaq	2015	18.7 (8.0)	7.72 (9.67)	0.60 (0.27)	0.18 (0.10)

should be reviewed by public health experts together with the known benefits of consuming beluga and recent findings of the protective actions of selenium (Lemire et al., 2016; Ayotte et al., 2016).

Recent marine mammal related publications (2009-15).

1. Loseto, L.L., Stern, G.A. 2015. Macdonald. Distant drivers or local signals: where do mercury trends in western Arctic belugas originate? Science of the Total Environment 509–510, 226–236.
2. Braune, B.; Chetelat, J.; et al. 2014. Mercury in the marine environment of the Canadian Arctic: Review of recent findings. STOTEN. In press.
3. Dietz, R. et al. 2013. What are the toxicological effects of mercury in Arctic biota? STOTEN, 443, 775-790.
4. Ostertag, S.K.; Stern, G.A.; Wang, F.; Lemes, M; Chan, L. 2013. Mercury distribution and speciation in different brain regions of beluga whales (*Delphinapterus leucas*). STOTE, 456-458,278-286.
5. Frouin, H.; Loseto, L.L.; Stern, G.A.; Haulena, M.; Ross, P.S. 2012. Mercury toxicity in beluga whale lymphocytes: Limited effects of selenium protection. Aquatic Toxical., 109, 185-193.
6. Gaden, A.; Ferguson, S.; Harwood, L.; Melling, H.; Alikamik, A.; Stern, G.A.; 2012 Western Canadian Arctic ringed seal organochlorine contaminant trends in relation to sea ice break-up. Environ. Sci, Technol. 46, 4427–4433.
7. Lemes, M,: Wang, F.; Stern, G.A.; Ostertag, S.K.; Chan, H.M., 2011, Methylmercury and selenium speciation in different tissues of beluga whales (*Delphinapterus leucas*) from the Western Canadian Arctic. Environ. Toxicol. Chem. 30, 2732–2738.
8. 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.
9. Gaden, A.; Ferguson, S. H.; Harwood, L.; Melling, H.; Stern, G. A. Mercury Trends in Ringed Seals (*Phoca hispida*) from the Western Canadian Arctic since 1973: Associations with Length of Ice-Free Season. Environ. Sci Technol. 2009, 43, 3646-3651.

Expected project completion date

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

References

Ayotte, P., et al. 2015. Selenoneine content of traditional marine foods consumed by the Inuit in Nunavik, Northern Canada. In *Global Advances in Selenium Research from Theory to Application: Proceedings of the 4th International Conference on Selenium in the Environment and Human Health 2015*. CRC Press, 32 (6).

Beak Consultants Limited (Calgary), 1978, Heavy metals project Mackenzie Delta and Estuary: A Report for Imperial Oil Limited. 61 pg + appendices.

Gaden, A., Ferguson, S.H., Harwood, L., Melling, H. and Stern, G.A. 2009. Mercury Trends in ringed seals *(Phoca hispida)* from the Western Canadian Arctic since 1973: Associations with length of ice-free season. *Environ. Sci. Technol.* 43: 3646-3651.

Gaden, A. and Stern, G.A. 2010. Temporal trends in beluga, narwhal and walrus mercury levels: Links to climate change. Manuscript in press, get final reference.

(I have an editor's proof but not the journal reference.)

He, K., Morris, S., Xun, P., Reis, J., Liu, K. and Guallar, E., 2013, Mercury exposure in young adulthood and incidence of diabetes later in life, Diabetes Care, Publish Ahead of Print published on line February 19, 2013.

Health and Welfare Canada, 1979, Methylmercury in Canada. Exposure of Indian and Inuit residents to methylmercury in the Canadian environment, Health and Welfare Canada, Medical Services Branch, 200 pg.

Health Canada, 2007, Human Health Risk Assessment of Mercury in Fish and Health Benefits of Fish Consumption, available on line at http://hc-sc.gc.ca/fn-an/pubs/mercur/merc_fish_poisson_e.html, downloaded as a PDF file April 19, 2013.

Huggins, F.E., Raverty, S.A., Nielsen, O.S., Sharp, N.E., Robertson, J.D. and Ralston, N.V.C. 2009, An XAFS Investigation of Mercury and Selenium in Beluga Whale Tissues. *Environmental Bioindicators.* 4291-302

Hermanson, M.H. 1993. Historical accumulation of atmospherically derived pollutant trace metals in the Arctic as measured in dated sediment cores. *Water Sci. Technol.* 28(8-9):33-41.

Lemes, M., Wang, F., Stern, G.A., Ostertag, S.K. and Chan, H.M. 2011. Methylmercury and Selenium Speciation in Different Tissues Of Beluga Whales (Delphinapterus Leucas) from the Western Canadian Arctic. *Env. Toxicol. Chem.* 30(12): 2732-2738.

Lemire, M., Achouba, A., Dumas, P.Y., Ouellet, N., Ayotte. S. 2016. Selenoneine is the major Se compound in the blood of Inuit consuming of traditional marine foods in Nunavik, Northern Canada. In *Global Advances in Selenium Research from theory to Application: Proceedings of the 4th International Conference on Selenium in the Environment and Human Health 2015.* CRC Press, 2015.

Lockhart, W.L., Wilkinson,P., Billeck, B.N., Danell, R.A., Hunt, R.V., Brunskill, G.J. , Delaronde, J. and St. Louis, V. 1998. Fluxes of mercury to lake sediments in central and northern Canada inferred from dated sediment cores. *Biogeochem.* 40: 163-173.

Lockhart, W.L., Stern, G.A., R. Wagemann, R., Hunt, R.V., Metner, D.A., DeLaronde, J., Dunn , B., Stewart, R.E.A., Hyatt, C.K., Harwood, L., and Mount, K. 2005. Concentrations of mercury in tissues of beluga whales (*Delphinapterus leucas*) from several communities in the Canadian Arctic from 1981 to 2002. *Sci. Total Environ.* 351/352: 391-412.

Loseto, L.L., Stern, G.A. 2015. Macdonald. Distant drivers or local signals: where do mercury trends in western Arctic belugas originate? *Sci. Total Environ.* 509–510: 226–236.

Lu, J.Y., Schroeder W.H., Barrie, L.A., Steffen, A., Welch, H.W., Martin, K., Lockhart, W.L., Hunt, R.V. and Boila, G. 2001. Magnification of atmospheric mercury deposition to polar regions in springtime: the link to tropospheric ozone depletion chemistry. *Geophys. Res. Lett.* 28: 3219-3222.

Outridge, P.M., Hobson, K.A., McNeely, R. and Dyke, A. 2002. A comparison of modern and preindustrial levels of mercury in teeth of beluga in the Mackenzie Delta, Northwest Territories, and walrus at Igloolik, Nunavut, Canada. *Arctic.* 22(2): 123-132.

Outridge, P. M., Wagemann, R. and McNeely, R.. 2000. Teeth as biomonitors of soft tissue mercury concentrations in beluga, *Delphinapterus leucas. Environ. Toxicol. Chem.* 19: 1517-1522.

Pleskach, K., Hoang, W., Chu, M., Halldorson, T., Loseto, L., Ferguson, S. Tomy, G. 2016. Use of mass spectrometry to measure aspartic acid racemization for ageing beluga whales. *Marine Mammal Science,* In Press.

Rosenberg, B., Neumann, D., Loseto, L. 2015. Freshwater Institute (DFO Winnipeg) stable Isotope Laboratory QA/QC and Inter-lab Comparison Report. *Can. Data Rep. Fish. Aquat. Sci.* 1260: vi+7p.

Slemr, F and Langer, E. 1992. Increase in global atmospheric concentrations of mercury inferred from measurements over the Atlantic Ocean. *Nature.* 355: 434-437.

Stern, G.A., and Macdonald, R.W. 2005. Biogeographic provinces of total and methyl mercury in zooplankton and fish from the Beaufort and Chukchi Seas: Results from the SHEBA drift. *Environ. Sci. Technol.* 39(13): 4707-4713.

Wagemann, R., Innes, S., Richard, P.R. 1996. Overview and regional and temporal differences of heavy metals in arctic whales and ringed seals in the Canadian Arctic. *Sci. Total Environ.* 186: 41-66.

Temporal Trends of Halogenated Organic Compounds in Canadian Arctic Beluga

Tendances temporelles relatives aux composés organohalogénés chez les bélugas de l'Arctique canadien

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Abstract

The objectives of this ongoing 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 ArcticNet, to understand the effects that climate variation may have on these contaminant levels.

Résumé

La présente étude, qui est encore en cours, a pour but de tenir à jour les données sur les concentrations de contaminants chez les mammifères marins et de poursuivre l'évaluation des tendances temporelles des composés organiques halogénés (COH). Cela nous permettra de déterminer si les niveaux de ces composés chez les mammifères marins et, par conséquent, l'exposition des habitants de l'Arctique qui, traditionnellement, les consomment, changent avec le temps. Les résultats obtenus aideront aussi à vérifier l'efficacité des mécanismes internationaux de restriction et, conjointement avec des projets comme ArcticNet, à comprendre les effets que les variations climatiques peuvent avoir sur les concentrations de ces contaminants.

Key messages

- In 2015, tissue samples from ten Hendrickson Island and Sanikiluaq animals were analyzed for OC/PCBs. Samples collected and analysed to date are shown in Table 1 & 2. No samples were received from Pangnirtung.
- We now have a very unique long-term data set for HOCs in western Arctic beluga; 18 time points spanning 26 years.
- 2015 samples were analyzed at ALS Environmental.
- 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.
- 2015 OC and PCB levels in HI blubber were an order of magnitude lower than was measure in all previous years. Selected tissues from 2015 and 2013 were reanalyzed by ALS and all values have been verified. Mercury levels were normal. Additional funds are being sought to analyze ten 2014 blubber samples and an additional subset of the 2015 animals.

Messages clés

- En 2015, on a prélevé des échantillons de tissus chez dix animaux de l'île Hendrickson et de Sanikiluaq pour en déterminer la teneur en pesticides organochlorés et en biphényles polychlorés. Les résultats obtenus pour les échantillons recueillis et analysés jusqu'ici sont présentés aux tableaux 1 et 2. Aucun échantillon n'a été reçu de Pangnirtung.
- On possède maintenant un ensemble de données à long terme sans pareil sur les composés organohalogénés (COH) chez les bélugas de l'ouest de l'Arctique (18 moments d'échantillonnage sur 26 ans).
- Les échantillons de 2015 ont été analysés par ALS Environmental.
- Aucune tendance n'a été observée pour les principaux groupes de COH chez le béluga de la partie ouest de l'Arctique. Plus particulièrement, les niveaux d'hexachlorure de benzène (HCH) ne reflètent pas les baisses observées dans l'atmosphère et dans l'océan Arctique depuis l'interdiction des mélanges techniques par la Chine en 1983, puis par l'Inde en 1990.
- En 2015, les concentrations de pesticides organochlorés et de biphényles polychlorés dans le pannicule adipeux des animaux de l'île Hendrickson avaient un ordre de grandeur de moins que la mesure de toutes les années précédentes. Certains tissus de 2015 et de 2013 ont été réanalysés par ALS et toutes les valeurs ont été vérifiées. Les niveaux de mercure étaient normaux. On cherche également des fonds supplémentaires pour analyser dix échantillons de pannicule adipeux de 2014 et un autre sous-ensemble des animaux de 2015.

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 beluga from selected Hendrickson Island (ISR) and Sanikiluaq (NU)

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 2015-2016

In 2015, tissue samples from 10 Hendrickson Island and Sanikiluaq animals were analyzed. Samples collected and analysed to date are shown in Table 1 & 2. No samples were received from Pangnirtung.

Results

As part of an ongoing whale sampling and stock identity program, supported by the FJMC 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. In 2015, all OC analyses were run at ALS Environmental.

We now have a very unique long-term data set for HOCs in western Arctic beluga that encompasses 18 time points spanning 26 years. As shown in Table 1, no real trends are evident. Of particular interest is the fact that HCHs are not showing the declines observed atmospherically and in the Arctic Ocean (Li et al., 2004) since the ban in the usage of the technical mixture by China in 1983 and followed by India in 1990. As was postulated for mercury, the lack of response of HCH in western Arctic beluga to the declining levels in the Arctic atmosphere and Ocean could be, at least in part, attributed to recent changes in ice cover, which may, for example, alter the foraging of the beluga whales or their prey (Stern and Macdonald, 2005; Gaden et al. 2009, 2010;

Loseto et al. 2006, 2008a,b, 2009; Kuzyk et al. 2010). First results from IPY CFL and ArcticNet Phase II field programs designed to try and determine the effects that climate change will have on the ocean-sea ice-atmosphere coupling of hexachlorocyclohexane (HCH) and transport within the western Arctic have been published (Pucko et al. 2010a,b, Pucko et al. 2011, 2012).

2015 OC and PCB levels in Hendrickson Island blubber were an order of magnitude lower than was measured in all previous years. Selected tissues from 2015 and 2013 were reanalyzed by ALS and all values have been verified. Mercury levels were normal. Additional funds are being sought to analyze 10 2014 blubber samples and an additional subset of the 2015 animals.

Expected Project Completion Data

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

References

Gaden, A.; Ferguson, S. H.; Harwood, L.; Melling, H.; Stern, G. A. 2009. Mercury Trends in Ringed Seals (*Phoca hispida*) from the Western Canadian Arctic since 1973 : Associations with Length of Ice-Free Season. *Environ. Sci Technol.* 43: 3646-3651.

Gaden, A. and Stern, G.A., Temporal Trends in Beluga, Narwhal and Walrus Mercury Levels: Links to Climate Change. In S.H. Ferguson, L. L. Loseto, and M. L. Mallory (eds.), *A Little Less Arctic: Top Predators in the World's Largest Northern Inland Sea, Hudson Bay.* Springer pp. 197.

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.

Li, Y. F.; R.W. Macdonald, J.M. Ma, H. Hung, S. Venkatesh. 2004. Historical a-HCH budget in the Arctic Ocean: the mass balance box model (AMBBM). *Sci. Total Environ.* 324: 115-139.

Loseto, L.L.; Richard, P.; Orr, J.; Stern, G.A.; Ferguson, H.S. 2006. Sexual segregation of Beaufort beluga whales during the open-water season. *Can. J. Zoology.* 84:1743-1751.

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.

Loseto, L. L.; Stern, G. A.; Ferguson, S.H. 2008b. Size and biomagnification: How habitat selection explains beluga mercury levels. *Environ. Sci. Technol.* 11: 3982-3988.

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. Exp. Mar. Biol. Ecol.* 374: 12-18.

Pućko, M.; Stern, G.A.; Macdonald, R.W.; Barber, D.G. 2010a. 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

Pućko, M.; Stern, G.A.; Barber, D.G.; Macdonald, R.W.; Rosenberg, B. 2010b. 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): 244-262.

Pućko, M.; Stern, G.A.; Macdonald, R.W.; Rosenberg. B.; Barber, D.G. 2011. The influence of the atmosphere-snow-ice-ocean interactions on the levels of hexachlorocyclohexanes (HCHs) in the Arctic cryosphere. *J. Geophysical Research – Oceans.* 116(C2).

Pućko, M.; Stern, G.A.; Macdonald, R.W.; Barber, D.G.; Rosenberg. B.; Walkusz, W. 2013. When will α-HCH disappear from the Arctic Ocean? *Journal of Marine Systems.* 127: 88-100.

Stern G.A., R.W. Macdonald. 2005. Biogeographic Provinces of Total and Methyl Mercury in Zooplankton and Fish from the Beaufort and Chukchi Seas: Results from the SHEBA Drift. *Environ. Sci. Technol.* 39: 4707-4713.
127: 88-100

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	SCBz	SHCH	SCHL	SDDT	SPCB	SCHB	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	35.6 (12.0)	80.1 (5.9)	392.4 (90.5)	121.5 (23.5)	1412.5 (582.7)	1348.7 (698.8)	3006.6 (1247.6)	4585.5 (2707.9)	209.2 (68.6)	290.5 (99.5)
HI	2009	M	10	33.7 (11.8)	94.0 (3.7)	434.8 (131.1)	191.2 (88.6)	1336.7 (380.6)	4309.7 (2317.5)	3697.7 1475.1)	7268.0 (4382.7)	347.7 (99.6)	432.0 (133.4)
HI	2010	M	10	25.5 (8.0)	92.1 (3.5)	497.7 (93.8)	222.4 (48.0)	1074.5 (260.1)	2619.5 (866.3)	2397.5 (438.4)	6081.2 (2470.8)	384.0 (97.2)	522.3 (104.3)
HI	2011	M	10	25.7 (6.2)	92.4 (3.7)	590.2 (110.6)	266.8 (66.2)	1768.6 (801.6)	3084.2 (2244.8)	3690.2 (2109.7)	4394.7 (2114.6)	484.7 (175.6)	517.7 (216.7)
HI	2012	M	10	26.6 (7.2)	93.6 (2.0)	563.4 (92.7)	245.8 (53.5)	1518.8 (379.9)	4251.2 (1744.2)	3524.3 (1397.0)	7549.7 (2414.7)	380.0 (133.8)	521.0 (145.8)
HI	2013*	M	10	31.4 (8.2)	75.0 (8.4)	558.3 (248.7)	181.2 (41.6)	2113.1 (687.4)	3260.0 (1512.8)	3269.0 (1617.0)	882.4 (106.81)	311.0 (70.1)	469.0 (357.0)
HI	2015**	M	10	26.3 (9.6)	-	45.86 (24.14)	32.29 (40.48)	117.93 (65.00)	199.17 (107.51)	336.02 (175.23)	74.37 (42.39)	33.71 (17.98)	49.70 (26.01)

HL = Husky Lakes; HI = Hendrickson Island;

DFO: SDDT = Sum of *p,p'*-DDT, *p,p'*-DDE, *p p'*-DDD, *o,p'*-DDT, *o,p'*-DDE and *o,p'*-DDD; SHCH = a- b- and g-HCH isomers; SCHL = all chlordane related compounds, including heptachlor; SCBz = Sum of 1245TCB, 1234TCB, P5CBz, HCBz; SPCB = 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'

*ALS: SCBz = HCB; Sum of *p,p'*-DDT, *p,p'*-DDE, *p p'*-DDD, *o,p'*-DDT, *o,p'*-DDE and *o,p'*-DDD; SHCH = sum of a- b- and g-HCH isomers; SCHL = sum of *cis*- and *trans*-Chlordane, *cis*- and *trans*-Nonachlor; SCHB = sum of Parlar 26, 50, 62; SPCB = Sum of 1, 3, 4/10, 7/9, 6, 8/5, 12/13, 15, 19, 18, 17, 27/24, 16/32, 26, 25, 31/28, 20/33/21, 22, 37, 53, 45, 46, 73/52, 43/49, 48/47/75, 44, 59/42, 71/41/68/64, 40, 57, 63, 74/61, 70/76, 80/66, 56/60, 81, 77, 95/93, 91, 92, 84/90/101/89, 99, 83/108, 97, 86/111/125/117/87/116/115, 120/85, 110, 82, 107/109, 123, 118/106, 114, 105/127, 126, 136, 151, 135/144, 139/149, 131/165/142/146, 153, 132/168, 141, 137, 163/164/138, 158/160, 129, 159, 128/167, 156, 157, 169, 182/187, 183, 185, 174/181, 177, 171, 172/192, 180, 193, 191, 170/190, 189, 202, 199, 196/203, 195, 194, 205, 208, 207, 206, 209, 201/204.

**2015 values seem to be an order of magnitude lower than those measured in all previous years. Selected tissues from 2015 and 2013 were reanalyzed by ALS and all values have been verified. Mercury levels were normal. Additional funds are being sought to analyze 10 2014 blubber samples and an additional subset of the 2015 animals.

ALS: SCBz = HCB; Sum of *p,p'*-DDT, *p,p'*-DDE, *p p'*-DDD, *o,p'*-DDT, *o,p'*-DDE and *o,p'*-DDD; SHCH = sum of a- b- and g-HCH isomers; SCHL = sum of *cis*- and *trans*-Chlordane, *cis*- and *trans*-Nonachlor; SCHB = sum of Parlar 26, 50, 62; SPCB = Sum of 1, 3, 4/10, 7/9, 6, 8/5, 12/13, 15 , 19, 18, 17, 27/24, 16/32, 26, 25, 31/28, 20/33/21, 22, 37, 53, 45, 46, 73/52, 43/49, 48/47/75, 44, 59/42, 71/41/68/64, 40, 57, 63, 74/61, 70/76, 80/66, 56/60, 81, 77, 95/93, 91, 92, 84/90/101/89, 99, 83/108, 97, 86/111/125/117/87/116/115, 120/85, 110, 82, 107/109, 123, 118/106, 114, 105/127, 126, 136, 151, 135/144, 139/149, 131/165/142/146, 153, 132/168, 141, 137, 163/164/138, 158/160, 129, 159, 128/167, 156, 157, 169, 182/187, 183, 185, 174/181, 177, 171, 172/192, 180, 193, 191, 170/190, 189, 202, 199, 196/203, 195, 194, 205, 208, 207, 206, 209, 201/204.

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

Loc	Year	Sex	n	Age	%lipid	SCBz	SHCH	SCHL	SDDT	SPCB	SCHB	Dieldrin	Oxychlor
Sk	2013	F	9	18.2 (7.9)	78.2 (3.0)	100.9 (89.4)	60.9 (22.5)	305.9 (155.7)	414 (289.6)	498.7 (296.2)	193.8 (106.81)	163.7 (102.1)	90.4 (59.3)
Sk	2013	M	1	16.0	80.2	21.20	40.1	240.5	575.3	741.6	248.6	96.1	86.8
Sk	2015	M	7	26.3 (8.0)	85.1 (6.8)	54.7 (34.4)	16.8 (10.57)	182.6 (123.2)	338.5 (307.5)	465.3 (338.7)	129.4 (81.1)	85.8 (47.8)	71.6 (54.1)

Temporal Trends of Contaminants in Arctic Seabird Eggs

Tendances temporelles des contaminants dans les œufs des oiseaux de mer en Arctique

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Abstract

Contaminants are monitored in arctic seabird eggs as an index of contamination of arctic marine ecosystems. Eggs of thick-billed murres and northern fulmars have been collected from Prince Leopold Island in the Canadian high Arctic since 1975, and thick-billed murre eggs have been monitored at Coats Island in northern Hudson Bay since 1993. Differences in contaminant concentrations in eggs of thick-billed murres from Coats Island and nearby Digges Island suggest that results for these two colonies may not be totally interchangeable. Total Hg concentrations in eggs of thick-billed murres and northern fulmars from Prince Leopold Island increased during the 1970s and 1980s, and are now plateauing. Climate change appears to be having a small, but significant, effect on contaminant concentrations in seabird eggs. Concentrations of organochlorine contaminants in arctic seabird eggs rose in tune

Résumé

Les contaminants dans les œufs d'oiseaux de mer de l'Arctique font l'objet d'une surveillance, car ils constituent un indice de la contamination des écosystèmes marins de l'Arctique. On recueille des œufs de guillemots de Brünnich et de fulmars boréaux à l'île Prince Leopold, dans l'Extrême-Arctique canadien, depuis 1975 et assure une surveillance des œufs de guillemots de Brünnich à l'île Coats, dans le nord de la baie d'Hudson, depuis 1993. Les différences dans les concentrations de contaminants dans les œufs de guillemots de Brünnich de l'île Coats et à proximité de l'île Digges laissent entendre que les résultats pour ces deux colonies pourraient ne pas être totalement interchangeables.
Les concentrations de mercure total dans les œufs de guillemots de Brünnich et de fulmars boréaux sur l'île Prince Leopold ont augmenté durant les années 1970 et 1980, et plafonnent actuellement. Les changements climatiques

with increasingly positive summer North Atlantic Oscillation and Arctic Oscillation conditions, suggesting that contaminant concentrations in seabird eggs may increase if these conditions become more prevalent in the future. This could have important implications for future interpretation of contaminant temporal trends as a measure of the effectiveness of international agreements to reduce emissions.

semblent avoir un effet léger, mais notable, sur les concentrations de contaminants des œufs d'oiseaux de mer. Les concentrations de contaminants organochlorés dans les œufs d'oiseaux de mer de l'Arctique ont augmenté en harmonie avec les conditions d'oscillation nord-atlantique et arctique estivales de plus en plus positives, ce qui laisse présager une hausse des concentrations de contaminants dans les œufs des oiseaux de mer si ces conditions se font plus prévalentes dans l'avenir. Voilà qui pourrait entraîner des conséquences importantes pour l'interprétation future des tendances temporelles liées aux contaminants en tant que mesure de l'efficacité des ententes internationales portant sur la réduction des émissions.

Key messages

- Differences in contaminant concentrations in eggs of thick-billed murres from Coats Isand and nearby Digges Island suggest that results for these two colonies may not be totally interchangeable.
- Concentrations of total Hg in thick-billed murre and northern fulmar eggs from Prince Leopold Island increased during the 1970s and 1980s and are now plateauing.
- Climate change appears to have a small, but significant, interannual effect on contaminant concentrations in seabird eggs.
- This could have important implications for future interpretation of contaminant temporal trends as a measure of the effectiveness of international agreements to reduce emissions.

Messages clés

- Les différences dans les concentrations de contaminants dans les œufs de guillemots de Brünnich de l'île Coats et à proximité de l'île Digges laissent entendre que les résultats pour ces deux colonies pourraient ne pas être totalement interchangeables.
- Les concentrations de mercure total dans les œufs de guillemots de Brünnich et de fulmars boréaux sur l'île Prince Leopold ont augmenté durant les années 1970 et 1980, et plafonnent actuellement.
- Les changements climatiques semblent avoir un effet interannuel léger, mais notable, sur les concentrations de contaminants des œufs d'oiseaux de mer.
- Voilà qui pourrait entraîner des conséquences importantes pour l'interprétation future des tendances temporelles liées aux contaminants en tant que mesure de l'efficacité des ententes internationales portant sur la réduction des émissions.

Objectives

- To monitor contaminants in seabird eggs as an index of contamination in arctic marine ecosystems.
- To examine annual variation in temporal trend data series by collecting eggs for contaminant analyses from northern fulmars and thick-billed murres from Prince Leopold Island, and from thick-billed murres from Coats Island in northern Hudson Bay.
- To evaluate whether or not climate change is affecting the contaminant temporal trend dataset for seabird eggs from Prince Leopold Island.

Introduction

To provide an index of contamination of the arctic marine ecosystem, eggs of thick-billed murres (Uria lomvia) and northern fulmars (Fulmarus glacialis) from Prince Leopold Island in Lancaster Sound, Nunavut, have been monitored for contaminants since 1975 (Braune 2007) and eggs of thick-billed murres from Coats Island in northern Hudson Bay have been monitored since 1993 (Braune et al. 2002). Eggs are analyzed for legacy persistent organic pollutants or POPs (biennially as of 2014), total mercury (Hg) (annually), and the murre and fulmar eggs from Prince Leopold Island are also analyzed annually for polybrominated diphenyl ethers (PBDEs) and perfluoroalkyl substances (PFASs), and biennially for polychlorinated dibenzo-p-dioxins (PCDDs) and furans (PCDFs) as well as coplanar PCBs. All eggs are analyzed for stable isotopes of nitrogen as indicators of trophic position.

Since 1975, most of the legacy POPs (e.g. PCBs, DDT) in the murre and fulmar eggs have been declining (Braune et al. 2015a), whereas total Hg increased during the 1970s and 1980s followed by a plateauing of levels from the 1990s onward (Braune et al. 2016). The PBDEs increased from 1975 to 2003 followed by a rapid decrease in response to the phase-out of BDE technical products (Braune et al. 2015b), and the perfluorinated carboxylates (PFCAs) also increased from 1975 to 2008/2010 followed by a decline (Braune 2015). It has generally been assumed that these temporal trends reflect changing emission patterns over time. However, there is increasing evidence that other factors may be influencing contaminant exposure in arctic ecosystems (e.g. Braune et al. 2014c, 2015a, Gaden et al. 2009, McKinney et al. 2013, Nadal et al. 2015, Riget et al. 2012; Stern et al. 2012).

Arctic regions are warming more rapidly than the global average (IPCC 2014), and climate change has been identified as a major factor affecting contaminant pathways and food webs in arctic ecosystems (AMAP 2011, AMAP/UNEP 2011, NCP 2012, 2013). To date, research has focused primarily on associations between contaminant levels in wildlife and changes in diet related to sea ice conditions as well as teleconnection indices such as the North Atlantic Oscillation and Arctic Oscillation (Gaden and Stern 2010, Bustnes et al. 2010, Loseto et al. 2015, McKinney et al. 2013).

Continued monitoring of seabird eggs for both legacy and new POPs as well as Hg will provide valuable information against which to compare the effectiveness of international agreements such as the 1998 United Nations Economic Commission for Europe (UNECE), Long-range Transboundary Air Pollution (LRTAP) Protocols on Heavy Metals and POPs, the 2001 Stockholm Convention on POPs, and the 2013 Minamata Convention on Mercury. Continued monitoring of POPs and Hg in seabird eggs will also provide opportunities for the investigation of the potential effects of climate change on contaminant exposure in arctic ecosystems.

Activities in 2015-2016

Sample Collection/Analysis: The Sulukvait Area Co-Management Committee recommended that only six eggs per species rather than the prescribed 15 eggs were to be collected from Prince Leopold Island in 2015. Northern fulmar eggs (n=6) were collected by hand on the basis of one egg per nest from Prince Leopold Island (74°02'N, 90°05'W) but, due to a combination of poor weather conditions and mechanical problems with the helicopter, we were unable to collect any thick-billed murre eggs from Prince Leopold Island. We successfully collected eggs of thick-billed murres (n=15) from both Coats Island (62°30'N, 83°00'W) in northern Hudson Bay and Digges Island (62°33'N, 77°50'W) near Ivujivik in northeastern Hudson Bay. Eggs from Digges Island were collected for comparison with eggs from Coats Island should we have to switch monitoring colonies for logistical reasons in the future. Collection and analysis of eggs from Digges Island were done at no extra cost to the NCP.

As legacy POPs are now analyzed on a biennial basis, egg samples were not analyzed for legacy POPs in 2015. Eggs from Coats and Digges Islands were analyzed for PBDEs and HBCD in pools of 3 eggs each (15 eggs per collection = 5 pools of 3 eggs each). As only six fulmar eggs were collected from Prince Leopold Island, those eggs were individually analyzed for PBDEs and PFASs. All eggs were individually analyzed for total Hg and stable isotopes of nitrogen ($^{15}N/^{14}N$) and carbon ($^{13}C/^{12}C$).

Analytical Methods: Analyses of PBDEs, HBCD, PFASs and total Hg were carried out at the National Wildlife Research Centre (NWRC) laboratories at Carleton University in Ottawa, Ontario. Analyses of the standard 14 PBDE congeners and total-a-HBCD were carried out using GC-low resolution MS run in negative ion chemical ionization (NCI) mode according to NWRC Method No. MET-CHEM-OC-06B. PFASs were analyzed using UPLC/MS/MS in negative electrospray mode (ESI^-) according to NWRC Method No. MET-OCRL-EWHD-PFC-04. PFASs analyzed include 13 PFCAs (including PFOA), 4 PFSAs (including PFOS), and PFOSA. FTUCAs and FTOHs are no longer analyzed because they have not been detected in seabird eggs from this study in the past. Total mercury (Hg) was analyzed using a Direct Mercury Analyzer (DMA-80) for solid samples according to NWRC Method No. MET-CHEM-THg-01A. Quality assurance/quality control (QA/QC) is monitored by NWRC Laboratory Services which is an accredited laboratory through the Canadian Association for Laboratory Accreditation (CALA). NWRC has also participated in the NCP's QA/QC Program. Stable isotope (C, N) analyses were carried out at the G.G. Hatch Stable Isotope Laboratory, University of Ottawa in Ottawa, Ontario. All samples are archived in the National Wildlife Specimen Bank at the NWRC in Ottawa.

Evaluation of climate change on contaminant temporal trends: Climate data related to air temperature and pressure, wind speed, rain/snow accumulation, surface ocean temperature, sea ice information, primary productivity information, as well as oscillation indices such as the Arctic Oscillation (AO) and North Atlantic Oscillation (NAO) were compiled from online databases. Before climate change effects could be assessed, the effect of historical emissions had to be removed from the data using statistical approaches. The data were then compared with contaminant concentrations in seabird eggs to determine if climate change was affecting the contaminant temporal trends.

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 35 years. As there was no field camp at Prince Leopold Island in 2015, there were no opportunities for capacity building and training at that location. However, Josiah Nakoolak from Coral Harbour was hired to help with the field work at Coats Island. Building on earlier successful collaborations between NWRC and the Nunavut Arctic College (NAC) in Iqaluit, Guy Savard (NWRC biologist) and Jennifer Provencher (Carleton graduate student) went to Iqaluit again in 2015 with

NCP support to work with NAC Environmental Technology Program students. One of the teaching modules involved teaching students proper protocols for dissection of birds in the context of marine bird research including contaminants work.

Communications: Presentations on the work that Environment and Climate Change Canada (ECCC) is doing on arctic birds are given regularly in Resolute Bay, the closest community to Prince Leopold Island. Prince Leopold Island is a Migratory Bird Sanctuary and, as such, it is now managed by the Sulukvait Area Co-Management Committee (ACMC) administered through ECCC. The committee includes members of the Hunters' and Trappers' Organization, as well as elders and land managers from Resolute Bay. Amie Black (ECCC, Ottawa), who has been involved in seabird research in the Canadian Arctic for a number of years, met with the Sulukvait ACMC and the Resolute Bay HTO in February 2016 to present a plain-language field report (English-Inuktitut) summarizing our 2015 field activities on Prince Leopold Island and discuss future sampling requests. Amie also met with the principal and science teacher at Qarmartalik School in Resolute Bay to discuss ways of incorporating aspects of contaminants research and monitoring into the curriculum. Paul Smith (ECCC, Ottawa), who also has a field camp on Coats Island, met with the Aiviit HTO and the the Irniurviit ACMC in Coral Harbour in April 2015 and again in March 2016 to present information on the monitoring and research activities on migratory birds in the region. In March 2016, Paul also made presentations on marine bird research to the Grades 8 and 9 classes at Sakku School in Coral Harbour, and participated in a Community Open House in Coral Harbour. Annual reports of the results to date are made to the NCP each year and results will continue to be published in a peer-reviewed scientific journals. Digital and hard copies of the translated Coastlines newsletter, which contains plain-language summaries of our work, were sent to all HTOs/HTAs in Nunavut, as well as Inuit Organizations and Institutes of Public Government that deal with the environment.

Traditional Knowledge Integration: 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 2015, we respected the concerns of the Sulukvait ACMC and reduced the number of seabird eggs sampled from Prince Leopold Island. Upon further discussions regarding the status of seabird populations on Prince Leopold Island, the ACMC approved the re-establishment of sample sizes to previous numbers.

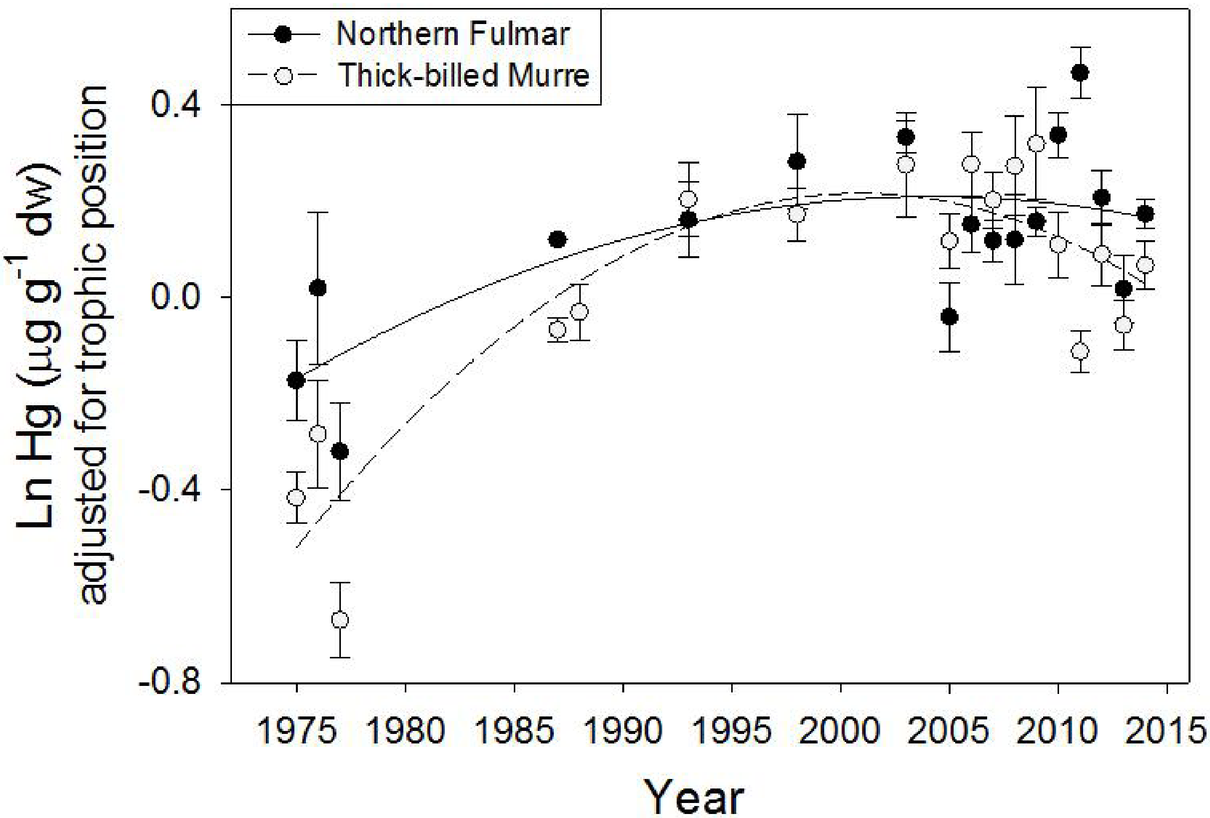
Results

Table 1. Comparison of mean concentrations (± standard deviation) of d15N (‰), total Hg (mg g-1 dry weight), and polybrominated diphenyl ethers (SPBDE), as ng g-1 lipid weight, in eggs of thick-billed murres from Coats Island and Digges Island in 2015. n = number of individual eggs for d15N and Hg, and number of 3-egg pools for HBCD and SPBDE.

	n	Coats Island		Digges Island
d15N	15	14.1 ± 0.50		14.8 ± 0.33
Hg	15	0.63 ± 0.23		0.87 ± 0.16
SPBDE	5	8.08 ± 2.78		7.39 ± 1.22

Intercolony Comparison: There was no significant difference found ($p>0.05$) in concentrations of SPBDE in eggs of thick-billed murres collected from Digges Island and Coats Island in 2015 (Table 1). There were, however, significant differences in $d^{15}N$ values ($t_{1,28} = 4.0$, $p<0.001$) and concentrations of total Hg ($t_{1,28} = 3.3$, $p=0.003$) in murre eggs between the two colonies.

Figure 1. Annual mean (± standard error) In-transformed Hg concentrations (mg g^{-1} dry weight) adjusted for trophic position (d^{15}N) in eggs of thick-billed murres and northern fulmars collected from Prince Leopold Island, Nunavut, 1975-2014. Modified from Braune et al. (2016).



Temporal Trends: Temporal trends of total Hg concentrations adjusted for trophic position in eggs of northern fulmars and thick-billed murres sampled from Prince Leopold Island from 1975 to 2014 were best described by second-order polynomial models which explained 30% and 56% of the variation, respectively, for each species (Figure 1). Total Hg increased during the 1970s and 1980s and now appears to be plateauing. Given the limited number of samples collected from Prince Leopold Island in 2015 as well as the reduced number of analytyes analyzed, there was no point in updating the annual rates of change using the statistical program PIA (Bignert 2013). The results for the fulmar eggs sampled from Prince Leopold Island are presented in Table 2.

Table 2. Mean concentrations (± standard deviation) of d^{15}N (‰), total Hg (mg g^{-1} dry weight), HBCD and SPBDE (ng g^{-1} lipid weight), and PFOS and SPFCA (C_6-C_{14}) (ng g^{-1} wet weight) in eggs (n=6) of northern fulmars collected from Prince Leopold Island in 2015.

	Mean ± sd
d15N	13.3 ± 0.27
Hg	1.44 ± 0.352
HBCD	20.1 ± 15.2
SPBDE	2.48 ± 2.31
PFOS	10.8 ± 3.49
SPFCA	18.4 ± 5.22

Effects of climate change on contaminant temporal trends: Climate change appears to have a small, but significant, effect on contaminant concentrations in seabird eggs. Summer oscillation (AO and NAO) is the climate variable that best correlated with contaminant concentrations in seabird eggs with a lag time of 6 to 7 years. Snowfall, wind speed and sea ice were also important variables on a more recent timescale (last ten years), but this trend didn't hold for the whole 39-year dataset.

Discussion and Conclusions

There was no significant difference found for concentrations of ΣPBDE in eggs of thick-billed murres collected from Digges and Coats Islands in 2015 (Table 1) which confirms the results for 2014 (Braune 2015). A comparison of ΣPBDE concentrations in livers of adult murres sampled from Coats and Digges Islands in 2007-2008 also showed no significant differences between the two colonies (Braune et al. 2014b) suggesting that contaminant data for murres from those two colonies are comparable. However, in 2015, $\delta^{15}N$ values and Hg concentrations were significantly higher in the murre eggs from Digges Island compared with Coats Island (Table 1). No significant differences were found for Hg between the two colonies in 2014 (Braune 2015) or in 1993 (Braune et al. 2002). A comparison of contaminant concentrations in livers of adult birds sampled from Coats and Digges Islands in 2007-2008 also showed no significant differences between the two colonies for total Hg (Braune et al. 2014a). Given that the mean $\delta^{15}N$ value was higher for murre eggs from Digges Island than at Coats Island in 2015, the difference found in total Hg concentrations between the two colonies may have been linked to differences in diet. These differences between the two colonies, which seem to change from year to year, suggest that results for thick-billed murre eggs from these two colonies may not be totally interchangeable.

Previous publications have documented the increase in total Hg concentrations in eggs of thick-billed murres and northern fulmars breeding on Prince Leopold Island (Braune 2007, Braune et al. 2001). A more recent update and analysis of the data suggest that total Hg increased during the 1970s and 1980s followed by a plateauing of levels from the 1990s onward (Figure 1) which appear to reflect atmospheric trends of Hg (Braune et al. 2016). Mercury trends similar to those observed in seabird eggs have also been observed for marine mammals (e.g. ringed seals Phoca hispida, beluga Delphinapterus leucas) sampled from the Canadian Arctic during the 1990s and post-2000 (Braune et al. 2015c).

Given that arctic regions are warming more rapidly than the global average (IPCC 2014), it is reasonable to ask how climate change may be affecting contaminant concentrations in arctic seabirds and on what timescale. It was determined that there was a correlation between increasingly positive summer NAO/AO conditions with higher organochlorine contaminants in arctic seabird eggs, suggesting that contaminant concentrations in seabird eggs may increase if conditions associated with positive NAO/AO events become more prevalent in the future. This could have important implications for the interpretation of contaminant temporal trends as a measure of the effectiveness of international agreements to reduce emissions.

Expected Project Completion Date

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

Acknowledgements

Thanks to all of the field crews for their collection of the seabird eggs over the years. Thanks also to the northern communities who have supported research activities on marine birds over the years. Sample preparation and chemical analyses were carried out by Laboratory Services at the National Wildlife Research Centre in Ottawa. Stable-nitrogen isotopes were analyzed by the G.G. Hatch Stable Isotope Laboratory at the University of Ottawa, Ottawa. Funding over the years has been provided by Environment and Climate Change Canada and the Northern Contaminants Program of Indigenous and Northern Affairs Canada. Logistical support out of Resolute Bay is provided by the Polar Continental Shelf Program, Natural Resources Canada.

References

AMAP. 2011. AMAP Assessment 2011: Mercury in the Arctic. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway, 193 pp.

AMAP/UNEP. 2013. Technical Background Report for the Global Mercury Assessment 2013. Arctic Monitoring and Assessment Programme, Oslo, Norway/UNEP Chemicals Branch, Geneva, Switzerland, vi + 263 pp.

Bignert, A. 2013. PIA statistical application developed for use by the Arctic Monitoring and Assessment Programme. (available from www.amap.no). Arctic Monitoring and Assessment Programme, Oslo, Norway.

Braune, B.M. 2007. Temporal trends of organochlorines and mercury in seabird eggs from the Canadian Arctic, 1975 to 2003. *Environ. Pollut.* 148: 599-613.

Braune, B. 2015. Temporal trends of contaminants in arctic seabird eggs. In: *Synopsis of research conducted under the 2014-2015 Northern Contaminants Program.* Ottawa: Aboriginal Affairs and Northern Development Canada. pp. 229-238.

Braune, B.M., G.M. Donaldson and K.A. Hobson. 2001. Contaminant residues in seabird eggs from the Canadian Arctic. I. Temporal trends 1975 - 1998. *Environ. Pollut.* 114: 39-54.

Braune, B.M., G.M. Donaldson and K.A. Hobson. 2002. Contaminant residues in seabird eggs from the Canadian Arctic. II. Spatial trends and evidence from stable isotopes for intercolony differences. *Environ. Pollut.* 117: 133-145.

Braune, B.M., A.J. Gaston, H.G. Gilchrist, M.L. Mallory and J.F. Provencher. 2014a. A geographical comparison of mercury in seabirds in the eastern Canadian Arctic. *Env. Int.* 66: 92-96.

Braune, B.M., A.J. Gaston, R.J. Letcher, H.G. Gilchrist, M.L. Mallory and J.F. Provencher. 2014b. A geographical comparison of chlorinated, brominated and fluorinated compounds in seabirds breeding in the eastern Canadian Arctic. *Environ. Res.* 134: 46-56.

Braune, B.M., A.J. Gaston, K.A. Hobson, H.G. Gilchrist and M.L. Mallory. 2014c. Changes in food web structure alter trends of mercury uptake at two seabird colonies in the Canadian Arctic. *Environ. Sci. Technol.* 48: 13246-13252.

Braune, B.M., A.J. Gaston, K.A. Hobson, H.G. Gilchrist and M.L. Mallory. 2015a. Changes in trophic position affect rates of contaminant decline at two seabird colonies in the Canadian Arctic. *Ecotox. Environ. Saf.* 115: 7-13.

Braune, B.M., R.L. Letcher, A.J. Gaston and M.L. Mallory. 2015b. Trends of polybrominated diphenyl ethers and hexabromocyclododecane in eggs of Canadian Arctic seabirds reflect changing use patterns. *Environ. Res.* 142: 651-661.

Braune, B., J. Chételat, M. Amyot, T. Brown, M. Claydon, M. Evans, A. Fisk, A. Gaden, C. Girard, A. Hare, J. Kirk, I. Lehnherr, R. Letcher, L. Loseto, R. Macdonald, E. Mann, B. McMeans, D. Muir, N. O'Driscoll, A. Poulain, K. Reimer, G. Stern. 2015c. Mercury in the marine environment of the Canadian Arctic: Review of recent findings. *Sci. Total Environ.* 509-510: 67-90.

Braune, B.M., A.J. Gaston and M.L. Mallory. 2016. Temporal trends of mercury in eggs of five sympatrically breeding seabird species in the Canadian Arctic. *Environ. Pollut.* In press.

Bustnes, J.O., G.W. Gabrielsen and J. Verreault. 2010. Climate variability and temporal trends of persistent organic pollutants in the Arctic: A study of glaucous gulls. *Environ. Sci. Technol.* 44: 3155–3161.

Gaden, A. and G.A. Stern. 2010. Temporal trends in beluga, narwhal and walrus mercury levels: Links to climate change. In: S.H. Ferguson, L.L. Loseto, L.L. and M.L. Mallory (eds.), *A little less Arctic: Top predators in The World's Largest Northern Inland Sea, Hudson Bay.* New York: Springer. pp. 197–216.

Gaden, A., S.H. Ferguson, L. Harwood, H. Melling and G.A. Stern. 2009. Mercury trends in ringed seals (*Phoca hispida*) from the western Canadian Arctic since 1973: associations with length of ice-free season. *Environ. Sci. Technol.* 43: 3646-3651.

IPCC. 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC, Geneva, Switzerland, 151 pp.

Loseto, L.L., G.A. Stern and R.W. Macdonald. 2015. Distant drivers or local signals: Where do mercury trends in western Arctic belugas originate? *Sci. Tot. Environ.* 509/510: 226-236.

McKinney, M.A., S.J. Iverson, A.T. Fisk, C. Sonne, F.F. Riget, R.J. Letcher, M.T. Arts, E.W. Born, A. Rosing-Asvid and R. Dietz. 2013. Global change effects on the long-term feeding ecology and contaminant exposures of East Greenland polar bears. *Global Change Biol.* 19: 2360-2372.

Nadal, M., M. Marqués, M. Mari and J.L. Domingo. 2015. Climate change and environmental concentrations of POPs: a review. *Environ. Res.* 143: 177-185.

NCP. 2012. *Canadian Arctic Contaminants Assessment Report III: Mercury in Canada's North.* Northern Contaminants Program (NCP), Aboriginal Affairs and Northern Development Canada, Ottawa. xxiii + 276 pp.

NCP 2013. *Canadian Arctic Contaminants Assessment Report On Persistent Organic Pollutants.* Northern Contaminants Program, Aboriginal Affairs and Northern Development, Canada, Ottawa. 487 pp.

Rigét, F.F., R. Dietz and K.A. Hobson. 2012. Temporal trends of mercury in Greenland ringed seal populations in a warming climate. *J. Environ. Monit.* 14: 3249–3256.

Stern, G.A., R.W. Macdonald, P.M. Outridge, S. Wilson, J. Chételat, A. Cole, H. Hintelmann, L.L. Loseto, A. Steffen, F. Wang and C. Zdanowicz. 2012. How does climate change influence arctic mercury? *Sci. Total Environ.* 414: 22-42.

Temporal trends and spatial variations in mercury in sea-run Arctic char from Cambridge Bay, Nunavut

Tendances temporelles et variations spatiales du mercure chez l'omble chevalier anadrome dans la région de Cambridge Bay, au Nunavut

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Abstract

Sea-run char form the basis of an important commercial fishery operating out of Ekaluktutiak (Cambridge Bay) in addition to being essential in traditional diets. Because of the commercial fishery, mercury concentrations were determined from the late 1970s to early 1990s in char runs at several rivers on southern Victoria Island and the mainland south of Queen Maud Gulf. Mercury concentrations were and remain exceedingly low in these char. Our study is now focussing on assessing trends in char mercury concentrations. Of particular importance is the influence of variations in climate (especially temperature) and mercury emissions on char mercury concentrations. In contrast to our studies in the Northwest

Résumé

Les ombles chevaliers anadromes constituent la base d'une importante pêche commerciale exploitée à Ekaluktutiak (Cambridge Bay), en plus d'être essentiels à l'alimentation traditionnelle. En raison de la pêche commerciale, des concentrations de mercure ont été décelées de la fin des années 1970 au début des années 1990 chez les ombles anadromes de plusieurs rivières du sud de l'île Victoria et sur la terre ferme au sud du golfe de la Reine-Maud. Les concentrations de mercure étaient et demeurent extrêmement faibles chez ces ombles. Notre étude se concentre maintenant sur l'évolution des tendances relatives aux concentrations de mercure chez les ombles. L'influence des

Territories where mercury concentrations are increasing in lake trout, mercury concentrations appear to be decreasing in sea-run char at Cambridge Bay with similar declines being observed in landlocked char at Resolute. These declines may be related to warming trends and/or decreasing mercury inputs. In addition, mercury concentrations tend to be lower in fish with higher condition factors (more weight for their length). Marlene visited Ekaluktutiak in August 2015 to discuss the char study and the Nunavut News/North published an article about this visit. Lake trout and char were provided by Ekaluktutiak fishermen from Grenier Lake for mercury analyses. In addition, Les Harris provided fillet from char caught from the Thirty-Mile/Halovik (2010-2015) and Lauchlan (2010-2014) fisheries west of Cambridge Bay and the Jayko (2010-2015) fishery east of Cambridge Bay. These collections are allowing us to better investigate differences and trends in mercury concentrations in char between river systems and their drivers.

variations du climat (surtout la température) et les émissions de mercure revêtent une importance particulière pour les concentrations de mercure chez les ombles. Contrairement à nos études menées dans les Territoires du Nord-Ouest où les concentrations de mercure sont à la hausse chez le touladi, les concentrations de mercure semblent diminuer chez l'omble chevalier anadrome à Cambridge Bay, des déclins similaires étant observés chez l'omble chevalier dulcicole à Resolute. Ces déclins pourraient être liés aux tendances de réchauffement ou aux apports de mercure décroissants. En outre, les concentrations de mercure ont tendance à être plus faibles chez les poissons ayant des coefficients de condition supérieurs (plus de poids pour leur longueur). Marlene a visité Ekaluktutiak en août 2015 afin de discuter de l'étude sur les ombles, et le journal Nunavut News/North a publié un article à propos de cette visite. Le touladi et l'omble ont été fournis par des pêcheurs de Grenier Lake à Ekaluktutiak aux fins d'analyses relatives au mercure. En outre, Les Harris a fourni des filets d'ombles pêchés dans les rivières Thirty Mile et Halovik (2010-2015) et Lauchlan (2010-2014) à l'ouest de Cambridge Bay et dans la rivière Jayko (2010-2015), à l'est de Cambridge Bay. Ces échantillonnages nous permettent de mieux étudier les différences et les tendances en matière de concentrations de mercure entre les réseaux hydrographiques et leurs facteurs.

Key messages

- Mercury concentrations are very low in sea-run char at Cambridge Bay.
- Mercury concentrations are very low in char from the various commercial fishery harvest areas.
- Mercury concentrations in sea-run char in Cambridge Bay are exhibiting a weak trend of decrease
- Mercury concentrations were higher in lake trout than in char from Grenier Lake.

Messages clés

- Les concentrations de mercure sont très faibles chez les ombles chevaliers anadromes de Cambridge Bay.
- Les concentrations de mercure sont très faibles chez l'omble provenant des diverses zones de récolte de pêche commerciale.
- Les concentrations de mercure chez l'omble chevalier anadrome à Cambridge Bay présentent une faible tendance à la diminution.
- Les concentrations de mercure étaient plus élevées chez le touladi que chez l'omble de Grenier Lake.

Objectives

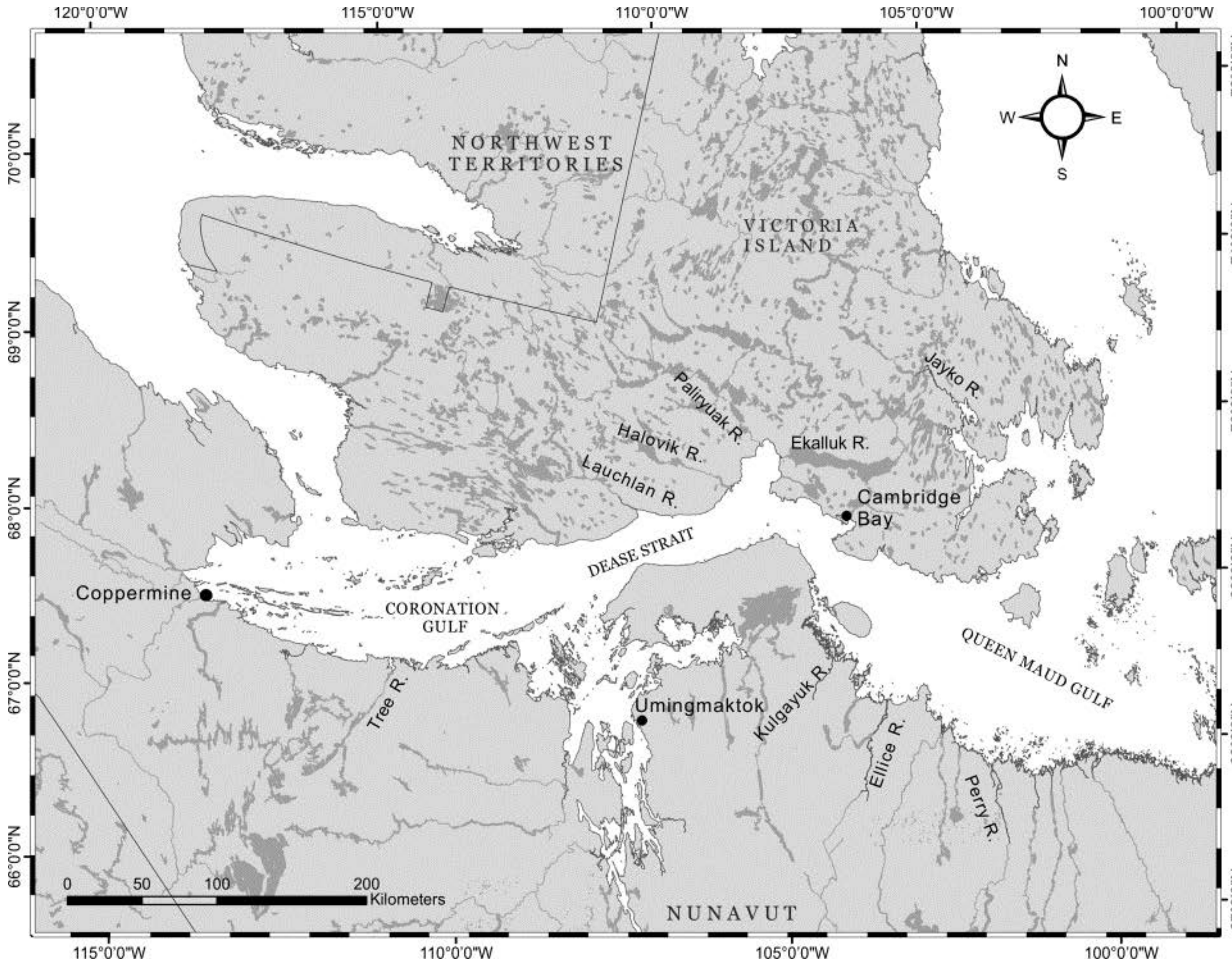
1. Continue our mercury trend monitoring of sea-run (anadromous) char from the domestic fishery at Ekaluktutiak with a focus on the role of climatic variability in affecting trends.
2. Obtain fish from the stock assessment studies being conducted by Fisheries and Oceans Canada (Les Harris) to investigate differences in mercury concentrations in char between various river/lake systems used by the commercial fisheries in order to extend our mercury temporal trend assessments.
3. In collaboration with the Canadian High Arctic Research Station (CHARS; Donald McLennan) and the Ekaluktutiak Hunters & Trappers Organization (HTO), continue our mercury investigations of char and lake trout in Grenier Lake.
4. Visit Ekaluktutiak to discuss the findings of the sea-run char project.
5. Contribute to the sea-run char monitoring being conducted at Nain by Rodd Laing with the Nunatsiavut Government.
6. Assist Pond Inlet in developing its monitoring programs.
7. Continue to provide contributions to the Arctic Monitoring and Assessment Programme (AMAP) on mercury trends.

Introduction

Arctic char (*Salvelinus alpinus*) are widespread across Arctic and subarctic waters with their range extending south into Labrador and the St. Lawrence River watershed; they are commonly found in rivers and lake systems which retain some connection to the sea although isolated (landlocked) populations are found within these watersheds (Gantner et al. 2010, Evans et al. 2015). Lake trout (*S. namaycush*), while extending similarly far north and south, are a more inland species; hence connections with the sea are limited (Scott and Crossman 1998a). Anadromous char migrate to the sea every two years to feed intensively for a few weeks during summer and then return inland. Reproduction generally occurs every second year. Resident char live in waters with access to the sea but do not migrate whereas landlocked char have no access to the sea. Lake trout inhabiting coastal lakes may also travel to the sea, however they do not migrate as far from the outflow river and most likely spend less time in the sea in comparison with sea-run char (Scott and Crossman 1998b).

Arctic char are important in traditional diets and, while populations are small in certain areas of their range, in areas such as Cambridge Bay, they are sufficiently abundant to support a commercial fishery in addition to meeting domestic needs (Day and Harris 2013). Important rivers from which these char are harvested while migrating are: the Halovik and Lauchlan, west of Cambridge Bay; the Jayko, east of Cambridge Bay and also on Victoria Island; and the Ellice, on the mainland and south of Queen Maud Gulf (Fig. 1). Mercury concentrations were measured periodically in these fisheries over 1977-1994. In more recent times, mercury concentrations were measured in char and lake trout populations in lakes south of Dease Strait and west of Cambridge Bay (Swanson et al. 2010, Swanson et al. 2011). In 2004, under the Northern Contaminants Program (NCP), Evans et al. (2015) began investigating spatial patterns in mercury and persistent organic pollutant concentrations in sea-run char at 20 locations across subarctic and Arctic Canada. Concentrations were low and in 2012 our trend monitoring was reduced to Cambridge Bay; monitoring has continued at Nain as a community-based program to build capacity and local knowledge.

Figure 1. Map of southern Victoria Island and the mainland showing Cambridge Bay and the location of rivers that are important to the commercial fishery. Fish are harvested at the river mouth while migrating inland. From Evans et al. (2014).



The rationale for continuing mercury monitoring of char at Cambridge Bay despite their low mercury concentrations is several-fold. Because early mercury records exist for char at this location, it is a good site for assessing mercury trends dating back to the late 1970s. The quality of the data is somewhat limited in that small numbers (generally <5) of fish were sampled each time and measurements were made on a sporadic basis on the various river stocks. The most frequent records are for Cambridge Bay where char migrate up Freshwater Creek to return to Grenier Lake; this stock is no longer harvested commercially; mercury records from this stock can be combined with data collected under NCP over 2004-2015. The entire historic data base also can be pooled to improve sample size with the assumption that variation in mercury concentrations between stocks is minor in comparison to differences between years. There are no other biological monitoring programs, e.g., marine mammals and birds, at Cambridge Bay.

The Canadian High Arctic Research Station (CHARS) is being built at Cambridge Bay and will investigate many aspects of the Arctic freshwater and marine environment with a focus on responses to climate change. Of particular interest with respect to Arctic monitoring programs are warming trends which are affecting the length of sea cover, enhancing productivity, extending species ranges and altering trophic feeding (Rose 2005, Hedd et al. 2006, Dodson et al. 2007, Cheung et al.

2009, Wassmann 2011, Provencher et al. 2012). Some CHARS programs will complement the more well-established studies at Resolute on Cornwallis Island; this station had its early beginnings with the International Biological Program (1968-1972) with programs continuing to this day (Rigler et al. 1974, Schindler et al. 1974, Hobson and Welch 1995, Michelutti et al. 2003, Muir et al. 2005, Apollonio 2013, Lescord et al. 2015). The char program at Resolute focusses on landlocked populations because of the scarcity of sea-run char in this northerly location. However, as landlocked, resident, and sea-run char populations are abundant in the Victoria Island area, there are possibilities to investigate the influence of climate change on marine feeding and lacustrine feeding char populations (van der Velden et al. 2013); lake trout, which are being monitored elsewhere under NCP and have been investigated on the mainland and co-occur with char in Grenier Lake, also can be monitored (Johnson 1962, Swanson et al. 2011, Evans et al. 2013, Chételat et al. 2014) .

Environment and Climate Change Canada (ECCC) have been investigating mercury in lake food webs (and sediment cores) under its Clean Air Regulatory Agenda (CARA) science program. While this research currently is focusing on major mercury emitters throughout southern Canada, some funds may be available for enhancing the biological trend monitoring being conducted in northern Canada under NCP.

Activities in 2015-2016

We published the paper "Sea-run char as an alternate food choice to marine animals: a synthesis of mercury concentrations and population features" in a special issue of *Science of the Total Environment* (Evans et al. 2015). This special issue was based on the recent Canadian Arctic Contaminant Assessment Report (CACAR; Chételat and Braune (2012)) and summarized our sea-run char studies over 2004-2013, reviewed known information on sea-run char at the major Arctic and subarctic char communities, and investigated mercury time trends in char. A poster was presented at the NCP workshop in December 2015 based on this publication.

In July, Marlene visited Ekaluktutiak where she had the opportunity to meet with representatives from the HTO to discuss the char study. This was facilitated by an open house organized by Diane Mala which included a posting on the HTO's Facebook page. During this meeting, people discussed other areas of interest including Grenier Lake and its char and lake trout populations. Following the meeting, Marlene was interviewed by Nunavut News/North and an article published in the August 10, 2015 edition (Burnett 2015) which featured the headline "Kitikmeot Char test Clean". Marlene also met with Don McLennan, Jean-Sebastian Moore, and Les Harris and discussed collaborations.

Sea-run char collections were delayed in 2015 until October when char (and lake trout) were obtained from Grenier Lake. This also occurred in 2007 when char were obtained from Kitiga Lake, west of Cambridge Bay and also with sea-run populations. Sea-run char harvested in August 2014 were larger, older, but with lower mercury concentrations than char caught from Grenier Lake (Table 1). Char caught from Grenier Lake in 2015 were similar to sea run caught in 2015. Lake trout were smaller, substantially older, and with substantially higher mercury concentrations.

Table 1. Biological features and mercury concentrations of char and lake trout caught in Cambridge Bay (sea-run) and Grenier Lake in 2014 and 2015.

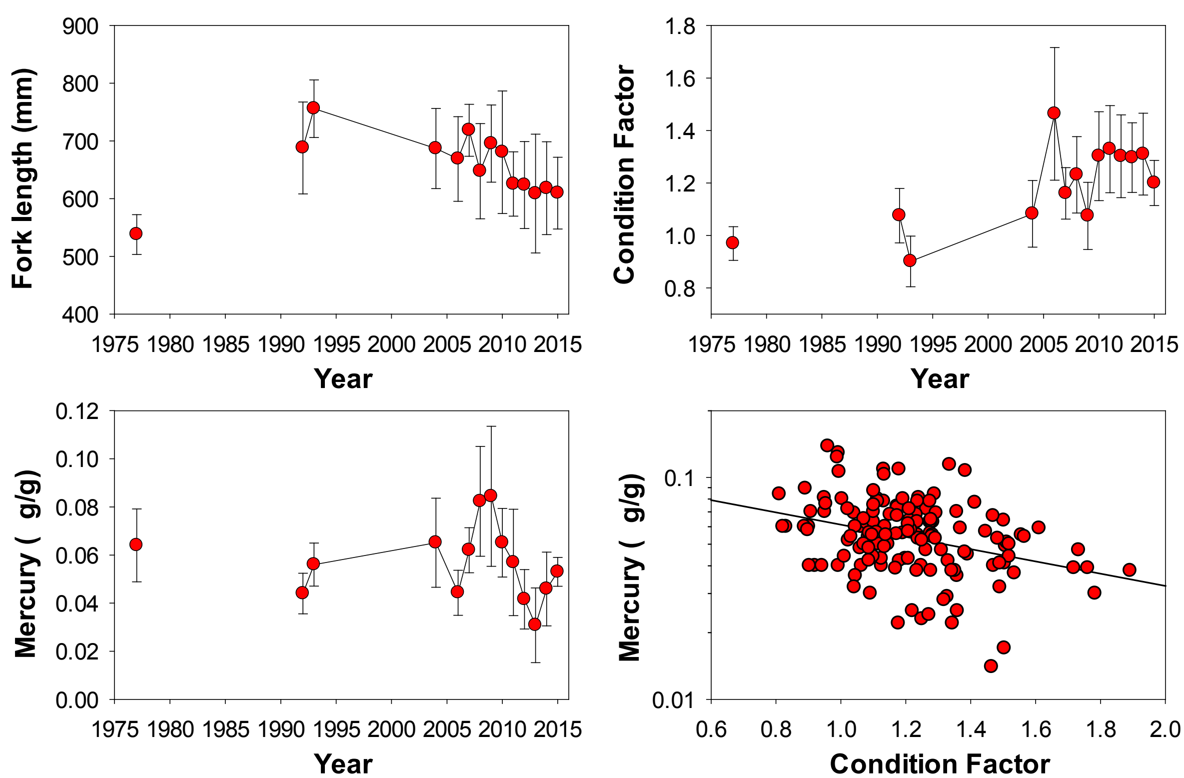
Species/ location		N	Fork Length (cm)	Condition Factor	Age (yr)	δ13C (‰)	δ15N (‰)	Hg (µg/g)
Arctic char								
Sea-run	2014	10	658 ± 90	1.3 ± 0.2	12.8 ± 3.4	-24.0 ± 0.4	14.4 ± 0.8	0.05 ± 0.02
Grenier Lake	2014	15	519 ± 53	1.1 ± 0.1	8.1 ± 3.2	-24.8 ± 1.3	12.7 ± 1.7	0.07 ± 0.04
Grenier Lake	2015	12	610 ± 62	1.2 ± 0.1	10.4 ± 1.5	-24.5 ± 0.7	14.6 ± 0.3	0.05 ± 0.01
Lake trout								
Grenier Lake	2014	15	501 ± 19	1.3 ± 0.1	22.7 ± 8.7	-25.5 ± 0.7	11.3 ± 0.6	0.40 ± 0.09
Grenier Lake	2015	9	593 ± 143	1.3 ± 0.2	29.7 ± 6.5	-26.5 ± 1.0	11.8 ± 1.5	0.51 ± 0.32

There was a significant trend of mercury decrease in Cambridge Bay char (500-800 mm fork length) over 2004-2015 (Fig. 2) with additional variance explained by condition factor (Equation 1). Variations on mercury concentration in Cambridge Bay over 1977-2015 were best explained by a negative relationship with condition factor without year as a significant term (Equation 2).

$$\text{Log Hg} = 28.326 - 0.015 \cdot \text{Yr} - 0.335 \cdot \text{CF}$$
($n = 108$; $R^2 = 0.23$, $F = 15.7$, $p < 0.001$)
Equation 1

$$\text{Log Hg} = -0.973 - 0.253 \cdot \text{CF}$$
($n=127$, $R2=0.32$, $F=14.53$, $p<0.001$)
Equation 2

Figure 2. Temporal variations in fork length, condition factor and mercury concentrations (fillet, wet weight) of char collected from the Cambridge Bay area over 1975-2015



In 2015, Les Harris provided sea-run char samples from Thirty-Mile and Jayko stocks. These samples have not been analyzed for mercury but samples provided from the Halovik (2011, 2014), Jayko (2010, 2014), and Lauchlan (2012) river systems have been analyzed and combined with earlier fish records (Fig. 3). Mercury concentrations tend to be higher in Jayko char than at other locations. Some of these fish appeared to be from the resident char based on their higher mercury concentrations.

Using the entire 1975-2015 mercury record for char from the Cambridge Bay area, there was a significant trend of mercury increase, again with a negative relationship with condition factor (Equation 3). Inclusion of spring (but not summer) air temperatures (1975-2014) explained additional variance (Equation 4).

Log Hg = -10.322+0.005*Yr-0.227*CF (n=338, R2=0.26, F=12.3, p<0.001) Equation 3

Log Hg = -9.747+0.00*Yr-0.162*CF-0.027*SpT (n=326, R2=0.30, F=10.6, p<0.001) Equation 4

Conclusions

Mercury concentrations remain low in sea-run char collected from the domestic fishery at Cambridge Bay. Concentrations appear to be decreasing over 2004-2015 as has been observed in landlocked char at Resolute and Greenland (Rigét et al. 2010, Muir et al. 2014). Additional variation in mercury concentrations are explained by condition factor. We are strengthening our ability to detect trends by analyzing char from other stocks in the Cambridge Bay area for mercury trends. We also have begun to investigate char and lake trout in Grenier Lake where the Cambridge Bay sea-run char analyzed in this study reside for most of their lives. This will provide a stronger research study on char in the Cambridge Bay area and provide a complimentary NCP and ECCC program.

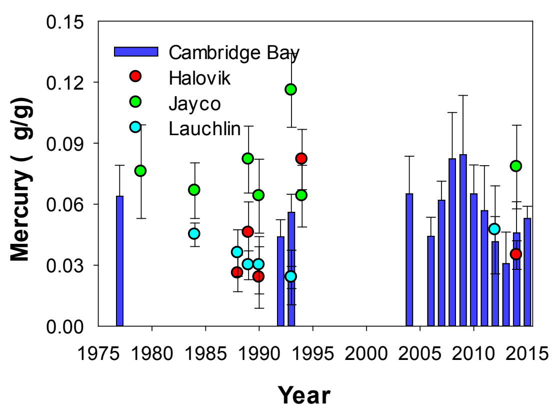
Expected Project Completion Date

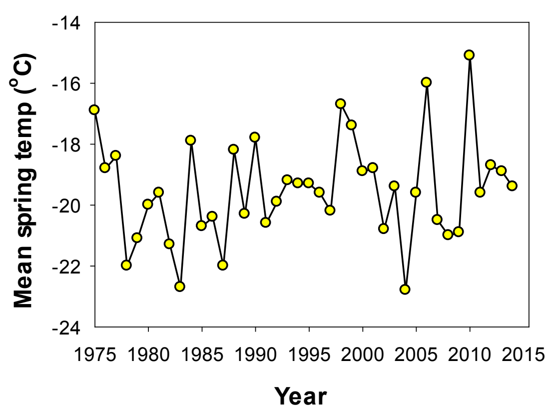
Ongoing.

Acknowledgments

Support for the mercury trend investigations of sea-run char were provided by NCP. Funding for lake trout collections and analyses were provided by ECCC under its CARA science program.

Figure 3. Temporal variations in mercury concentrations in char over the entire Cambridge Bay area, 1976-2015 and average spring air temperatures at Cambridge Bay.





Special appreciation is extended to Diane Mala with the Ekaluktutiak HTO for organizing an excellent community visit last August and for coordinating the collection of the char.

References Cited

Apollonio, S. 2013. Temporal patterns of Arctic and Subarctic zooplankton community composition in Jones Sound, Canadian Arctic Archipelago (1961-62, 1963). Arctic 66:463-469.

Burnett, S. 2015. Kitikmeot char test clean. Page 6 Nunavut News North.

Chételat, J., M. Amyot, P. Arp, J. M. Blais, D. Depew, C. A. Emmerton, M. Evans, M. Gamberg, N. Gantner, C. Girard, J. Graydon, J. Kirk, D. Lean, I. Lehnherr, D. Muir, M. Nasr, A. J. Poulain, M. Power, P. Roach, G. Stern, H. Swanson, and S. van der Velden. 2014. Mercury in freshwater ecosystems of the Canadian Arctic: Recent advances on its cycling and fate. Science of The Total Environment.

Chételat, J., and B. Braune. 2012. Mercury in Canada's North. III, Ottawa.

Cheung, W. W. L., V. W. Y. Lam, J. L. Sarmiento, K. Kearney, R. Watson, and D. Pauly. 2009. Projecting global marine biodiversity impacts under climate change scenarios. Fish and Fisheries 10:235-251.

Day, A. C., and L. N. Harris. 2013. Information to support an updated stock status of commercially harvested Arctic Char (*Salvelinus alpinus*) in the Cambridge Bay region of Nunavut, 1960-2009. 068, Freshwater Institute, Department of Fisheries and Oceans Canada, Winnipeg, MB.

Dodson, J. J., S. Tremblay, F. Colombani, J. E. Carscadden, and F. Lecomte. 2007. Trans-Arctic dispersals and the evolution of a circumpolar marine fish species complex, the capelin (Mallotus villosus). Molecular Ecology 16:5030-5043.

Evans, M., D. Muir, R. B. Brua, J. Keating, and X. Wang. 2013. Mercury trends in predatory fish in Great Slave Lake: the influence of temperature and other climate drivers. Environmental Science & Technology 47:12793-12801.

Evans, M. S., D. C. G. Muir, J. Keating, and X. Wang. 2015. Anadromous char as an alternate food choice to marine animals: A synthesis of Hg concentrations, population features and other influencing factors. Science of the Total Environment 509-510:175-194.

Evans, M. S., D. C. G. Muir, K. Keating, and X. Wang. 2014. Sea-run char as an alternate food choice to marine animals: a synthesis of mercury concentrations and population features. Science of The Total Environment.

Gantner, N., M. Power, D. Iqaluk, M. Meili, H. Borg, M. Sundbom, K. R. Solomon, G. Lawson, and D. C. Muir. 2010. Mercury concentrations in landlocked Arctic char (*Salvelinus alpinus*) from the Canadian Arctic. Part I: Insights from trophic relationships in 18 lakes. Environmental Toxicology and Chemistry 29:621-632.

Hedd, A., D. F. Bertram, J. L. Ryder, and I. L. Jones. 2006. Effects of interdecadal climate variability on marine trophic interactions: Rhinoceros auklets and their fish prey. Marine Ecology Progress Series 309:263-278.

Hobson, K. A., and H. E. Welch. 1995. Cannibalism and trophic structure in a high Arctic lake: insights from stable-isotope analysis. Canadian Journal of Fisheries and Aquatic Sciences 52:1195-1201.

Johnson, L. 1962. The relict fauna of Greiner Lake, Victoria Island, NWT, Canada. Journal Fisheries Research Board of Canada 19:1105-1120.

Lescord, G. L., K. A. Kidd, J. L. Kirk, N. J. O'Driscoll, X. Wang, and D. C. G. Muir. 2015. Factors affecting biotic mercury concentrations and biomagnification through lake food webs in the Canadian high Arctic. Science of The Total Environment 509:195-205.

Michelutti, N., M. S. V. Douglas, and J. P. Smol. 2003. Diatom response to recent climatic change in a high arctic lake (Char Lake, Cornwallis Island, Nunavut). Global and Planetary Change 38:257-271.

Muir, D., G. Kock, and X. Wang. 2014. Temporal Trends of Persistent Organic Pollutants and Mercury in Landlocked Char in High Arctic Lakes. Aboriginal Affairs and Northern Development Canada, Ottawa, ON.

Muir, D., X. Wang, D. Bright, L. Lockhart, and G. Köck. 2005. Spatial and temporal trends of mercury and other metals in landlocked char from lakes in the Canadian Arctic archipelago. Science of The Total Environment 351–352:464-478.

Provencher, J., A. Gaston, P. O'Hara, and H. Gilchrist. 2012. Seabird diet indicates changing Arctic marine communities in eastern Canada. Marine Ecology Progress Series 454:171-182.

Rigét, F., K. Vorkamp, and D. Muir. 2010. Temporal trends of contaminants in Arctic char (Salvelinus alpinus) from a small lake, southwest Greenland during a warming climate. Journal of Environmental Monitoring 12:2252-2258.

Rigler, F., M. MacCallum, and J. Roff. 1974. Production of zooplankton in Char Lake. Journal of the Fisheries Board of Canada 31:637-646.

Rose, G. A. 2005. Capelin (Mallotus villosus) distribution and climate: A sea "canary" for marine ecosystem change. ICES Journal of Marine Science 62:1524-1530.

Schindler, D., H. Welch, J. Kalff, G. Brunskill, and N. Kritsch. 1974. Physical and chemical limnology of Char Lake, Cornwallis Island (75 N lat.). Journal of the Fisheries Board of Canada 31:585-607.

Scott, W. B., and E. J. Crossman. 1998a. Freshwater Fishes of Canada. Galt House, Oakville, ON.

Scott, W. B., and E. J. Crossman. 1998b. Freshwater Fishes of Canada. Ottawa, Bulletin of Fishery Resource Board of Canada.

Swanson, H., N. Gantner, K. A. Kidd, D. C. G. Muir, and J. D. Reist. 2011. Comparison of mercury concentrations in landlocked, resident, and sea-run fish (*Salvelinus spp.*) from Nunavut, Canada. Environmental Toxicology and Chemistry 30:1459-1467.

Swanson, H. K., K. A. Kidd, and J. D. Reist. 2010. Effects of partially anadromous Arctic charr (Salvelinus alpinus) populations on ecology of coastal Arctic lakes. Ecosystems 13:261-274.

Van der Velden, S., M. S. Evans, J. B. Dempson, D. C. G. Muir, and M. Power. 2013. Comparative analysis of total mercury concentrations in anadromous and non-anadromous Arctic charr (*Salvelinus alpinus*) from eastern Canada. Science of The Total Environment 447:438-449.

Wassmann, P. 2011. Arctic marine ecosystems in an era of rapid climate change. Progress in Oceanography 90:1-17.

Temporal Trends of Persistent Organic Pollutants and Mercury in Landlocked char in High Arctic Lakes

Tendances temporelles des polluants organiques persistants et du mercure chez l'omble chevalier dulcicole de l'Extrême-Arctique

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Abstract

This long term study is examining trends over time of mercury and other trace elements, as well as legacy and new persistent organic pollutants (POPs) in landlocked Arctic char collected annually from lakes near the community of Resolute Bay on Cornwallis Island (Amituk, North, Small, and Resolute) and in Lake Hazen in Quttinirpaaq National Park on Ellesmere Island. In 2015, arctic char samples were successfully collected from all lakes. Results from 2015 follow the previously observed declining trends of mercury in char in Amituk, Hazen, North and Resolute lakes. No change in mercury was found

Résumé

Cette étude à long terme porte sur les tendances temporelles relatives au mercure et à d'autres éléments traces, de même qu'à des polluants organiques persistants (POP), hérités du passé et d'apparition récente, qui sont présents chez les ombles chevaliers dulcicoles recueillis annuellement dans des lacs près de la collectivité de Resolute Bay, sur l'île Cornwallis (lacs Amituk, Char, North, Small et Resolute), et dans le lac Hazen, dans le parc national Quttinirpaaq, sur l'île d'Ellesmere. En 2015, on est arrivé à recueillir des échantillons d'omble chevalier dans tous les lacs. Les résultats de

for char from Small Lake. Concentrations of brominated flame retardants (BFRs) increased in char from all four lakes from the mid-2000s to 2013 although concentrations remain lower than legacy POP such as PCBs. The increases in BFRs in char contrast with declines in BFRs observed in seals and seabirds feeding in nearby Lancaster Sound and illustrates that temporal trends in freshwater environments have to be considered separately from those in the ocean.

2015 font suite aux tendances à la baisse du mercure précédemment observées chez les ombles dans les lacs Amituk, Hazen, North et Resolute. Aucune variation du mercure n'a été observée chez les ombles de Small Lake. Les concentrations de produits ignifuges bromés ont augmenté chez les ombles des quatre lacs, entre le milieu des années 2000 et 2013, bien que les concentrations demeurent plus faibles que celles des polluants organiques persistants anciens, tels que les BPC. Les augmentations de BPC chez les ombles sont incompatibles avec les déclins de BPC observés chez les phoques et les oiseaux de mer se nourrissant près du détroit de Lancaster et montrent que les tendances temporelles dans les environnements d'eau douce doivent être considérées séparément de celles dans l'océan.

Key messages

- Concentrations of mercury in landlocked char have continued to decline slowly since 2005 in five of six lakes for which we have long term results
- Legacy POPs (PCBs, DDT, chlordane) are continuing to decline in all studied lakes
- Brominated flame retardant chemicals are generally increasing in landlocked char in all four of the studied lakes

Messages clés

- Les concentrations de mercure chez les ombles chevaliers dulcicoles continuent de décliner lentement depuis 2005 dans cinq des six lacs pour lesquels nous avons des résultats à long terme.
- Les polluants organiques persistants anciens (BPC, DDT, chlordane) continuent de décliner dans tous les lacs étudiés.
- Les produits chimiques ignifuges bromés sont généralement à la hausse chez l'omble chevalier dulcicole dans l'ensemble des quatre lacs étudiés.

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

As the only top predators in most high latitude Arctic lakes (Köck et al. 2004, Power et al. 2008), landlocked char are good indicators of changes in inputs of bioaccumulative contaminants such as persistent organic pollutants (POPs) and methylmercury. Analysis of landlocked char provides information on the range of chemical contaminants and time trends of these chemicals in Arctic freshwater systems and this information complements studies on marine mammals and seabirds from the same regions. However, there is much lake to lake and individual variation in contaminant levels and trends which need to be better understood. This information is also needed to help interpret temporal trends of contaminants in char. This temporal trend study has been supported by a series of food web studies on these lakes related to mercury and perfluorinated chemicals conducted by Gantner et al. (2010a), (2010b); Kidd et al. (2012), Drevnick et al.(2013), and Lescord et al.(2015a, 2015b).

This study has previously reported on results of 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 to try to achieve the goal of detection of a 5% change over a 10-15 year period with a power of 80% and confidence level of 95% (INAC 2005). Landlocked char annual collections have been successfully carried out in Resolute Lake since 1997 (Köck et al. 2004, Muir et al. 2005), however, in Char and Amituk lakes, fishing has been 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 to the high cost of flights into the Parks Canada Hazen camp on the northwestern shore of the lake. While collections of char from Char, Amituk and Hazen have not been as consistent as in Resolute Lake, all lakes have 12 or more years of sample collections. Collection numbers have typically ranged from 7 to 25 adult fish (>200 g) per lake except in Char Lake where the range has been 3 to 10 fish annually. Further details on past results from these study lakes are given in previous synopsis reports: Muir et al. (2013), (2014, 2015).

Activities in 2015-16

Sample collection: Char were successfully collected in late-July and early August 2015 from Amituk, North, Small, and Resolute lakes (Table 1). At Lake Hazen the collections were successfully carried out in mid-June by Parks Canada staff at Quttinirpaaq National Park. Fish were dissected in PCSP labs at Resolute. Samples (skin-on fillets) were frozen in Resolute and then shipped to the Environment Canada labs (Burlington, ON) and stored at -20°C until analysis. Char otoliths were removed and archived for age determinations. Age determinations were conducted by John Babaluk (Winnipeg, MB).

Chemical analysis: Thirty-one elements were determined in Arctic char muscle (skinless) by

Inductively Coupled Plasma-Mass spectrometry (ICP-MS) (NLET 2002). In brief, muscle (1 g) was digested with nitric acid and hydrogen peroxide (8:1) in a high pressure microwave oven at 200°C for 15 minutes and the digest was analysed by ICP-MS. Mercury in char muscle was analyzed by Direct Mercury Analyser using US EPA Method 7473 (US EPA 2007).

POPs (organochlorine pesticides (OCPs), PCBs and polybrominated diphenyl ethers (PBDEs) and other brominated flame retardants (BFRs) were determined in char samples from 2015 as part of the two year cycle described in the NCP Call for Proposals (2015-16). Method details for POPs analyses are available in previous synopsis reports.

Stable isotope analyses: Muscle from all fish analysed for mercury and POPs were analysed for stable isotopes of carbon ($d^{13}C$) and nitrogen (d15N) at University of Waterloo Environmental Isotope Lab in muscle samples using isotope ratio mass spectrometry.

Quality assurance (QA): Certified reference materials (CRMs) for heavy metals and mercury included DOLT-2, DORM-2 and TORT-2 (National Research Council of Canada) and SRM 1946 lake trout from NIST (National Institute of Standards and Technology) for PCBs, OCPs, PBDEs and PFASs. CRMs and reagent blanks were also run with each sample batch of 10 samples. Blanks for all analytes generally had non-detectable concentrations or levels <5% of measured values. No blank correction was used. Non-detect concentrations for POPs were replaced with 50% of the instrumental detection limit if analyte detection was >10%, or zero if the analytes were all nondetect.

NLET organics and metals labs, the Muir lab (mercury, PFASs) as well as ALS Global (contractor for OCP/PCBs) are participants in the NCP Quality Assurance Program (Tkatcheva et al. 2013, Myers et al. 2014, Myers and Reiner 2015).

Statistical analyses: Based on previous data analyses (Muir et al. 2013) results for mercury, other elements and POPs were log10 transformed in order to reduce coefficients of skewness and kurtosis to <2. Length adjusted geometric mean concentrations and upper/lower standard errors were calculated with log transformed data using analysis of covariance. Logged geomeans were back transformed for graphical presentation. Results for POPs were lipid adjusted by dividing by fraction lipid. Temporal trends of POPs and mercury, expressed as % per year, were determined using the PIA program (Bignert 2007). Lipid weight concentrations for individual samples were used and various time intervals were investigated (Table 1).

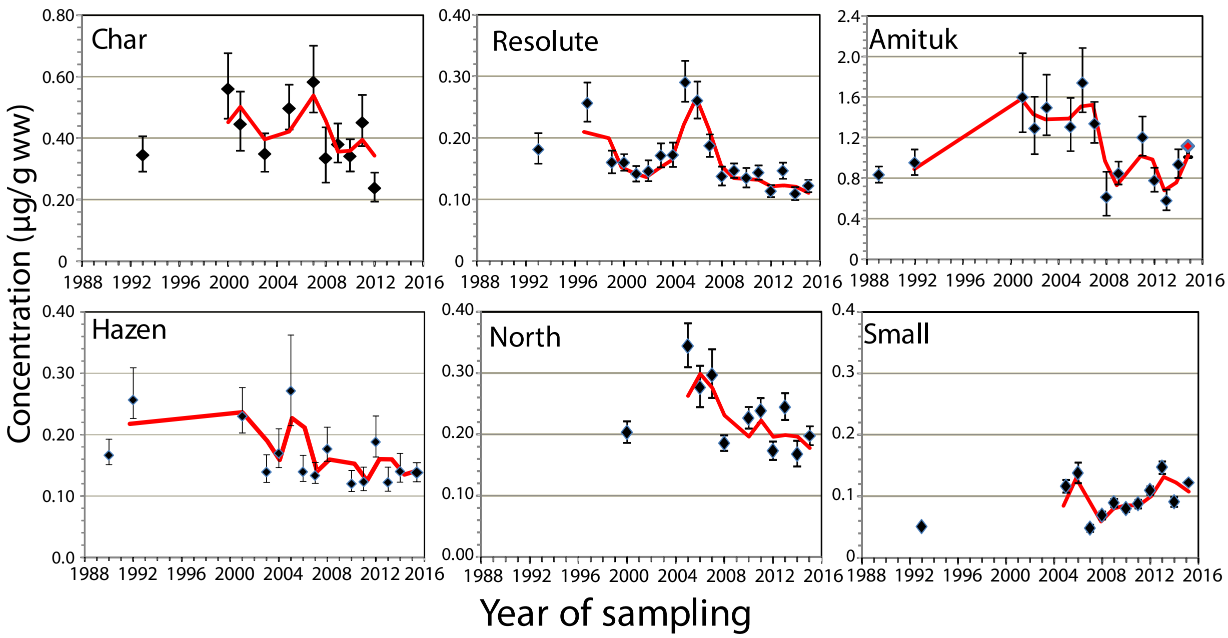
Capacity Building: The project depends on the help of local people in the Hamlet of Resolute. Debbie Iqaluk has worked on the project most years since 1997. Her hard work and knowledge has enabled us to collect fish from all our targeted lakes on Cornwallis Island in a wide range of weather and ice conditions. This was particularly the case when the lakes have been ice covered, which was the case in late July 2014. The project also benefitted from the assistance of summer student Alicia Manik and NRI student Joeffrey Okalik in 2014.

Communications: A summary of results of the work in 2015 was sent to the Resolute Bay HTA in late March 2016. Muir met with the Manager of the HTA office during his trip to Resolute in early August 2015 as well as informally with members of the HTA. In December 2015, results were presented at the NCP results workshop and ArcticNet joint contaminants session.

Traditional Knowledge Integration: Although traditional knowledge integration is not formally part of the project the success of the project depends heavily on the community field team's knowledge of the fish habitat in the lakes as well as ice and water conditions. This was particularly the case when the lakes were partially ice covered, which was the case in late July 2013 and again in 2014.

Results

Figure 1. Trends of mercury (geometric means ± 95% confidence interval) in landlocked char from Resolute, Amituk, Char, Hazen, North and Small lakes (early 90s-2015). All results are length adjusted using analysis of covariance. Red lines represent two year moving averages. Results for Char Lake end in 2012.



Mercury: The trends of mercury over time, updated with results from 2015 are shown in Figure 1. The two year running average shown for each lake suggests declining concentrations in five of the six lakes since approximately 2005. Statistically significant declines were found in length adjusted mercury in Hazen (-7.9 %/y), North (-6.8 %/y) and Resolute (-6.9 %/y). A declining trend was also seen in Amituk Lake but was not significant (-3.3 %/y). Small Lake was the only lake with an increase in concentrations in more recent years; however, the increase (3.0 %/y) was not statistically significant.

Table 1. Percent annual decline (negative) and increase in selected POPs1 in arctic char from the four study lakes using the PIA program (Bignert 2007). PIA was run using lipid weight concentrations for each sample.

	Time period	Sampling Years	Toxa-phene	SPCB	SDDT	a-HCH	b-HCH	SCHL	SPBDEs
Amituk	1989-2015	14	-6.8*	-6.5*	-7.0*	-13*	-6.3	-6.4*	-4.0
	Mid-00s-2013	8	-3.8	-	-	-	-		+13*
Char3	1993-2012	12	-3.7	-8.1*	-10*	-13*	+2.0	-5.1	+6.2
	Mid-00s-2012	7	+0.21						+12
Hazen	1990-2015	12	-5.6	-7.2*	-11*	-12*	+6.1*	-6.0*	+22*
	Mid-00s-2013	8	+11	-	-	-	-		+12
Resolute	1997-2015	17	+17*	-4.4*	-3.2*	-9.3*	-4.3	-2.6	+10*
	Mid-00s-2013	11	+19*	-	-	-	-		+14

1 * indicated statistically significant trend (P <0.05)

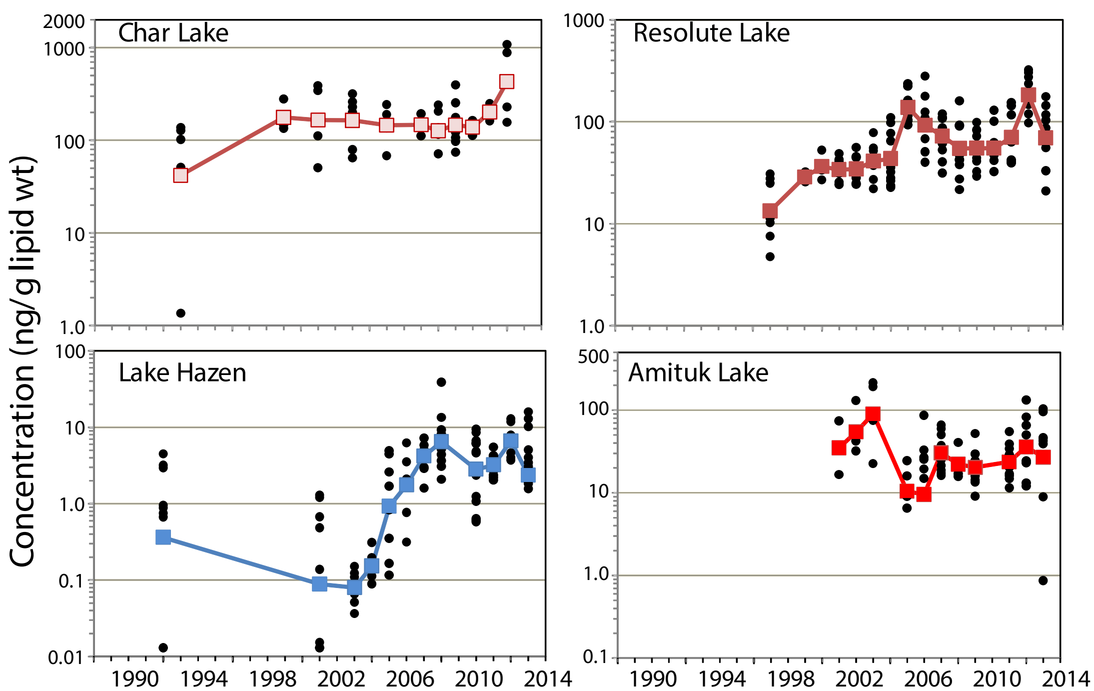
2 Results for toxaphene and PBDEs have 2 or 3 fewer years than other analytes due to use of retrospective analyses for samples from the 1990s and early 2000s. eg. 11 years for toxaphene and PBDEs at Resolute and Amituk

3 Sampling of Char Lake was discontinued after 2012.

POPs: Trends for legacy POPs are based on samples collected up to 2015. Results for analysis of PBDEs and PFASs in the 2015 samples are pending. Alpha-HCH declined more rapidly than all other POPs with an annual decline of -9.3 to -13 %/y (Table 1). β-HCH actually increased significantly in char from Hazen Lake while declining in Amituk and Resolute lakes although the trend was not statistically significant. ΣDDT and ΣPCBs declined significantly in all four lakes. Chlordane-related compounds (SCHL) declined significantly in Amituk and Hazen lakes but the decline in Resolute Lake was not statistically significant. Toxaphene concentrations declined significantly in Amituk Lake while the decline in Hazen Lake (-5.6%) was not statistically significant. In Resolute Lake, toxaphene showed an overall increasing trend (+19% from 2005-13). This increasing trend is difficult to explain but given that is only seen in Resolute Lake it must be related to a legacy source that is being released within the lake catchment.

Trends of polybrominated diphenyl ethers (PBDEs) in landlocked char muscle from Lake Hazen, Amituk, Char, and Resolute Lakes are shown in Figure 2 and percent declines for ΣPBDEs are included in Table 1. SPBDEs (sum of 13 congeners: BDE 17, 28, 47, 49, 66, 85, 99, 100, 138, 153, 154, 183, 190) increased significantly in all four lakes during the mid-2000s to 2013 with increases ranging from 12 to 14 %/y. Some PBDE data were available from archived samples from the 1990s and early 2000s: Lakes Hazen (1992), Resolute (1997, 1999), Char (1993) and Amituk (2001). With these included the percent per year trends are generally lower except for Lake Hazen where the increase rises to 26 %/y due to inclusion of the very low concentrations in the 1992 samples. Also detected in the majority of recent samples from all four lakes (2010-2013) were newer, replacement flame retardants, hexabromocyclododecane (HBCDD) and bis(tribromophenyl)-ethane (BTBPE) although concentrations were <0.5 ng/g wet wt. Further analyses are underway to confirm these measurements and assess temporal trends.

Figure 2. Trends of total PBDEs (sum 13 congeners) in landlocked char muscle from Resolute, Amituk, Char, and Hazen lakes (early 90s – 2013). Symbols represent geometric means. Black circles are individual data for each year. Note that a log scale is used due to the wide range of concentrations.



Discussion and Conclusions

Mercury concentrations in landlocked char continue to decline from higher levels in the mid-2000s in almost all study lakes. An analysis of all available data for mercury time trends in landlocked char encompassing nine lakes (six in this study plus Meretta Lake near Resolute and East and West Lake on Melville Island) found that the annual rate of decline was greatest in the oligotrophic lakes. The declines were significantly inversely related to dissolved Nitrogen ($R^2 = 0.58$, P=0.016, N=9) and weakly related to the ratio of methylmercury to dissolved organic carbon ($R^2 = 0.29$, P=0.16, N=9) (Muir et al. 2015). This suggests that the decline may be linked to limited net methylmercury production in the more oligotrophic lakes. Further analyses are underway to compare mercury trends with climate and water chemistry variables.

The increases in PBDEs in the three lakes on Cornwallis Island contrast with a decreasing trend in PBDEs observed in seals and seabirds from Lancaster Sound over the period of 2000-2013 (Braune 2015, Houde and Muir 2016). Atmospheric concentrations of PBDEs have remained relatively constant during the mid-2000s to 2012 (Hung 2015). This suggests that continued atmospheric inputs along with the availability of past deposition in lake sediments and the surrounding catchments is driving the increasing trends of PBDEs in arctic char.

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References

Bignert, A. 2007. PIA statistical application developed for use by the Arctic Monitoring and Assessment Programme. (available from www.amap.no). Oslo, Norway, Arctic Monitoring and Assessment Programme: 13

Braune, B. 2015. Temporal Trends of Contaminants in Arctic Seabird Eggs. In: *Synopsis of research conducted under the 2013-2014 Northern Contaminants Program. Ottawa, ON, Aboriginal Affairs and Northern Development Canada. pp. 229-238.*

Drevnick, P., B. Barst, D. Iqaluk, D. Muir, G. Köck, P. Campbell and C. Fortin. 2013. Investigation of mercury toxicity in landlocked char in High Arctic lakes. In: Synopsis of research conducted under the 2012-2013 Northern Contaminants Program. Ottawa: Aboriginal Affairs and Northern Development Canada. pp. 305-316.

Gantner, N., D. C. G. Muir, M. Power, J. D. Reist, J. Babaluk, D. Iqaluk, M. Meili, G. Köck, J. B. Dempson, H. Borg, J. Hammar and K. R. Solomon. 2010a. Mercury Concentrations in Landlocked Arctic char (Salvelinus alpinus) in the Canadian High Arctic: Part II - Spatial comparison of 27 populations. Environ. Toxicol. Chem. 29(3): 633-643.

Gantner, N., M. Power, G. Lawson, D. Iqaluk, M. Meili, G. Köck, H. Borg, M. Sundbom, K. R. Solomon and D. C. G. Muir. 2010b. Mercury Concentrations in Landlocked Arctic char (Salvelinus alpinus) in the Canadian High Arctic: Part I - insights from trophic relationships in 18 lakes. Environ. Toxicol. Chem. 29(3): 621-632.

Houde, M. and D. C. G. Muir (2016). Temporal trends of persistent organic pollutants and metals in ringed seals from the Canadian Arctic. In: Synopsis of research conducted under the 2015-2016, Northern Contaminants Program. Ottawa, ON, Aboriginal Affairs and Northern Development Canada.

Hung, H. (2015). Northern contaminants air monitoring: Organic pollutant measurement. In: S. Smith and J. Stow (eds.), Synopsis of Research Conducted under the 2014-2015 Northern Contaminants Program. S. Smith and J. Stow. Ottawa, ON, Aboriginal Affairs and Northern Development Canada: pp 161-171.

INAC (2005). Northern Contaminants Program, Call for Proposals 2005-2006. Ottawa ON, Indian and Northern Affairs Canada: 74.

Kidd, K., D. Muir and G. Lescord. 2012. Contaminant Bioaccumulation in Landlocked Char Food Webs in the High Arctic. In: Synopsis of research conducted under the 2011-2012 Northern Contaminants Program. Ottawa, ON, Aboriginal Affairs and Northern Development Canada: 353-366.

Köck, G., J. Babaluk, B. Berger, D. Bright, C. Doblander, M. Flannigan, Y. Kalra, L. Loseto, H. Miesbauer, D. Muir, H. Niederstätter, J. Reist and K. Telmer. 2004. Fish from sensitive ecosystems as bioindicators of global climate change - “High-Arctic 1997-2003”. Innsbruck, Austria, Veröffentlichungen der Universität Innsbruck.

Lescord, G. L., K. A. Kidd, A. De Silva, C. Spencer, M. Williamson, X. Wang and M. D.C.G. 2015a. Perfluorinated and Polyfluorinated Compounds in Lake Food Webs in the Canadian High Arctic. Environ. Sci. Technol. 49: 2694–2702.

Lescord, G. L., K. A. Kidd, J. L. Kirk, N. J. O’Driscoll, X. Wang and D. C. G. Muir. 2015b. Factors affecting biotic mercury concentrations and biomagnification through lake food webs in the Canadian high Arctic. Sci. Total Environ. 509-510: 195-205.

Muir, D., X. Wang, D. Bright, L. Lockhart and G. Köck. 2005. Spatial and Temporal Trends of Mercury and other Metals in Landlocked Char from Lakes in the Canadian Arctic Archipelago. Sci. Total Environ. 351-352: 464-478.

Muir, D. C. G., G. Köck and X. Wang. 2013. Temporal trends of Persistent Organic Pollutants and Mercury in Landlocked char in the High Arctic. In: Synopsis of research conducted under the 2011-2012, Northern Contaminants Program. Ottawa: Aboriginal Affairs and Northern Development Canada: 211-222.

Muir, D. C. G., G. Köck and X. Wang (2014). Temporal trends of Persistent Organic Pollutants and Mercury in Landlocked char in the High Arctic. In: Synopsis of research conducted under the 2013-2014, Northern Contaminants Program. Ottawa: Aboriginal Affairs and Northern Development Canada. pp. 251-260.

Muir, D. C. G., G. Köck, X. Wang, D. Iqaluk, K. Hudelson, P. Drevnick, K. Roberts and S. Lamoureux. 2015. Long term trends of mercury and POPs in landlocked arctic char and linkages to climate indices. Northern Contaminants Program Results Workshop. Vancouver, BC, Aboriginal Affairs and Northern Development Canada.

Myers, A. and E. Reiner. 2015. Northern Contaminants Interlaboratory Quality Assurance Program (NCP III – Phase 9). Final report. Toronto ON, Ontario Ministry of Environment & Climate Change: 123pp + Appendix.

Myers, A., V. Tkatcheva and E. Reiner. 2014. Northern Contaminants Interlaboratory Quality Assurance Program (NCP III – Phase 8). Final report. Toronto ON, Ontario Ministry of Environment & Climate Change: 224pp.

NLET. 2002. Standard Operating Procedure for the Analysis of Total and Dissolved Trace Metals in Water by In-bottle Digestion and Inductively Coupled Plasma-Mass Spectrometry and Inductively Coupled Plasma-Optical Emission Spectrometry. SOP 02-2002. Burlington ON: National Laboratory for Environmental Testing, NWRI.

Power, M., J. D. Reist and J. B. Dempson. 2008. Fish in high-latitude Arctic lakes. In: W. F. Vincent and J. Laybourn-Parry (eds.) Polar Lakes and Rivers Limnology of Arctic and Antarctic Aquatic Ecosystems. Oxford, UK: Oxford University Press. pp. 249-268.

Tkatcheva, V., B. Ali and E. Reiner. 2013. Northern Contaminants Interlaboratory Quality Assurance Program. NCP III, Phase 7. Toronto ON, Ontario Ministry of Environment: 191 pp.

US EPA. 2007. Method 7473. Mercury in Solids and Solutions By Thermal Decomposition, Amalgamation, and Atomic Absorption Spectrophotometry. Washington, DC: US Environmental Protection Agency.

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

Tendances spatiales et à long terme des contaminants organiques persistants et des métaux chez les touladis et les lottes des Territoires du Nord-Ouest

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Abstract

This Great Slave Lake study contributes to the Northern Contaminants Program trend monitoring component by investigating contaminant trends in fish species which are important in traditional diets. In 2015, lake trout were investigated from the Hay River region (West Basin) and Lutsel K'e (East Arm); burbot were monitored from Fort Resolution, located on the Slave River delta. Fish were analyzed for mercury, metals and persistent organic pollutants. In addition, under other programs, we investigated northern pike at Fort Resolution and burbot at Lutsel K'e for mercury trends. Mercury concentrations remain relatively low in these fish and previously reported trends of mercury

Résumé

Cette étude du Grand lac des Esclaves contribue au volet de surveillance des tendances du Programme de lutte contre les contaminants dans le Nord en étudiant les tendances liées aux contaminants chez les espèces de poisson importantes dans l'alimentation traditionnelle. En 2015, des touladis provenant de la région de Hay River (bassin ouest) et de Lutsel K'e (bras de l'est); des lottes en provenance de Fort Resolution, situées sur le delta du lac des Esclaves, ont fait l'objet d'une surveillance. Les poissons ont été analysés pour déceler la présence de mercure, de métaux et de polluants organiques persistants. En outre, dans le cadre d'autres programmes, nous avons étudié le grand brochet à Fort Resolution et la lotte

increase have become more muted. Persistent organic pollutant concentrations are declining, particularly ΣDDT and ΣHCH for both species and locations and ΣPCBs for West Basin fish. We gave a presentation on our studies to the Akaitcho General Assembly and published a scientific paper in the *Journal of Great Lakes Research* synthesizing our early 1990s sediment and food webs studies on Great Slave Lake. We continue to work with Fort Resolution on its water intake study and contribute to related studies being conducted by other researchers and communities, including mercury trends in fish in Dehcho lakes and Great Bear Lake.

à Lutsel K'e afin de découvrir les tendances en matière de mercure. Les concentrations de mercure demeurent relativement faibles chez ces poissons, et les tendances à la hausse relatives au mercure précédemment signalées se sont tempérées. Les concentrations de polluants organiques persistants sont en déclin, en particulier celles du ΣDDT et du ΣHCH pour les espèces comme les endroits, et celles de ΣPCB pour les poissons du bassin de l'ouest. Nous avons livré une présentation sur nos études à l'assemblée générale de l'Akaitcho et publié un article scientifique synthétisant nos études sur les sédiments et les réseaux trophiques au milieu des années 1990 dans le *Journal of Great Lakes Research*. Nous continuons à travailler avec Fort Resolution à son étude sur les prises d'eau et contribuons aux études connexes menées par d'autres chercheurs et collectivités, entre autres sur les tendances relatives au mercure dans les lacs du Deh coh et le Grand lac de l'ours.

Key messages

- Mercury concentrations remain relatively low (average <0.5 µg/g) in lake trout, burbot and northern pike.
- A few years ago, mercury concentrations appeared to be increasing in lake trout and burbot, but there is less evidence of a temporal increase in recent years.
- Persistent organic pollutant concentrations are declining, particularly in West Basin fish.

Messages clés

- Les concentrations de mercure demeurent relativement faibles (moyenne inférieure à 0,5 µg/g) chez le touladi, la lotte et le grand brochet.
- Il y a quelques années, les concentrations de mercure semblaient à la hausse chez le touladi et la lotte, mais ces dernières années, on a moins de raisons de conclure à une augmentation sur le plan temporel.
- Les concentrations de polluants organiques persistants sont en déclin, en particulier chez les poissons du bassin de l'ouest.

Objectives

- Determine mercury, metals and persistent organic pollutants (POPs) concentrations in lake trout harvested from two locations (West Basin near Hay River, East Arm at Lutsel K'e) and burbot harvested from one location (West Basin at Fort Resolution) in 2015 to further extend our long-term POPs and mercury data bases.
- Investigate mercury trends in Great Slave Lake fish and investigate the drivers of mercury trends.
- Investigate trends in POPs and contribute information to AMAP expert work groups for trend monitoring for POPs.
- Continue to work with Fort Resolution on their water quality monitoring of Resolution Bay waters and continue northern pike mercury monitoring.
- Work with Lutsel K'e in the collection of burbot from the East Arm and provide advice where requested. Work with other researchers including Xinhua Zhu in his fish community monitoring in the Hay River area; John Chételat in his arsenic studies in the Yellowknife Bay area; George Low for mercury in fish in lakes in the Dehcho and Sean Backus for mercury and flame retardants Great Bear Lake fish.
- Continue to provide support as requested to the Tłı̨chǫ **Aquatic Ecosystem Monitoring Program (TAEMP).**
- Communicate results to communities and the commercial fisheries in a timely manner.

Introduction

This study is investigating trends in mercury (and other metals), legacy POPs and newer chemicals (flame retardants and surfactants) in Great Slave Lake predatory fish as part of NCP's Freshwater Ecosystems (7.4.7) Trend Monitoring Program. These studies are considering two species of fish – lake trout and burbot. Lake trout, in addition to being important in the domestic diet of a number of communities, have economic importance supporting commercial fisheries in the West Basin and a growing sports fishery in the East Arm of the lake. A historic record of mercury concentrations in fish important in the commercial fisheries dates back to the late 1970s (Lockhart et al. 2005). Lake trout are wide-spread throughout northern Canada where, as a pelagic, cold-water stenotherm, they are limited to lakes which thermally stratify in the summer and maintain a well-oxygenated hypolimnion (Scott and Crossman 1998). We previously reported that mercury concentrations have shown a significant trend (1999-2012) of increase in West Basin lake trout; large (>590 mm fork length) lake trout from the East Arm also showed a trend of mercury increase whereas small lake trout showed a significant trend of decrease (Evans et al. 2013). No trends in mercury concentration have been detected in Lake Laberge where lake trout also are being monitored under the NCP (Stern 2015). In contrast to lake trout in Lake Laberge, persistent organic pollutant concentrations were low in Great Slave Lake fish in the early 1990s (Kidd 1996, Evans and Muir 2016). Lake trout are being monitored at Lutsel K'e (East Arm) and from the commercial fishery operating out of Hay River (West Basin). Under a Chemical Management Plan study of flame retardants, we have been contributing to the monitoring of lake trout from Great Bear Lake (Gewurtz et al. 2011, Gewurtz et al. 2013) and investigating mercury trends.

Burbot are the second species being monitored. This species is not important in the commercial and sports fisheries but has some importance in the domestic fishery as its lipid-rich liver is a highly-prized food item. This species, like lake trout, is a predator and persistent organic pollutants especially PCBs and toxaphene tend to be high in its liver. In the early 1990s, consumption advisories were issued (Lake Laberge) or considered (Slave River) based on these levels. Burbot are sedentary and may be more responsive to conditions occurring at the sediment water interface (Rawson 1951, Scott and Crossman 1998) than lake trout, a pelagic species; burbot also inhabit large river systems such as the Mackenzie and deeper waters in lakes. Burbot are being monitored at Resolution Bay by the community of Fort Resolution, located on the Slave River delta. Burbot monitoring at Lutsel K'e under NCP ended in 2004 but resumed in 2008 as part of Environment Canada studies. For both locations, burbot have shown significant trends of mercury increase over 1999-2012 levels, and rates of increase are greater than for lake trout. Burbot also are being monitored on the Mackenzie River near Fort Good Hope and have shown pronounced trends of increase up to 2009 (Carrie et al. 2010).

Northern pike are a nearshore predator inhabiting warm waters and often residing in weedy areas. Mercury concentrations tend to be high in this species, most likely because of its habitat and proximity to sites of significant mercury methylation (Evans et al. 2005a, Lockhart et al. 2005, Chételat and Braune 2012). Contaminant concentrations were measured in northern pike from the Resolution Bay area in the mid-1990s and again over 1999-2002 under NCP (Evans et al. 1998a, Evans et al. 1998b, Evans et al. 2005b). We resumed mercury monitoring of northern pike in Resolution Bay in 2008 to track trends in a species which, based on its habitat, was expected to show a strong increase in mercury concentrations as has burbot in the Mackenzie River; no trends of increase have been detected (Evans et al. 2013). As part of our collaborative studies with George and Mike Low, we also have been contributing to the periodic assessments of mercury in northern pike (in addition to walleye, lake trout, and lake whitefish) in smaller lakes to the west of Great Slave Lake. This is contributing to a broader data base to allow us to investigate trends in warm-water lacustrine species.

Activities in 2015-2016

1. In autumn 2015, 20 lake trout were collected from Lutsel K'e, from the commercial fishery operating out of Hay River, and 20 burbot from Fort Resolution were shipped to Saskatoon as part of the current NCP biomonitoring program. As in past years, we have continued burbot collections at Lutsel K'e and northern Pike at Fort Resolution for additional mercury trend assessments and because of community interests. Length, weight, and sex were determined for all fish from each location; liver and gonad weights were also determined and the presence of parasites and/or disease (cysts, etc.) noted. Aging structures (otoliths) were removed from each fish and submitted for analyses. A fillet sample and the liver and stomach were retained from each of the 20 fish. Ten of the 20 lake trout (Lutsel K'e, Hay River) and burbot (Fort Resolution) were selected for mercury, metals, legacy organic contaminants and PDBE and PFCA analyses; most analyses are complete.

2. We have been contributing to the AMAP assessment of trends in POPs in lake trout and burbot. Time trends initially were examined using PIA software (Bignert 2007) for lake trout and burbot (lipid adjusted) with data available for most compounds from 1993-2013. Since then, we have continued these analyses using the fuller series of data available to us and General Linear regression models with and without lipid adjustments. These analyses will be repeated using the newly received 2015 data.

3. As part of our investigation of factors affecting regional differences in POPs concentrations in Great Slave Lake fish, we synthesized limnological and organic contaminant data of water, sediment, plankton, forage fish, and adult fish

measurements made over 1993-1996 under the NCP, Northern River Basins Study, and the Slave River Environment Quality Monitoring Programs (Evans and Muir 2016). This paper allowed for a more critical examination of our early data and will set the background for the POPs trend paper.

4. Marlene gave an invited presentation on the Great Slave Lake study results at the Akaitcho General Assembly held in Lutsel K'e in July. This was a well-attended meeting and provided a good opportunity for information exchange and discussion. She also met with GNWT Health and GNWT Environment and Natural Resources in Yellowknife to discuss consumption advisories and provided them with our most recent data for assessment.

5. Meeting with GNWT Environment and Natural Resources (ENR) in Yellowknife to discuss community based monitoring with a focus on Resolution Bay and the water intake study. We also met with Boyan Tracy and Jody Pellissey to discuss monitoring contaminants in fish in lakes north of Yellowknife and contributed to the proposal development for the the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP)

6. Gave an oral presentation at the joint NCP and ArcticNet Workshop held in December in Vancouver.

7. Continued to work with Fort Resolution on its water quality monitoring of Resolution Bay waters using its domestic water intake. Hosted Kathleen Fjordy during her visit the Institute, where she learned basic computer skills, saw the University, learned of its educational opportunities, and visited Saskatoon's water treatment plant.

8. We dissected and processed walleye from Trout Lake as part of a study investigating skinny fish with some analyses ongoing.

9. Sediment cores collected in March 2014 under Environment and Climate Change Canada's Clean Air Regulatory Agenda mercury science assessment at two sites in the West Basin (as reported in Evans et al. (2013) have been dated and analyzed for mercury and metal trends. Cores from Stark Lake, east of Lutsel K'e, and Kakisa Lake in the Dehcho where a small commercial fishery has existed since the 1940s (Johnson 1976, Tonn et al. 2016) also have been dated and analyzed for mercury and metals.

10. Contributions were made to related studies including our monitoring of lake trout from Great Bear Lake for mercury and flame retardant trends; Cumulative Impacts Monitoring of Aquatic Ecosystem Health of Yellowknife Bay, Great Slave Lake (J. Chetelat); Tłı̨chǫ **Aquatic Ecosystem Monitoring Program proposal development (J. Pellissey);** Integrated fishery stock assessment plan for sustainable harvest of lake whitefish in Great Slave Lake, Northwest Territories (X. Zhu); and Mercury levels in food species in lake used by Community Members (G. Low).

Results and discussion

Fish mercury trend assessment

While **northern Canada** is experiencing a long-term trend of air temperature increase, there is substantial interannual variability (Carrie et al. 2010, Evans et al. 2013). For example, average annual air temperatures at Hay River were highest in 1998 (-0.1 °C), 2006 (-0.2°C) and 2010 (-0.3 °C); declined over 2011-2014 to -2.7°C and then increased to -1.0 °C in 2015 (Fig. 1). We previously reported that lake trout harvested from the West Basin commercial fishery were exhibiting a long-term trend of mercury increase with higher mercury concentrations occurring in cooler years. This trend has changed with the inclusion of three additional years of monitoring (Fig. 1). For West Basin lake trout, variations in their mercury concentration were explained by a negative relationship with air temperature and fork length (FL) as is shown in Equation 1. Lake trout from the East Arm were divided into small (<590 mm FL) and large (>590 mm FL) fish because of a significant FL*Year interaction. Variations in mercury concentration for small fish were explained by a negative relationship with year and a positive relationship for both fork length and air temperature (Equation 2); there was no explanation for variations in mercury concentration in large lake trout.

Mercury concentrations in burbot from Resolution Bay continued to show a significant trend of increase when total length (TL); condition factor (CF) explained additional variance (Figure 1; Equation 3); air temperature was not a significant influencing term. Highest mercury concentrations were observed in northern pike (Resolution Bay) but no time trend was evident. Burbot from the East Arm continued to show a significant trend of increase when TL and air temperature were include in the model (Equation 4): inclusion of condition factor explained additional variance.

Log Hg=1.724+0.001*FL-0.023*Temp (n=145, R^2=0.46; F=59.7, p<0.001)

Equation 1, lake trout, West Basin

Log Hg=18.428-0.010*Yr+0.001*FL+0.041*Temp (n=81, R2=0.19, F=5.95, p=0.001)

Equation 2, lake trout, East Arm, <580 mm FL

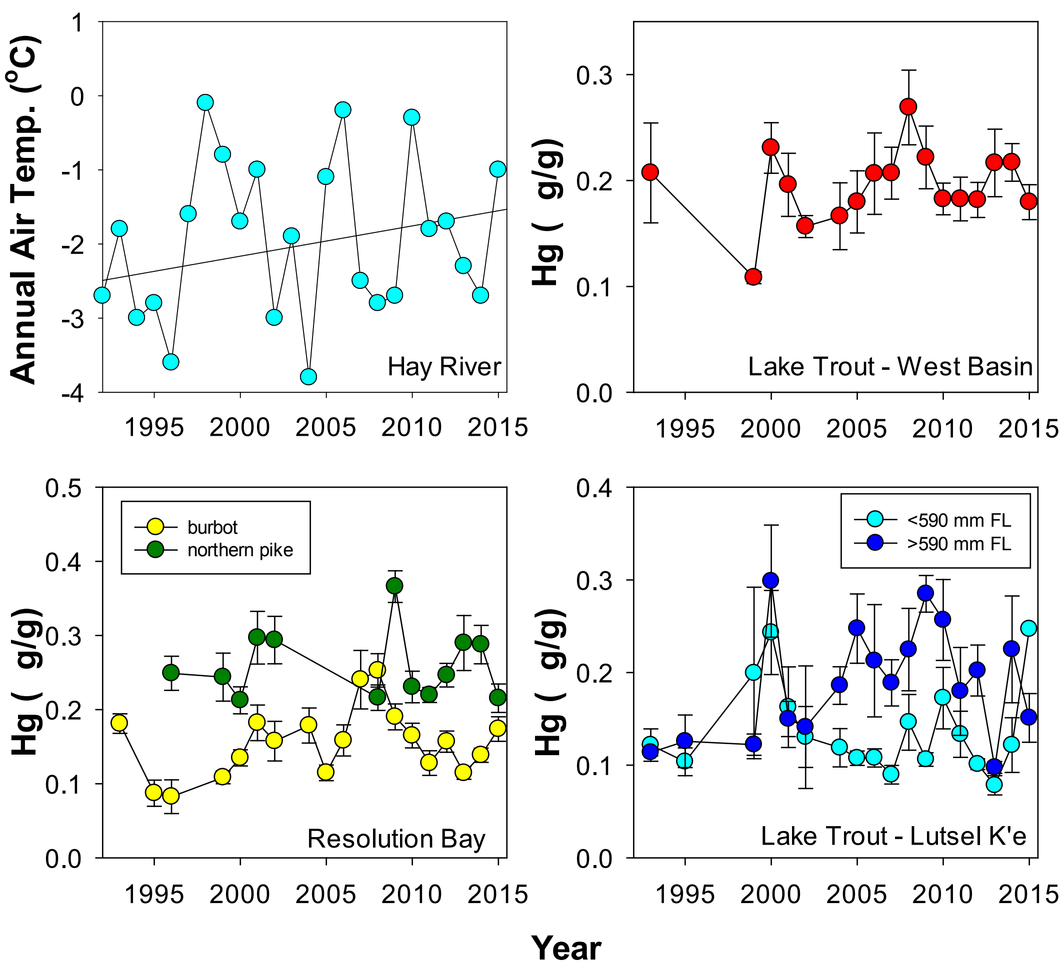
Log Hg=12.118+0.005*Yr+0.001*FL+0.001*TL+0.290*CF (n=167, R2=0.23, F=16.2, p<0.000)

Equation 3, burbot, Resolution Bay

Log Hg=-13.211+0.006*Yr+0.007*TL-0.033*Tm (n=116, R2=0.15, F=6.78, p=0.0003)

Equation 4, burbot, East Arm

Figure 1. Time trends in mean mercury concentrations (± 1 standard error) in lake trout (West Basin and East Arm) and burbot and northern pike at Resolution Bay (West Basin) of Great Slave Lake. Also shown are average air temperatures at Hay River.



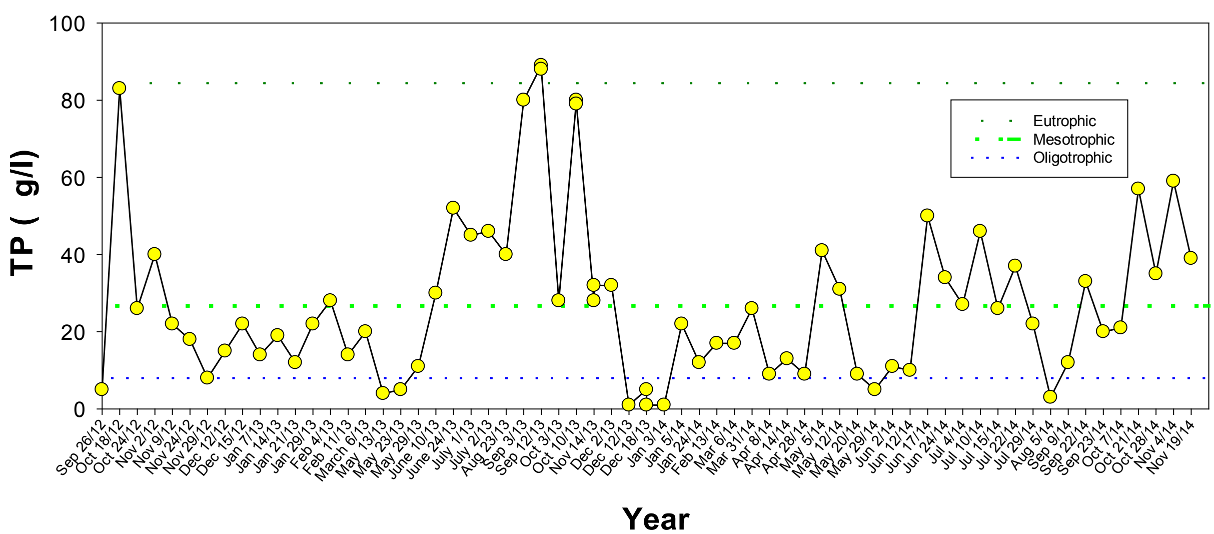
Water intake samples: temporal variability in total phosphorus

The water intake study at Fort Resolution initially began as a capacity building study to provide training in water quality sampling. Between 2012 and 2013, collections were made at approximately monthly intervals of nutrients, major ions, metals, chlorophyll, and algal communities; approximately weekly samples were collected of total phosphorus and chlorophyll. In 2013, the program was scaled back to only record regular measurements made on untreated intake water and collecting samples for total phosphorus (TP) and chlorophyll analyses. TP collections ended in 2014 because of funding considerations, but chlorophyll measurement has continued. This sampling has provided year round information on total phosphorus concentrations (Fig. 2). During the winter months, the trophic status of Resolution Bay waters is between oligotrophic and mesotrophic based on TP concentrations. However, during the ice-free months when Slave River flow is strong and sediments readily resuspended in the shallow waters of the Bay, the trophic status is between mesotrophic and eutrophic. The West Basin supports very productive commercial fisheries for its average depth and primary productivity (Rawson 1955, Fee et al. 1985) with Slave River inflow with its large quantities of TP undoubtedly an influencing factor. Warming trends are enhancing productivity in unmeasured ways and with uninvestigated influences on contaminant pathways.

Persistent organic pollutants

The earliest measurements of legacy persistent organic pollutants for Great Slave Lake were made in 1993, with periodic measurements made in 1994 and 1996 for some species and locations, particularly burbot at Resolution Bay (Evans et al. 1998c, Evans and Muir 2016). The formal contaminant trend monitoring did not begin until 1999 when 10 specimens of each species from each of the two locations were analyzed; no collections were made in 2003. While monitoring of burbot at Lutsel K'e discontinued under NCP in 2004, addition data have been generated with Environment and Climate Change Canada funding. Most contaminants are showing evidence of declining concentrations **(Fig. 3).** Trend analyses were performed using PIA software developed by Anders Bignert and as described in (Rigét et al. 2010). Analyses were performed for lake trout adjusted for fork length and burbot adjusted for lipid. Significant declines were observed in ΣDDT and ΣHCH for both species and locations (Table 1). In addition, West Basin burbot and lake trout showed significant declines in Σ**Chlordane** and ΣPCBs (including

Figure 2. Seasonality in total phosphorus concentrations in Resolution Bay waters, September 2012-November 2014. Trophic status classification is from Wetzel (Wetzel 1983).



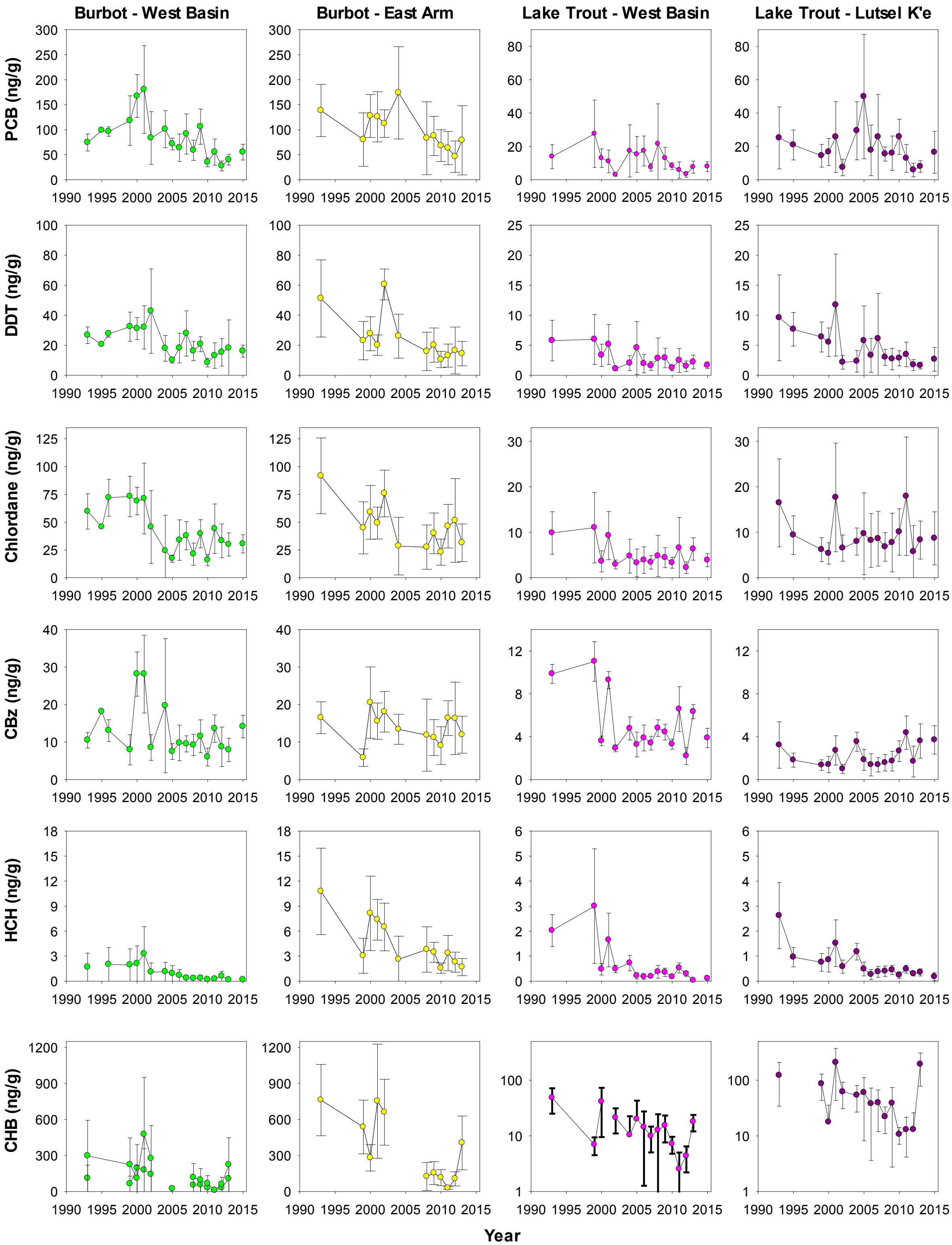
Σ10-PCBs). While these compounds tended to decline in East Arm fish, these trends were not statistically significant. East Arm waters have a longer residence time than West Basin (Rawson 1950, Evans 2000) which potentially may be a factor accounting for the slower decline in legacy organic contaminants from its fish. Moreover, sedimentation rates are lower in the low productivity waters of the East Arm than the more productive waters of the West Basin where the Slave River also brings in a substantial suspended sediment load. There was no evidence of statistically significant declines in ΣPCBs concentrations. ΣHCH and, to a lesser extent, ΣCBz concentrations were similar among species whereas ΣPCBs, ΣDDT, and **ΣChlordane** occurred in substantially higher concentrations in burbot liver than lake trout fillet. POP concentrations were higher overall in East Arm than West Basin fish, despite the fact that West Basin lake trout fillet was more lipid rich (9.9 ± 5.3%) than East Arm fish (5.8 ± 4.2%) and that contaminant concentrations in surface sediment were also higher (Evans and Muir 2016). This may be related to the greater bioavailability of POPs in the clear East Arm waters than the more turbid waters of the West Basin.

No time trends were detected in ΣPBDEs and ΣPFCAs over the length of our record from 2004-present. This record is shorter than our legacy persistent contaminant measurements, but some older measurements of **ΣPBDEs and ΣPFCAs** were analyzed.

Table 1. Time trends in legacy persistent organic pollutants for lipid-adjusted burbot from Fort Resolution (1993-2015; n=17 years) and Lutsel K'e (1993-2013, n=11 years) and fork-length adjusted lake trout from the Hay River commercial fisheries (1999-2015, n=15 years) and Lutsel K'e (1993-2015, n=17 years). While the first collections were made in 1993, missing length or lipid data reduces the number of years that can be tested for adjusted data. Temporal trend is shown as the percent decline in contaminant concentration (log-linear) per year over the record; statistically significant ($p<=0.05$) slopes shown in bold. Also shown is YQR, the number of years required to detect an annual change of 5% with a power of 80% and a one-sided test (α = 5%).

	Lake Trout Hay River		Burbot Fort Resolution		Lake trout Lutsel K'e		Burbot Lutsel K'e	
Parameter	%/yr	YQR	%/yr	YQR	%/yr	YQR	%/yr	YQR
% lipid	2.6	18	+2.1	17	2.5	23	-2.4	16
ΣCBz	-3.6	14	-2.2	21	3.2	20	0.9	19
Σ-CHL	-6.6	19	-5.5	22	0.2	18	-3.6	18
Σ-DDT	-10	18	-4.3	19	-5.7	20	-5.3	18
Σ-HCH	-15	20	-12	24	-7.5	19	-6.4	20
Σ-PCB	-11	29	-5.0	17	-2.0	22	-2.5	15
Σ-10 PCB	-11	26	-4.2	19	-2.0	20	-1.8	18

Figure 3. Time trends in legacy persistent organic pollutants in burbot from the West Basin (Fort Resolution) and East Arm (Lutsel K'e) and lake trout from the West Basin (Hay River commercial fishery) and East Arm (Lutsel K'e). Concentrations are on a wet weight basis. Also shown is ± 1 standard deviation.



Trout Lake: normal versus skinny walleye

In 2014, Jessica Jumbo arranged for the collection of 11 normal and 10 skinny walleye from Trout Lake for us. The purpose of this small study was to learn more about skinny fish including their age and other body metrics such as parasite and determine the impact of skinniness on mercury concentration. While the parasite and mercury analyses have not been done, other metrics have been determined. Skinny fish were slightly larger than normal walleye although weight was less, particularly three walleye which could not be sexed. Liver and gonad weight were much smaller for skinny than normal fish, particularly the fish which could not be sexed. Normal female walleye ranged in age from 7-25 years with a mean age of 17.4±5.9 years whereas skinny walleye were 21-25 years old with a mean of 23.7 ± 0.6 years. According to Scott and Crossman (1998) walleye live to ca. 20 years in their northern range (Table 2). It is possible that these skinny fish were approaching the end of their natural life and are living with the physiological impairment that can accompany increasing age.

Conclusions

This ongoing study is providing high quality data investigating trends in mercury concentrations as global warming continues and Asian mercury emissions increase. The trend of mercury increase has become more muted in recent years as has warming trends. Average mercury concentrations in predatory fish are well below the 0.5 µg/g commercial sale guidelines. Most legacy POPs are declining in concentration, particularly in West Basin fish. We have had numerous positive interactions with others interested in and conducting research on various aspects of the Great Slave Lake ecosystem.

Expected project completion date

Ongoing as a Core Biomonitoring Project.

Acknowledgements

We appreciate the high quality of harvests that have been provided to us for analyses by Gab Lafferty who harvested burbot and northern pike from Resolution Bay, Ernest Boucher who harvested lake trout and burbot from Lutsel K'e and Shawn Buckley who provided lake trout from the commercial fishery. This study was funded by the Northern Contaminants Program and Environment Canada, including support from its CARA mercury science program.

Table 2. Metrics of skinny and normal walleye harvested from Trout Lake in 2014.

	Female		Male		Undetermined
	Skinny	Normal	Skinny	Normal	Skinny
Number	3	7	4	4	3
Fork length (mm)	572 ± 67	545 ± 37	546 ± 25	510 ± 29	512 ± 9
Weight (g)	1,353 ± 424	1,907 ± 174	1,333 ± 184	1,558 ± 213	887 ± 72.3
Condition factor	0.71 ± 0.11	1.19 ± 0.15	0.82 ± 0.04	1.17 ± 0.06	0.66 ± 0.03
Liver weight (g)	7.2 ± 3.8	36.0 ± 6.6	7.7 ± 3.2	17.4 ± 4.0	3.7 ± 0.2
Gonad weight (g)	14.7 ± 5.8	62.2 ± 13.3	19.7 ± 8.9	34.8 ± 21.0	1.9 ± 0.4
Age	23.7 ± 0.6	17.4 ± 5.9	23.5 ± 1.3	18.3 ± 7.6	23.0 ± 1.7

References

Bignert, A. 2007. PIA statistical application developed for use by the Arctic Monitoring and Assessment Programme., Arctic Monitoring and Assessment Programme.

Carrie, J., F. Wang, H. Sanei, R. W. Macdonald, P. M. Outridge, and G. A. Stern. 2010. Increasing contaminant burdens in an arctic fish, Burbot (*Lota lota*), in a warming climate. Environ. Sci. Tech. 44:316-322.

Chételat, J., and B. Braune (eds). 2012. Mercury in Canada's North. Canadian Arctic Contaminants Assessment Report III. Ottawa, Aboriginal Affairs and Northern Development Canada.

Evans, M. 2000. The large lake ecosystems of northern Canada Aquatic Ecosystem Health and Management 3:65-79.

Evans, M., D. Muir, R. B. Brua, J. Keating, and X. Wang. 2013. Mercury Trends in Predatory Fish in Great Slave Lake: The Influence of Temperature and Other Climate Drivers. *Environ. Sci. Tech.* 47:12793-12801.

Evans, M. S., J. F. Klaverkamp, and L. Lockhart. 1998a. Metal studies of water, sediments and fish from the Resolution Bay area of Great Slave Lake: studies related to the decommissioned Pine Point mine. National Water Research Institute.

Evans, M. S., W. L. Lockhart, L. Doetzel, G. Low, D. Muir, K. Kidd, G. Stephens, and J. Delaronde. 2005a. Elevated mercury concentrations in fish in lakes in the Mackenzie River Basin: The role of physical, chemical, and biological factors. *Sci. Total Environ.* 351-352:479-500.

Evans, M. S., D. Muir, L. Lockhart, and G. Stern. 1998b. Metal and persistent organochlorine pollutant (POP) concentrations in four species of predatory fish from Resolution Bay, Great Slave Lake: summer 1996 studies. Report.

Evans, M. S., D. Muir, L. Lockhart, and G. Stern. 1998c. Metal and persistent organochlorine pollutant (POP) concentrations in four species of predatory fish from Resolution Bay, Great Slave Lake: summer 1996 studies. Report.

Evans, M. S., D. Muir, W. L. Lockhart, G. Stern, M. Ryan, and P. Roach. 2005b. Persistent organic pollutants and metals in the freshwater biota of the Canadian Subarctic and Arctic: An overview. *Sci. Total Environ.* 351–352:94-147.

Evans, M. S., and D. C. G. Muir. 2016. Persistent organic contaminants in sediments and biota of Great Slave Lake, Canada: Slave River and long-range atmospheric source influences. *J. Great Lakes Res.* 42:233-247.

Fee, E. J., M. P. Stainton, and H. J. Kling. 1985. Primary production and related limnological data for some lakes of the Yellowknife, NWT area. Department of Fisheries.

Gewurtz, S. B., S. M. Backus, A. O. De Silva, L. Ahrens, A. Armellin, M. Evans, S. Fraser, M. Gledhill, P. Guerra, T. Harner, P. A. Helm, H. Hung, N. Khera, M. G. Kim, M. King, S. C. Lee, R. J. Letcher, P. Martin, C. Marvin, D. J. McGoldrick, A. L. Myers, M. Pelletier, J. Pomeroy, E. J. Reiner, M. Rondeau, M. C. Sauve, M. Sekela, M. Shoeib, D. W. Smith, S. A. Smyth, J. Struger, D. Spry, J. Syrgiannis, and J. Waltho. 2013. Perfluoroalkyl acids in the Canadian environment: Multi-media assessment of current status and trends. *Env. Int.* 59:183-200.

Gewurtz, S. B., D. J. McGoldrick, M. G. Clark, M. J. Keir, M. M. Malecki, M. Gledhill, M. Sekela, J. Syrgiannis, M. S. Evans, A. Armellin, J. Pomeroy, J. Waltho, and S. M. Backus. 2011. Spatial trends of polybrominated diphenyl ethers in Canadian fish and implications for long-term monitoring. *Environ. Toxicol. Chem.* 30:1564-1575.

Johnson, L. 1976. Ecology of Arctic Populations of Lake Trout, *Salvelinus namaycush*, Lake Whitefish, *Coregonus clupeaformis*, Arctic Char, *S. alpinus*, and Associated Species in Unexploited Lakes of the Canadian Northwest Territories. *Journal of the Fisheries Board of Canada*. 33:2459-2488.

Kidd, K. A. 1996. Use of stable Nitrogen isoptope ratios to characterize food web structure and organochlorine accumulation in subartcic lakes in Yukon territory. Ph.d thesis, University of Alberta, Edmonton

Lockhart, W. L., G. A. Stern, G. Low, M. Hendzel, G. Boila, P. Roach, M. S. Evans, B. N. Billeck, J. DeLaronde, S. Friesen, K. Kidd, S. Atkins, D. C. G. Muir, M. Stoddart, G. Stephens, S. Stephenson, S. Harbicht, N. Snowshoe, B. Grey, S. Thompson, and N. DeGraff. 2005. A history of total mercury in edible muscle of fish from lakes in northern Canada. *Sci. Total Environ.* 351-352:427-463.

Rawson, D. S. 1950. The physical limnology of Great Slave Lake. *J. Fish. Res. Board Can.* 8:3-66.

Rawson, D. S. 1951. Studies of the fish of Great Slave Lake. *J. Fish. Res. Board Can.* **8**:207-240.

Rawson, D. S. 1955. Morphometry as a dominant factor in the productivity of large lakes. *Verhandlungen des Internationalen Verein Limnologie.* **12**:164-175.

Rigét, F., A. Bignert, B. Braune, J. Stow, and S. Wilson. 2010. Temporal trends of legacy POPs in Arctic biota, an update. *Sci. Total Environ.* 408:2874-2884.

Scott, W. B., and E. J. Crossman. 1998. Freshwater Fishes of Canada. Galt House, Oakville.

Tonn, W., H. Swanson, C. Paszkowski, J. Hanisch, and L. Chavarie. 2016. Northern North America. First edition. John Wiley & Sons, Ltd, Chichester (UK).

Wetzel, R. G. 1983. Limnology. 2nd edition. Saunders College Publishing, Philadelphia, Pa.

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

Études des tendances temporelles des métaux traces et des contaminants organiques halogénés, y compris des composés persistants nouveaux et émergents, chez la lotte du fleuve Mackenzie à Fort Good Hope (Territoires du Nord-Ouest)

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Abstract

Tissues from burbot collected at Fort Good Hope (Rampart Rapids) in January 2016 were analysed for mercury (Hg), Selenium (Se) and Arsenic (As). Data 2016 was combined with existing metal data that contains 20 observations over a span of 30 years. 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 0.359 ± 0.141 (n = 642) and 0.098 ± 0.085 (n = 648) μg g-1, respectively. Muscle mercury levels are below the recommended guideline level of 0.50 mg g-1 for commercial sale.

Résumé

Les tissus de lotte prélevés à Fort Good Hope (rapides Rampart) en janvier 2016 ont été analysés afin de déterminer s'ils contenaient du mercure (Hg), du sélénium (Se) et de l'arsenic (As). Les données de 2016 ont été combinées aux données existantes sur les métaux, qui englobent 20 observations sur une période de 30 ans. Aucune corrélation significative entre la longueur des lottes et les concentrations de mercure n'a été observée dans les muscles et le foie chez les deux sexes. Les concentrations moyennes de mercure dans les muscles et le foie pour les ensembles complets de données étaient de 0,359 ± 0,141 (n = 642) et de 0,098 ± 0,085 (n = 648) μg g-1, respectivement. Les niveaux de mercure dans les muscles se situent sous le niveau recommandé dans les directives, qui est de 0,50 mg g^{-1} pour la vente commerciale.

Key messages

- Mean Hg concentrations in muscle and liver over the entire data sets were 0.359 ± 0.141 (n = 642) and 0.098 ± 0.085 (n = 648) μg g^{-1}, respectively.
- Since the mid-1980s, an approximate 2- and 3-fold increase in mercury concentrations has been measured in Fort Good burbot muscle and liver, respectively.
- Muscle liver and mercury levels are below the recommended guideline level of 0.50 μg g^{-1} for commercial sale.
- ΣHCB, ΣHCH, ΣDDT, ΣCHB and ΣPCB wet weight concentrations (±SD) in ng/g for the 2015 liver samples were 5.25 (2.94), 0.47 (0.18), 8.89 (2.98), 4.54 (7.67) and 14.84 (6.10), respectively.

Messages clés

- les concentrations moyennes de mercure dans les muscles et le foie pour les ensembles complets de données étaient de 0,359 ± 0,141 (n = 642) et de 0,098 ± 0,085 (n = 648) μg g^{-1}, respectivement.
- Depuis le milieu des années 1980, une augmentation de deux à trois fois environ des concentrations de mercure a été mesurée dans les muscles et dans le foie, respectivement, de la lotte de Fort Good Hope.
- Les niveaux de mercure dans les muscles et dans le foie se situent sous le niveau recommandé dans les directives, qui est de 0,50 μg g^{-1} pour la vente commerciale.
- Les concentrations en poids humide de ΣHCB, de ΣHCH, de ΣDDT, de ΣCHB et de ΣPCB (± écart type) en ng/g pour les échantillons de foies de 2015 étaient de 5,25 (2,94), de 0,47 (0,18), de 8,89 (2,98), de 4,54 (7,67) et de 14,84 (6,10), respectivement.

Objectives

The objective of this project is to assess long term trends and to maintain current data on levels of bioaccumulating substances such as mercury, organochlorine contaminants (e.g. PCBs, DDT, toxaphene) and current use 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 organohalogen (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 rising 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 2015-2016 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, Fort Good Hope was selected as one of the priority sampling location for long temp temporal trend studies.

FWI/UM currently maintains a very extensive archive of Fort Good Hope burbot sample tissues and data on trace metals (30 years and 20 time points; 1985, 1988, 1993, 1995, 1999, 2000, 2001, 2002, 2003 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015 and POPs (27 years and 18 time points; 1988, 1994, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015).

Activities in 2015-2016

In January 2016, 48 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

Currently heavy metal (mercury, selenium and arsenic) time trend data from Fort Good Hope (Rampart Rapids) burbot tissues cover 30 years and 21 time points (1985, 1988, 1993, 1995, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, Jan 2016). Mean Hg concentrations in muscle and liver over the entire data sets were 0.359 ± 0.141 (n = 642) and 0.098 ± 0.085 (n = 648) mg g^{-1}, respectively. Mercury levels in muscle are below the recommended guideline level of 0.50 mg g^{-1} for commercial sale.

Mean mercury, selenium and arsenic concentrations for burbot muscle and liver samples for each collection year are shown in Tables 1 and 2, respectively. No significant correlation between length and mercury concentration was observed with muscle or liver for either sex. Mercury trends and levels in male and female burbot muscle and liver follow quite closely from the early 1990's to 2008. Figure 1 shows an approximate 2- and 3-fold increase in mercury concentrations in Fort Good burbot muscle and liver, respectively, since the mid-1980s. For selenium and arsenic no trends were observed in either the muscle or liver (Tables 1 and 2). The highest measured As concentration, 17.16 mg g^{-1}, occurred in a muscle sample from a female burbot collected in 1999.

SHCB, SHCH, SDDT, SCHB and SPCB wet weight concentrations (±SD) in ng/g for the 2015 liver samples were 5.25 (2.94), 0.47 (0.18), 8.89 (2.98), 4.54 (7.67) and 14.84 (6.10), respectively.

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	M	10	633 (84)	0.222 (0.035)	0.358 (0.087)	-
Dec-93	M	7	677 (109)	0.231 (0.113)	0.534 (0.163)	2.291 (3.151)
Sept-95	M	2	-	0.265 (0.035)	-	-
Dec-99	M	21	676 (107)	0.286 (0.095)	0.395 (0.107)	0.637 (0.637)
Dec-00	M	21	699 (104)	0.345 (0.097)	0.478 (0.136)	1.333 (1.944)
Dec-01	M	10	720 (164)	0.342 (0.151)	0.581 (0.272)	3.106 (3.897)
Dec-02	M	12	699 (92)	0.297 (0.139)	0.427 (0.132)	1.555 (2.746)
Jan-04	M	9	705 (79)	0.336 (0.179)	0.377 (0.061)	3.324 (4.506)
Dec-04	M	17	681 (112)	0.413 (0.130)	0.523 (0.199)	1.011 (1.680)
Dec-05	M	13	616 (67)	0.301 (0.118)	0.434 (0.420)	1.663 (2.271)
Dec-06	M	17	700 (78)	0.389 (0.118)	0.401 (0.080)	0.873 (0.913)
Dec-07	M	16	642 (61)	0.420 (0.110)	0.520 (0.132)	0.522 (0.717)
Dec-08	M	15	624 (75)	0.410 (0.115)	0.506 (0.157)	0.310 (0.294)
Dec-09	M	22	703 (94)	0.406 (0.096)	0.405 (0.094)	0.354 (0.327)
Dec-10	M	21	672 (66)	0.349 (0.126)	0.422 (0.074)	0.784 (0.905)
Dec-11	M	17	701 (112)	0.418 (0.141)	0.481 (0.112)	0.681 (0.838)
Dec-12	M	8	713 (77)	0.313 (0.074)	0.408 (0.163)	1.854 (2.797)
Dec-13	M	13	657 (91)	0.353 (0.111)	0.434 (0.133)	1.655 (2.004)
Dec-14	M	10	657 (86)	0.430 (0.137)	-	-
Jan-16	M	28	689 (107)	0.340 (0.149)	1.740 (1.170)2	1.060 (1.410)2
Apr-851	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)1	2.626 (3.815)
Dec-00	F	15	732 (127)	0.364 (0.140)	0.460 (0.175)	1.929 (1.621)
Dec-01	F	10	747 (122)	0.336 (0.180)	0.304 (0.096)	1.098 (1.821)
Dec-02	F	17	727 (118)	0.294 (0.126)	0.400 (0.297)	2.704 (3.258)
Jan-04	F	22	726 (98)	0.254 (0.179)	0.376 (0.125)	2.827 (3.425)
Dec-04	F	18	708 (115)	0.432 (0.138)	0.451 (0.114)	1.562 (2.075)
Dec-05	F	25	710 (104)	0.350 (0.112)	0.409 (0.120)	1.587 (1.942)
Dec-06	F	21	695 (106)	0.477 (0.174)	0.435 (0.121)	0.958 (1.179)
Dec-07	F	25	671 (111)	0.376 (0.115)	0.466 (0.152)	0.533 (0.777)
Dec-08	F	22	689 (118)	0.339 (0.114)	0.433 (0.156)	0.570 (0.706)
Dec-09	F	18	701 (110)	0.402 (0.125)	0.436 (0.098)	0.471 (0.706)
Dec-10	F	18	672 (105)	0.347 (0.179)	0.414 (0.137)	0.986 (1.518)
Dec-11	F	24	725(108)	0.448 (0.106)	0.458 (0.146)	1.032 (1.355)
Dec-12	F	32	703 (119)	0.379 (0.137)	0.449 (0.148)	1.219 (2.147)
Dec-13	F	24	667 (157)	0.323 (0.123)	0.410 (0.128)	1.125 (1.965)
Dec-14	F	28	687 (109)	0.462 (0.137)	-	-
Jan-16	F	20	744 (142)	0.367 (0.097)	-	-

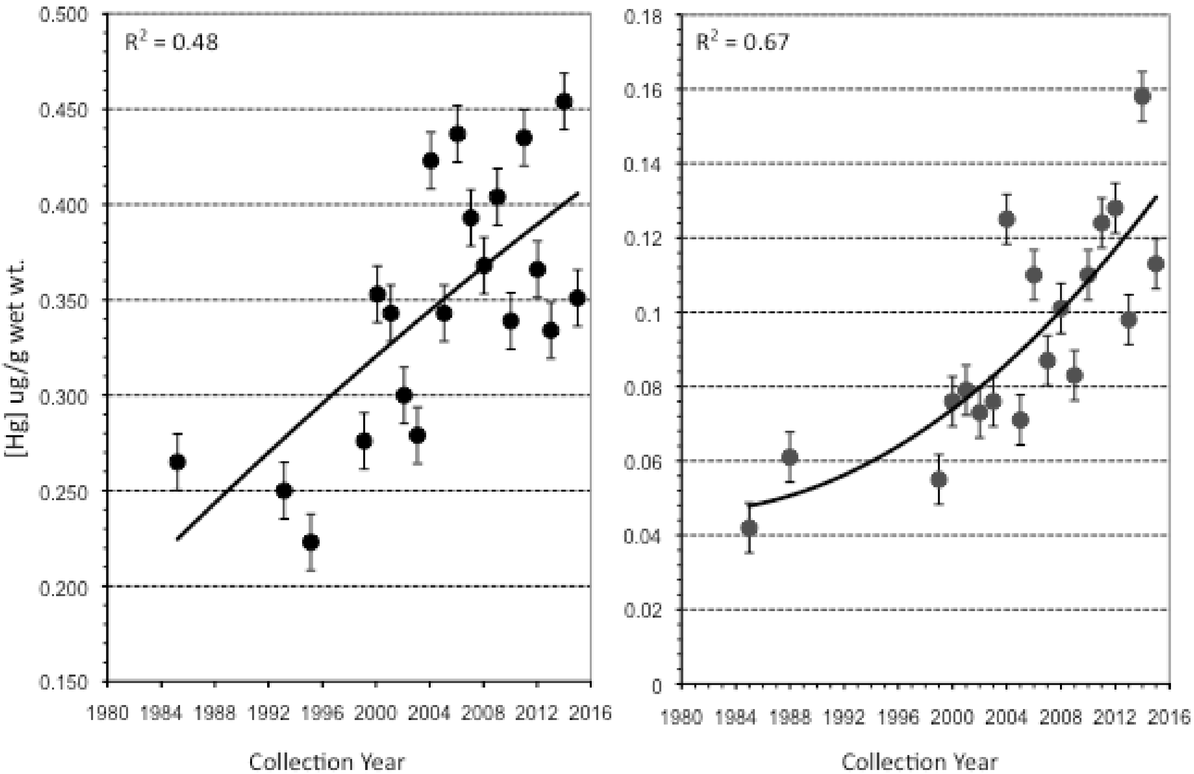
[1]n = 20; [2]n=7

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-851	M	9	643 (82)	0.044 (0.019)	1.759 (0.558)	-
Dec-88	M	8	706 (84)	0.054 (0.026)	1.230 (0.555)	3.119 (1.725)
Dec-93	M	7	677 (109)	-	-	1.016 (1.328)
Dec-99	M	21	676 (107)	0.046 (0.024)	1.071 (0.628)2	0.607 (0.326)
Dec-00	M	21	699 (104)	0.064 (0.026)	1.646 (0.733)	0.585 (0.412)
Dec-01	M	10	720 (164)	0.063 (0.048)	1.434 (1.278)	0.839 (0.822)
Dec-02	M	12	699 (92)	0.063 (0.031)	1.437 (0.808)	0.771 (0.539)
Jan-04	M	9	705 (79)	0.126 (0.179)	1.981 (1.370)	1.994 (1.447)
Dec-04	M	17	681 (112)	0.111 (0.065)	3.267 (2.437)	0.496 (0.605)
Dec-05	M	13	616 (67)	0.053 (0.047)	1.677 (0.782)	0.527 (0.540)
Dec-06	M	17	700 (78)	0.094 (0.064)	1.939 (1.117)	-
Dec-07	M	16	642 (61)	0.076 (0.035)	2.090 (0.837)	-
Jan-09	M	15	324 (75)	0.114 (0.055)	3.416 (1.722)	0.335 (0.300)
Dec-09	M	22	703 (94)	0.064 (0.030)	2.038 (0.985)	-
Dec-10	M	21	672 (66)	0.100 (0.075)	2.571 (2.118)	0.630 (0.568)
Dec-11	M	17	701 (112)	0.119 (0.079)	2.333 (1.407)	-
Dec-12	M	8	713 (119)	0.063 (0.024)	1.946 (0.623)	0.456 (0.378)
Dec-13	M	13	657 (91)	0.095 (0.081)	2.490 (1.523)	0.487 (0.405)
Dec-14	M	10	657 (86)	0.091 (0.046)	-	-
Jan-16	M	27	684 (105)	0.115 (0.130)	-	-
Apr-851	F	6	714 (140)	0.097 (0.098)	1.272 (0.715)	-
Dec-88	F	2	623 (86)	0.072 (0.035)	1.460 (1.529)	1.280 (1.018)
Dec-93	F	3	812 (129)	-	-	1.062 (0.546)
Dec-99	F	20	749 (77)	0.064 (0.069)	0.687 (0.552)2	1.353 (0.811)
Dec-00	F	15	732 (127)	0.094 (0.056)	1.203 (0.469)	0.632 (0.349)
Dec-01	F	10	747 (122)	0.098 (0.108)	1.235 (0.720)	1.074 (1.227)
Dec-02	F	17	727 (118)	0.082 (0.067)	1.488 (1.203)	1.063 (0.890)
Jan-04	F	22	726 (98)	0.057 (0.033)	1.245 (0.511)	1.522 (1.348)
Dec-04	F	17	700 (112)	0.138 (0.081)	2.616 (2.030)	0.489 (0.335)
Dec-05	F	25	710 (104)	0.080 (0.050)	1.585 (1.013)	0.489 (0.585)
Dec-06	F	21	695 (106)	0.125 (0.076)	1.906 (1.006)3	-
Dec-07	F	24	674 (113)	0.094 (0.098)	2.064 (1.096)	-
Jan-09	F	22	689 (118)	0.092 (0.059)	1.690 (1.095)	0.451 (0.401)
Dec-09	F	18	701 (110)	0.107 (0.141)	1.752 (1.023)	-
Dec-10	F	18	672 (105)	0.122 (0.135)	1.399 (0.688)	0.556 (0.571)
Dec-11	F	24	725 (108)	0.128 (0.043)	1.664 (0.973)	-
Dec-12	F	32	703 (119)	0.144 (0.114)	2.730 (2.410)	0.409 (0.586)
Dec-13	F	24	667 (157)	0.100 (0.072)	1.769 (1.329)	0.672 (0.905)
Dec-14	F	28	687 (109)	0.181 (0.141)	-	-
Jan-16	F	17	752 (145)	0.111 (0.079)	-	-

[1]Wagemann 1985; [2,3]n = 19

Figure 1. Mean Hg concentrations (SE) in muscle (left) and liver (right) from Fort Good Hope burbot (males + females).



Expected project completion date

Temporal trend studies are long-term projects and thus annual sampling is projected to continue into the foreseeable future.

References

Borgmann, U. and D.M. Whittle. 1991. Contaminant concentration trends in Lake Ontario lake trout. J. Great Lakes Res. 17: 368-381.

Carrie, J.; Wang, F.; Sanei, H; Macdonald, R.W.; Outridge, P.M.; Stern, G.A. 2010.

Increasing contaminant burdens in an Arctic fish, burbot (Lota lota), in a warming climate. Environ. Sci. Technol. 44: 316-322.

Rouse W.R., Douglas M.S.V., Hecky R.E., Hershey A.E., Kling G.W., Lesack L., Marsh P., Mcdonald M., Nicholson B.J., Roulet N.T., and Smol J.P. 1997. Effects of climate change on the freshwaters of Arctic and Subarctic North America. Hydrol. Proc. 11:873-902.

Trace metals and organohalogen contaminants in fish from selected Yukon lakes: A temporal and spatial study

Métaux traces et contaminants organohalogénés chez les poissons de certains lacs au Yukon : étude des tendances temporelles et spatiales

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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 metal (Hg/Se/As) contaminants. Currently heavy metal time trend data from Laberge and Kusawa Lake trout muscle cover 22 years, 19 and 17 time points, respectively. The mean mercury levels of all data sets for the Laberge sample was 0.47 ± 0.21 (n=202), while the mean mercury level of all Kusawa samples was 0.37 ± 0.22 (n=164) mg g^{-1}, respectively. In both lakes, levels are below the recommended guideline level of 0.50 mg g^{-1} for commercial sale. No significant trends have been observed in the Laberge over the last 22 years. In Kusuwa Lake, after a significant drop in the length adjusted Hg trout muscle concentrations in 2001, no significant trends have been observed. The current length adjusted mean Hg concentration for trout in Kusawa Lake is now at its highest level since 1999.

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 22 ans, 19 et 17 moments d'échantillonnage, respectivement. Les niveaux de mercure moyens de tous les ensembles de données pour l'échantillon du lac Laberge étaient de 0,47 ± 0,21 (n=202), tandis que le niveau de mercure moyen de tous les échantillons du lac Kusawa était de 0,37 ± 0,22 (n=164) mg g-1, respectivement. Dans les deux lacs, les niveaux se situent sous le niveau recommandé dans les directives, qui est de 0,50 mg g-1 pour la vente commerciale. Au cours des 22 dernières années, aucune tendance significative n'a été observée dans le lac Laberge.

Dans le lac Kusuwa, après une chute importante des concentrations de mercure corrigées en fonction de la longueur dans les muscles de truites du lac en 2001, aucune tendance significative n'a été observée. La concentration moyenne actuelle de mercure corrigée en fonction de la longueur pour la truite dans le lac Kusawa est maintenant à son niveau le plus élevé depuis 1999.

Key messages

- Currently heavy metal (mercury, selenium and arsenic) time trend data from Laberge and Kusawa Lake trout cover 22 years, 19 and 17 time points, respectively
- The mean Hg levels over the entire data sets for the Laberge and Kusawa samples were 0.47 ± 0.21 (n=202) and 0.37 ± 0.22 (n=164) $\mu g\ g^{-1}$, respectively. In both lakes, levels are just below the recommended guideline level of 0.50 $\mu g\ g^{-1}$ for commercial sale.
- No significant trends have been observed in the Laberge over the last 22 years.
- In Kusuwa Lake, after a significant drop in the length adjusted mean Hg trout muscle concentrations in 2001, no significant trends have been observed. The current length adjusted mean Hg concentration is now at its highest level since 1999.

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 22 ans, et est constituée de 19 dates d'échantillonnage pour le lac Laberge et de 17 pour le lac Kusawa.
- Pour l'ensemble des données, la concentration moyenne de mercure est de 0,47 ± 0,21 (n=202) au lac Laberge et de 0,37 ± 0,22 (n=164) $\mu g\ g^{-1}$, au lac Kusawa, respectivement. Dans les deux lacs, les niveaux se situent sous le niveau recommandé dans les directives, qui est de 0,50 $\mu g\ g^{-1}$ pour la vente commerciale.
- Au cours des 22 dernières années, aucune tendance significative n'a été observée dans le lac Laberge.
- Dans le lac Kusuwa, après une chute importante des concentrations de mercure corrigées en fonction de la longueur dans les muscles de truites du lac en 2001, aucune tendance significative n'a été observée. La concentration moyenne actuelle de mercure corrigée en fonction de la longueur est maintenant à son niveau le plus élevé depuis 1999.

Objectives

The objective of this project is to maintain current data on contaminants levels in lake trout from two Yukon lakes (Laberge and Kusawa) and 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). This assessment of temporal trends will help 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 19 years (1993-2013). 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 to the subsistence diet of northerners, the need to continue to assess the effect of climate variation on fish contaminant levels, and 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 2015-2016

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 2015, 10 lake trout were collected from Kusawa Lake and 20 from Lake Laberge.

Results and discussion

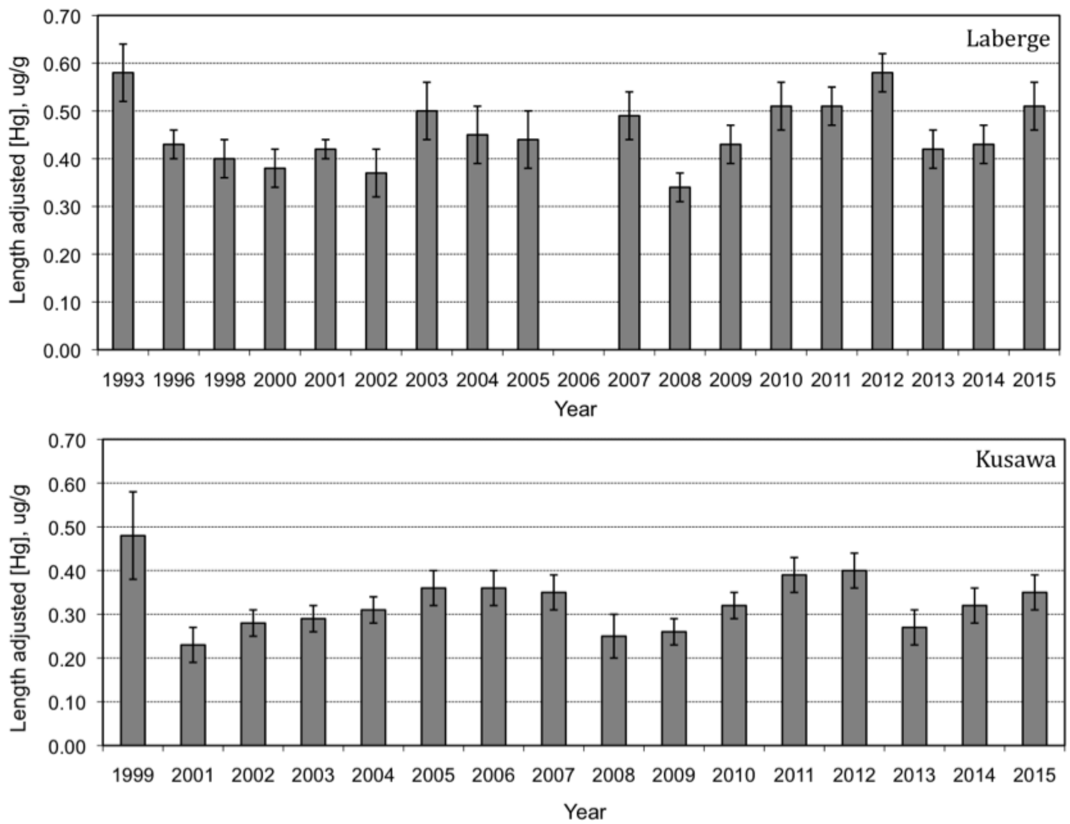
<u>Hg, Se, As</u>: Currently heavy metal (mercury, selenium and arsenic) time trend data from Laberge and Kusawa Lake trout cover 22 years, with 19 and 17 time points, respectively (Table 1). The mean Hg levels over the entire data sets for the Laberge and Kusawa samples were 0.47 ± 0.21 (n=202) and 0.37 ± 0.22 (n=164) $\mu g\ g^{-1}$, 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, r^2 = 0.59, p<0.001, n=143) and Kusawa ([Hg] = m*length + b, m=0.0018, b=-0.5046, r^2 = 0.52, p<0.001, n=124) trout. ANCOVA was used to assess the effects of year to year collections

(temporal trends), length and length*year interactions (homogeneity of the slope between length and [Hg]). No significant trends have been observed in Lake Laberge over the last 22 years. In Kusawa Lake, after a significant drop in the length adjusted mean Hg trout muscle concentrations in 2001, no significant trends have been observed. The current length adjusted mean Hg concentration is now at its highest level since 1999.

Table 1. Mean (standard deviation) concentrations of mercury, selenium and arsenic in lake trout muscle from Laberge and Kusawa Lakes. All levels are in μg/g.

	Year	n	Length	Hg	Se	As
Laberge	1993	13	483 (110)	0.44 (0.11)	0.45 (0.08)	0.15 (0.04)
	1996	18	472 (93)	0.32 (0.10)	0.32 (0.12)	0.12 (0.06)
	1998	7	700 (125)	0.61 (0.24)	0.42 (0.07)	0.18 (0.12)
	2000	6	590 (108)	0.43 (0.21)	0.66 (0.14)	0.13 (0.04)
	2001	22	639 (92)	0.54 (0.23)	0.57 (0.13)	0.10 (0.04)
	2002	5	570 (120)	0.38 (0.15)	0.61 (0.12)	0.11 (0.05)
	2003	8	593 (98)	0.56 (0.25)	0.47 (0.10)	0.10 (0.03)
	2004	5	614 (68)	0.54 (0.23)	0.38 (0.09)	0.09 (0.04)
	2005	10	606 (97)	0.50 (0.19)	0.47 (0.09)	0.06 (0.03)
	2006	1	800	0.68	0.45	0.08
	2007	9	674 (109)	0.70 (0.27)	0.42 (0.05)	0.08 (0.03)
	2008	10	580 (78)	0.37 (0.19)	0.43 (0.07)	0.06 (0.02)
	2009	10	538 (58)	0.41 (0.18)	0.41 (0.03)	0.06 (0.02)
	2010	10	547 (49)	0.49 (0.19)	0.45 (0.07)	0.08 (0.03)
	2011	10	553 (64)	0.52 (0.29)	0.41 (0.09)	0.08 (0.04)
	2012	10	579 (47)	0.63 (0.24)	0.46 (0.06)	0.07 (0.02)
	2013	8	499 (87)	0.33 (0.13)	0.45 (0.07)	0.08 (0.03)
	2014	20	564 (64)	0.40 (0.11)	0.45 (0.07)	0.08 (0.03)
	2015	20	548 (83)	0.48 (0.17)	-	-
Kusawa	1993	3	535 (72)	0.54 (0.21)	0.43 (0.17)	-
	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)	-
	2002	10	500 (74)	0.29 (0.09)	0.55 (0.07)	0.02 (0.01)
	2003	10	487 (90)	0.35 (0.13)	0.35 (0.24)	0.03 (0.02)
	2004	9	553 (117)	0.39 (0.13)	0.64 (0.14)	0.03 (0.01)
	2005	10	510 (118)	0.43(0.31)	0.60 (0.11)	0.01 (0.01)
	2006	9	568 (168)	0.56 (0.38)	0.59 (0.17)	0.02 (0.01)
	2007	10	446 (80)	0.36 (0.24)	0.57 (0.08)	0.02 (0.01)
	2008	10	471 (94)	0.24 (0.07)	0.54 (0.08)	0.02 (0.01)
	2009	10	453 (54)	0.23 (0.08)	0.56 (0.08)	0.02 (0.01)
	2010	10	449 (97)	0.31 (0.19)	0.47 (0.09)	0.04 (0.03)
	2011	10	433 (43)	0.32 (0.06)	0.51 (0.07)	0.02 (0.01)
	2012	10	433 (47)	0.53 (0.13)	0.54 (0.13)	0.04 (0.03)
	2013	10	418 (72)	0.29 (0.08)	0.54 (0.08)	0.02 (0.01)
	2014	10	412 (42)	0.31 (0.10)	0.54 (0.08)	0.02 (0.01)
	2015	10	425 (40)	0.37 (0.11)	-	-

Figure 1. Length adjusted Hg concentrations in trout muscle from Lake Laberge (1993-2015) and Kusawa (1993–2015). Only Kusawa trout less than 700 mm in length were used in the ANCOVA.



Organohalogens: Tables 2 and 3 list the mean wet weight HOC concentration in trout from Lake Laberge and Kusawa Lake, respectively, over the 20 year time period from 1983 to 2014. Significant variability in the Laberge and Kusawa samples is observed over time and as a result no temporal trends are evident. Major PBDE congener concentrations in Lake trout from Lakes Laberge and Kusawa are shown in Table 4. HOCs were not analyzed in 2015.

FOC levels in Kusawa and Laberge lake trout liver are listed in Table 5 and Table 6, respectively.

Table 2. Mean (S.D.) HOC levels (ng/g wet wt.) in lake trout muscle from Lake Laberge

Laberge	N	Age	% lipid	SPCB	SDDT	SCHL	SHCH	SCHB	SCBz
1993	24	15 (2)	7.9 (0.9)	328.28 (121.49)	391.54 (132.69)	47.60 (8.84)	4.69 (0.78)	310.96 (62.36)	3.92 (0.57)
1996	13	22 (5)	9.6 (1.4)	209.32 (52.08)	236.51 (41.39)	53.38 (13.74)	6.50 (1.79)	212.23 (28.31)	4.90 (1.24)
2000	6	12 (2)	3.7 (0.8)	138.95 (60.89)	96.46 (14.21)	22.36 (5.84)	2.30 (1.08)	207.33 (49.90)	2.26 (0.59)
2001	16	14 (2)	4.9 (0.5)	139.71 (53.75)	89.46 (14.04)	26.37 (5.14)	0.80 (0.07)	154.20 (60.46)	2.11 (0.17)
2002	5	12 (4)	4.2 (0.9)	48.60 (8.81)	54.50 (11.58)	7.26 (1.59)	1.58 (0.50)	139.23 (16.88)	1.15 (0.25)
2003	8	12 (1)	4.7 (0.8)	81.01 (29.83)	61.48 (8.55)	7.44 (2.24)	0.54 (0.10)	179.31 (42.79)	1.21 (0.28)
2004	6	12 (4)	8.7 (3.9)	48.93 (34.30)	94.09 (60.68)	7.46 (4.90)	0.19 (0.09)	79.92 (52.01)	0.49 (0.28)
2005	10	14 (7)	2.0 (1.22)	28.94 (20.27)	50.91 (30.27)	2.61 (1.28)	0.16 (0.10)	34.50 (19.97)	0.35 (0.27)
2006	1	21	1.0	25.52	31.25	4.82	0.07	76.87	0.35
2007	9	14 (5)	1.2 (0.80)	37.36 (25.89)	43.98 (29.93)	5.32 (4.05)	0.10 (0.09)	25.78 (14.58)	0.27 (0.80)
2008	10	12 (5)	2.3 (1.1)	50.23 (36.89)	70.06 (41.29)	4.04 (2.88)	0.18 (0.08)	24.48 (16.85)	0.77 (0.23)
2009	10	10 (3)	2.9 (1.1)	28.92 (14.89)	35.33 (20.81)	2.30 (1.06)	0.14 (0.06)	37.60 (19.57)	0.60 (0.34)
2010	10	9 (2)	2.3 (1.3)	12.08 (3.74)	40.43 (12.12)	1.18 (0.47)	0.12 (0.05)	24.91 (13.84)	0.29 (0.12)
2011	10	8 (3)	2.2 (1.0)	23.13 (12.65)	31.24 (13.24)	1.94 (0.93)	0.12 (0.05)	10.48 (4.09)	0.39 (0.16)
2012	10	11 (5)	2.0 (1.2)	31.80 (20.61)	20.24 (9.62)	2.14 (1.49)	0.13 (0.08)	11.57 (7.37)	0.65 (0.25)
2013	8	14 (6)	6.7 (2.8)	45.97 (26.83)	93.44 (58.44)	5.56 (4.29)	0.26 (0.16)	10.59 (9.23)	2.04 (1.00)
2014	7	20 (5)	-	47.65 (20.96)	92.27 (29.75)	4.99 (1.51)	0.17 (0.08)	9.77 (4.42)	1.86 (0.70)

Table 3. Mean (S.D.) OC levels (ng/g wet wt.) in lake trout muscle from Kusawa Lake

Kusawa	N	Age	% lipid	SPCB	SDDT	SCHL	SHCH	SCHB	SCBz
1993	10	19 (2)	1.8 (1.6)	85.62 (26.07)	44.16 (21.50)	17.33 (2.78)	1.21 (0.36)	120.80 (24.94)	1.15 (0.28)
1999	14	18 (1)	4.6 (3.0)	91.09 (11.85)	139.16 (19.72)	17.82 (2.74)	1.68 (0.23)	148.38 (29.29)	1.52 (0.20)
2001	9	12 (1)	2.4 (1.4)	48.55 (7.91)	56.58 (15.30)	7.45 (2.35)	0.91 (0.14)	61.03 (8.55)	0.84 (0.14)
2002	10	12 (1)	1.4 (0.8)	32.45 (3.66)	26.66 (4.15)	3.01 (0.48)	0.62 (0.08)	43.47 (5.02)	0.61 (0.09)
2003	9	9 (3)	5.8 (3.6)	8.16 (5.86)	8.21 (15.67)	3.50 (2.28)	0.14 (0.08)	45.05 (32.20)	0.44 (0.30)
2004	9	13 (4)	7.9 (4.7)	11.29 (3.78)	5.70 (3.70)	4.52 (2.16)	0.15 (0.07)	49.73 (30.17)	0.50 (0.27)
2005	10	15 (6)	0.61 (0.51)	5.48 (4.84)	2.35 (3.02)	1.17 (0.88)	0.03 (0.03)	12.37 (11.57)	0.12 (0.10)
2006	9	12 (4)	1.82 (1.49)	6.28 (4.58)	2.97 (2.57)	2.49 (1.84)	0.09 (0.06)	42.63 (34.97)	0.47 (0.26)
2007	9	10 (4)	1.52 (1.43)	9.88 (9.93)	2.35 (1.88)	2.78 (2.90)	0.10 (0.06)	22.44 (23.88)	0.42 (0.33)
2008	10	9 (2)	1.16 (0.42)	18.30 (27.27)	2.35 (0.94)	1.30 (0.40)	0.13 (0.26)	22.55 (7.87)	0.47 (0.13)
2009	10	9 (1)	1.51 (1.11)	2.55 (1.59)	0.78 (0.67)	0.95 (0.72)	0.05 (0.03)	21.20 (17.20)	0.18 (0.11)
2010	10	10 (3)	1.9 (1.6)	3.20 (2.24)	2.12 (2.13)	0.93 (0.81)	0.06 (0.03)	22.00 (23.05)	0.20 (0.12)
2011	10	8 (2)	0.80 (0.51)	5.49 (2.09)	0.81 (0.35)	0.80 (0.39)	0.13 (0.07)	5.86 (3.57)	0.22 (0.10)
2012	10	10 (4)	1.5 (1.1)	8.48 (4.47)	1.70 (0.90)	1.68 (0.83)	0.15 (0.11)	13.10 (9.96)	0.74 (0.33)
2013	10	12 (5)	3.3 (3.1)	22.45 (16.32)	3.19 (2.53)	3.15 (2.53)	0.10 (0.10)	6.22 (4.80)	1.23 (0.74)
2014	7	15 (3)	-	8.79 (9.92)	13.11 (31.05)	2.49 (1.31)	< 0.20	4.02 (2.81)	0.80 (0.85)

Table 4. Mean (S.D.) PBDE levels (pg g^{-1}, wet wt.) in lake trout muscle from Lakes Laberge and Kusawa

	Laberge	n	% Lipid	BDE 47	BDE 49	BDE 99	BDE 100	BDE 153	BDE 154
Laberge	1993	10	2.0 (1.7)	1481 (728)	348 (112)	2943 (1531)	700 (341)	642 (491)	1530 (1009)
	2000	6	0.5 (0.3)	4900 (1680)	2100 (240)	8590 (1170)	3380 (630)	5740 (1320)	4460 (1190)
	2003	8	0.4 (0.2)	3170 (1430)	1290 (750)	5890 (2860)	2450 (1200)	3920(4050)	3200 (2810)
	2005	10	2.0 (1.2)	2659 (1977)	165 (117)	4093 (2389)	1848 (1235)	740 (580)	986 (732)
	2006	1	1.0	24920	1630	35900	11370	4120	3240
	2007	9	1.2 (0.8)	5500 (901)	1100 (1130)	9680 (1627)	6700 (5850)	200 (560)	1900 (1450)
	2008	10	2.3 (1.1)	2389 (1207)	2175 (1476)	1721 (1222)	139 (99)	258 (152)	560 (211)
	2009	10	2.9 (1.1)	1590 (1815)	1546 (1476)	2799 (1165)	1421 (729)	347 (141)	250 (355)
	2010	10	2.3 (1.3)	2907 (3266)	2640 (2525)	3124 (3989)	1271 (1457)	365 (487)	566 (646)
	2011	10	2.2 (1.0)	525 (700)	320 (280)	629 (994)	229 (339)	82 (115)	131 (193)
	2013	8	6.6 (4.1)	383 (321)	nd	685 (839)	276 (294)	98 (147)	111 (129)
	2014	8	-	253 (148)	nd	451 (377)	211 (170)	67 (67)	103 (96)
Kusawa	1999	10	3.0 (2.2)	4377 (2490)	nd	3636 (2011)	2573 (1623)	894 (622)	1495 (895)
	2001	10	2.8 (1.6)	700 (990)	130 (160)	720 (1090)	250 (250)	260 (480)	230 (330)
	2003	5	0.2 (1.1)	960 (1220)	360 (47)	2630 (3510)	950 (1260)	1180 (1590)	870 (1150)
	2006	9	1.8 (1.5)	1103 (1231)	66 (99)	824 (911)	446 (514)	136 (140)	202 (236)
	2007	9	1.6 (1.4)	9900 (1216)	300 (700)	12300 (1271)	3900 (5990)	1100 (830)	600 (790)
	2008	10	1.2 (0.4)	4178 (1781	648 (240)*	1653 (1394)	294 (113)	58 (103)	1653 (609)
	2009	10	1.5 (1.1)	417 (135)	73 (88)	273 (106)	121 (53)	27 (10)	69 (38)
	2010	10	1.9 (1.6)	359 (640)	231 (471)	252 (510)	138 (283)	33 (64)	65 (124)
	2011	10	0.8 (0.5)	240 (110)	70 (130)	180 (100)	80 (40)	70 (50)	60 (50)
	2013	10	3.1 (4.4)	61 (98)	nd	101 (189)	43 (76)	13 (24)	19 (34)
	2014	7	-	22 (37)	nd	24 (41)	14 (26)	12 (18)	12 (22)

nd = non-detect

Table 5: Laberge (ng g-1, wet wt.) FOC levels

Year (n)	PFOS (± SD)	PFNA (± SD)	PFDA/PFOSA (± SD)
2006 (n=1)	PFOS = 2.18	N/A	N/A
2007 (n=9)	PFOS = 2.47 (1.86)	PFNA = 5.78 (6.33)	PFDA = 32.40 (30.34)
2008 (n=10)	PFOS = 1.28 (2.31)	PFNA = 0.06 (0.14)	PFOSA = 1.31 (1.24)
2009 (n=10)	PFOS = 1.93 (1.60)	PFNA = 1.39 (1.48)	PFDA = 4.87 (6.55)
2010 (n=10)	PFOS = 2.66 (3.93)	PFNA = 3.11 (6.01)	PFDA = 1.65 (2.86)
2011 (n=10)	PFOS = 1.61 (1.62)	PFNA = 3.86 (7.45)	PFDA = 1.11 (1.57)
2012 (n=10)	PFOS = 1.98 (1.89)	PFNA = 5.61(12.17)	N/A
2013 (n=10)	N/A	PFNA = 0.54 (0.46)	PFOSA = 0.28 (0.50)
2014 (n=12)	N/A	PFNA = 0.42 (0.84)	PFDA = 0.44 (1.58)

Table 6: Kusawa (ng g-1, wet wt.) FOC levels

Year (n)	PFOS/PFUA (± SD)	PFNA (± SD)	PFDA (± SD)	PFOA/PFOSA (± SD)
2006 (n=9)	n/a	n/a	n/a	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)	n/a
2008 (n=9)	PFOS = 0.44 (0.88)	PFNA = 0.06 (0.14)	PFDA = 0.10 (0.24)	PFOSA = 0.32 (0.65)
2009 (n=10)	PFOS = 0.55 (0.60)	PFNA = 0.40 (0.14)	PFDA = 3.76 (5.24)	n/a
2010 (n=10)	PFOS = 0.19 (0.60)	PFNA = 2.93 (3.48)	PFDA = 3.85 (5.25)	n/a
2011 (n=10)	PFOS = 0.21 (0.40)	PFNA = 1.53 (2.51)	PFDA = 5.68 (5.71)	n/a
2012 (n=10)	PFOS = 0.31 (0.67)	PFNA = 3.51(4.12)	PFDA = 1.37 (4.23)	n/a
2013 (n=10)	n/a	PFUA = 0.45 (0.66)	n/a	n/a
2014 (n=12): PFNA = 0.27 (0.35)	n/a	n/a	PFDA = 0.51 (1.26)	n/a

Expected project completion date

Temporal trend studies are long-term propositions and thus annual sampling is projected until well into the future.

References

Ryan, M., G.A. Stern, M. Diamond, M.V. Croft, P. Roach, K. Kidd, 2005, Temporal trends of organochlorine contaminants in burbot and lake trout from three selected Yukon lakes. S*ci. Total Environ.* 351-352: 501-522.

Ryan, M.J., G.A. Stern, K.A. Kidd, M.C Croft, S. Gewurtz, M. Diamond, L. Kinnear, P. Roach. 2012. Biotic interactions in temporal trends (1992–2010) of organochlorine contaminants in the aquatic food web of Lake Laberge, Yukon Territory. *Sci. Total Environ.* 443: 80-92

Arctic Caribou Contaminant Monitoring Program

Programme de surveillance des contaminants dans le caribou de l'Arctique

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Abstract

This project studies contaminant levels in caribou in the Canadian Arctic to determine if these populations remain healthy (in terms of contaminant loads), whether these important resources remain safe and healthy food choices for northerners and if contaminant levels are changing over time. In 2015/2016, samples were collected from 18 Porcupine, 19 Qamanirjuaq, 13 Dolphin & Union and 20 Bluenose East caribou. Sample analyses for these collections had not been completed at the time this report was prepared. Qamanirjuaq and Beverly caribou samples collected in the 2014/2015 year have been analyzed, and results are presented in this report. Age was positively correlated with renal cadmium and zinc in both

Résumé

Ce projet vise à étudier les concentrations de contaminants chez les caribous de l'Arctique canadien afin de déterminer si ces populations demeurent en santé (en ce qui concerne les niveaux de contaminants), si cette ressource alimentaire importante continue d'être une source de nourriture saine et sécuritaire pour les résidants du Nord, et si les concentrations de contaminants évoluent au fil du temps. En 2015-2016, des échantillons ont été prélevés sur 18 caribous de Pocupine, 19 de Qamanirjuaq, 13 de Dolphin-et-Union et 20 de Bluenose East. Leur analyse n'était pas terminée au moment où le présent rapport a été rédigé. Les résultats concernant les échantillons recueillis en 2014-2015 chez les caribous de Qamanirjuaq et de

herds. In the Beverly herd, cows had higher concentrations of renal cadmium and lead than bulls, while in the Qamanirjuaq herd, concentrations of renal arsenic, cadmium and mercury were higher in cows than bulls. These toxic elements tended to be higher in cows than bulls, likely due to the relatively higher volume of food intake (and hence toxic element intake) due to their smaller size and higher energetic requirements from parturition and lactation. Temporal trends were unable to be assessed in the Beverly herd due to insufficient data from the past. Contaminant concentrations in the Qamanirjuaq caribou appear to be stable. Marrow and brain tissue sampled from the Qamanirjuaq caribou do not have elevated levels of contaminants and continue to be a healthy traditional food choice. Levels of most elements measured in caribou kidneys were not of concern toxicologically, although renal mercury and cadmium concentrations may cause some concern for human health depending on the quantity of organs consumed.   Yukon Health has advised restricting intake of kidney and liver from Yukon caribou, the recommended maximum varying depending on herd (*e.g.*, a maximum of 32 Porcupine caribou kidneys/year). The health advisory confirms that heavy metals are very low in the meat (muscle) from caribou and this remains a healthy food choice.

Beverly sont fournis dans le présent rapport. L'âge était en corrélation positive avec les concentrations de cadmium et de zinc présentes dans les reins chez les deux hardes. Dans la harde de Beverly, les vaches présentaient de plus fortes concentrations de cadmium et de plomb dans leurs reins que les taureaux, alors que dans la harde de Qamanirjuaq, les concentrations d'arsenic, de cadmium et de mercure dans les reins étaient plus élevées chez les vaches que chez les taureaux. Ces éléments toxiques tendaient à être plus abondants chez les vaches que chez les taureaux, probablement en raison du volume relativement plus élevé de prise alimentaire (et donc de consommation d'éléments toxiques), en raison de leur plus petite taille et des besoins énergétiques plus importants découlant de la mise bas et de la lactation. Les tendances temporelles n'ont pas pu faire l'objet d'une évaluation au sein de la harde de Beverly en raison de données antérieures insuffisantes. Les concentrations de contaminants dans la harde de caribous de Qamanirjuaq semblent stables. Les tissus de la moelle osseuse et du cerveau prélevés sur les caribous de Qamanirjuaq ne présentent pas de niveaux élevés de contaminants et demeurent un choix d'aliment traditionnel santé. La concentration de la plupart des éléments mesurés dans les reins des caribous ne constituait pas une préoccupation sur le plan de la toxicologie, bien que les concentrations de mercure et de cadmium dans les reins puissent être préoccupantes pour la santé humaine, selon la quantité d'organes consommée. Le ministère de la Santé du Yukon a conseillé aux citoyens de limiter la quantité de rognons et de foie provenant de caribous du Yukon qu'ils consomment; la quantité maximale recommandée varie selon la harde (*p. ex.*, au maximum 32 rognons de caribous de la harde de la Porcupine par année). L'avis de santé publique confirme que les concentrations de métaux lourds sont faibles dans la viande (les muscles) des caribous et que celle-ci demeure un aliment sain.

Key messages

- Levels of most elements measured in caribou tissues are not of concern, although kidney mercury and cadmium concentrations may cause some concern for human health depending on the quantity of organs consumed.
- Caribou meat (muscle) does not accumulate high levels of contaminants and is a healthy food choice.
- Contaminant levels in the Qamanirjuaq caribou appear to be stable.
- Marrow and brain tissue from the Qamanirjuaq caribou do not have elevated levels of contaminants and continue to be healthy traditional food choices.
- This program will continue to monitor the Porcupine and Qamanirjuaq caribou herds annually to maintain confidence in this traditional food and to better understand the dynamics of contaminants within this ecosystem (particularly mercury).

Messages clés

- La concentration de la plupart des éléments mesurés dans les tissus de caribou ne constitue pas une préoccupation, bien que les concentrations de mercure et de cadmium dans les reins puissent être préoccupantes pour la santé humaine, selon la quantité d'organes consommée.
- La viande (les muscles) des caribous n'accumule pas de grandes concentrations de contaminants et constitue donc un aliment sain.
- Les concentrations de contaminants dans la harde de caribous de Qamanirjuaq semblent stables.
- Les tissus de la moelle osseuse et du cerveau prélevés sur les caribous de Qamanirjuaq ne présentent pas de niveaux élevés de contaminants et demeurent un choix d'aliment traditionnel santé.
- Dans le cadre de ce programme, on continuera de surveiller les hardes de caribous de Porcupine et de Qamanirjuaq sur une base annuelle, et ce, afin de s'assurer que cette source alimentaire traditionnelle demeure saine et de mieux comprendre la dynamique des contaminants (en particulier du mercure) dans l'écosystème.

Objectives

To determine levels of and temporal trends in contaminants in Arctic caribou in order to:

1. Provide information to Northerners regarding contaminants in these traditional foods, so that:
   a. They may be better able to make informed choices about food consumption. This includes providing information for health assessments and/or advisories as required.
   b. Wildlife managers can assess possible health effects of contaminants on Arctic caribou populations.
2. 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 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, and two additional herds are sampled each year on a rotating basis.

Activities in 2015-2016

Samples were collected from 18 Porcupine caribou in the fall of 2015 by hunters in Old Crow with the assistance of Environment Yukon (Martin Kienzler and Mike Suitor). Samples were collected from 19 Qamanirjuaq caribou herd in Arviat in the fall of 2015 in cooperation with the Arviat Hunters and Trappers Organization. GNWT (Brett Elkin) provided 20 kidneys from the Bluenose East caribou herd, collected in the spring of 2013. This herd was sampled in the spring of 2000, 2005 and 2006. The Dolphin & Union caribou were sampled by GN (Myles Lamont and Lisa LaClerc) in Kugluktuk in the fall of 2015 in cooperation with local hunters. Only 13 samples were collected, so they will continue the sampling in the spring of 2016 to try to attain the maximum number of samples (20).

Current-year samples are currently being analyzed for a suite of 34 elements using Inductively coupled plasma mass spectrometry (ICP-MS) by the National Laboratory for Environmental Testing (NLET), Environment Canada, Burlington (Xiaowa Wang, Derek Muir). Ten liver samples from the Porcupine and Qamanirjuaq herds are being analyzed for PBDEs (including deca-BDE), PFOS and PFCAs by a private laboratory (ALS Global). Liver and muscle samples were archived at the National Wildlife Research Centre (Environment Canada). Incisors were used to analyze age of the animal using the cementum technique (Angela Milani, Government of Yukon).

In 2014-2015, only two samples were collected from the Porcupine caribou. Six Porcupine caribou kidney samples from the tissue archive were analyzed to fill in data gaps from previous years. Results are presented for samples from 22 Qamanirjuaq caribou collected in the fall of 2014 and 16 Beverly caribou collected in the spring of 2013. In addition to kidneys, 10 marrow and 10 brain samples from the Qamanirjuaq herd were also analyzed in response to concerns from local hunters regarding these traditional foods.

Although kidneys were analyzed for 34 elements, only results for 7 elements of concern were statistically analyzed in detail (arsenic [As], cadmium [Cd], copper [Cu], lead [Pb], mercury [Hg], selenium [Se] and zinc [Zn]). Qamanirjuaq results were compared to previous results from fall-collected animals and Beverly results were compared with previous results from spring-collected animals. Note that As and Se were not measured in the Beverly herd in 1994 or 2000 (these are not NCP data, but were kindly provided by GNWT). In all statistical analyses, data were log-transformed, where necessary to achieve normality. If normality was not achieved by this transformation, non-parametric tests were used to analyze the data.

Capacity Building

In October, 2015, the PI participated in a wildlife contaminants workshop presented to the students of the Environmental Technology Program of Arctic College in Iqaluit, providing information on contaminants in the general environment as well as in caribou, specifically. This workshop is proposed to be offered again in October, 2016.

Communications

A summary of this long-term project was presented to the following: Environmental Technology Program of Arctic College in Iqaluit (Oct 2015); Canadian Ecotoxicity Conference in Saskatoon (Oct 2015); Wood Street High School in Whitehorse (Oct 2015); Yukon Biodiversity Forum in Whitehorse (Nov 2015); NCP Results Workshop in Vancouver (Dec 2015); Dolphin and Union Caribou Management Plan Meeting in Kugluktuk (Jan 2016; via internet). A plain language summary of current results for the Qamanirjuaq caribou was sent to Nunavut stakeholders (in English and Inuktitut) in Nov 2015. This summary was included in the Winter 2016 edition of the newsletter of the

Beverly Qamanirjuaq Caribou Management Board (Caribou News in Brief). Presentations of current results for the Porcupine caribou were made to Chief and Council of the Vuntut Gwitch'in First Nation, students of the Chief Zzeh Gittlit School (Old Crow) and the community of Old Crow in a public meeting in Jan 2016. Synopsis reports will be distributed to all stakeholders.

Two manuscripts are currently being prepared for publication of data from this project. The first will be a comparison of contaminant profiles of various Arctic caribou herds which will incorporate mostly data collected under NCP, but will also include data provided collaboratively by other researchers on caribou from Banks Island NWT, Greenland, Sweden and Svalbard. The second paper will focus on temporal trends of contaminants in the Porcupine caribou and will attempt to interpret temporal changes with environmental drivers.

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 both submitting samples and providing food for their families. Meetings between the PI and local HTOs provide an opportunity for the exchange of traditional and western scientific information that will enhance understanding of contaminants in caribou and facilitate the implementation of this project. In the fall of 2014, meetings with HTOs in the small communities in the Hudson Bay region yielded the Traditional Inuit Knowledge that caribou commonly consume seaweed, which could be a significant source of mercury for Qamanirjuaq caribou. This information has been incorporated into the workplan for this project in the coming year.

Results and Discussion

Results for the seven elements of interest are presented in Table 1. Age was positively correlated with renal Cd and Zn in both the Qamanirjuaq and Beverly caribou. Correlations between certain elements and age are common in ungulates and need to be considered when comparing element concentrations within and among caribou herds (Gamberg et al. 2005).

In the Beverly herd, cows had higher concentrations of renal Cd and Pb than bulls, while in the Qamanirjuaq herd, concentrations of renal As, Cd and Hg were higher in cows than bulls. It is interesting that toxic elements (As, Cd, Pb, Hg) tended to be higher in cows than bulls, likely due to the relatively higher volume of food intake (and hence toxic element intake) by cows due to their smaller size and higher energetic requirements from parturition and lactation (Gamberg 2008). Other non-toxic elements are more likely to be homeostatically controlled and so we do not see a difference between the genders.

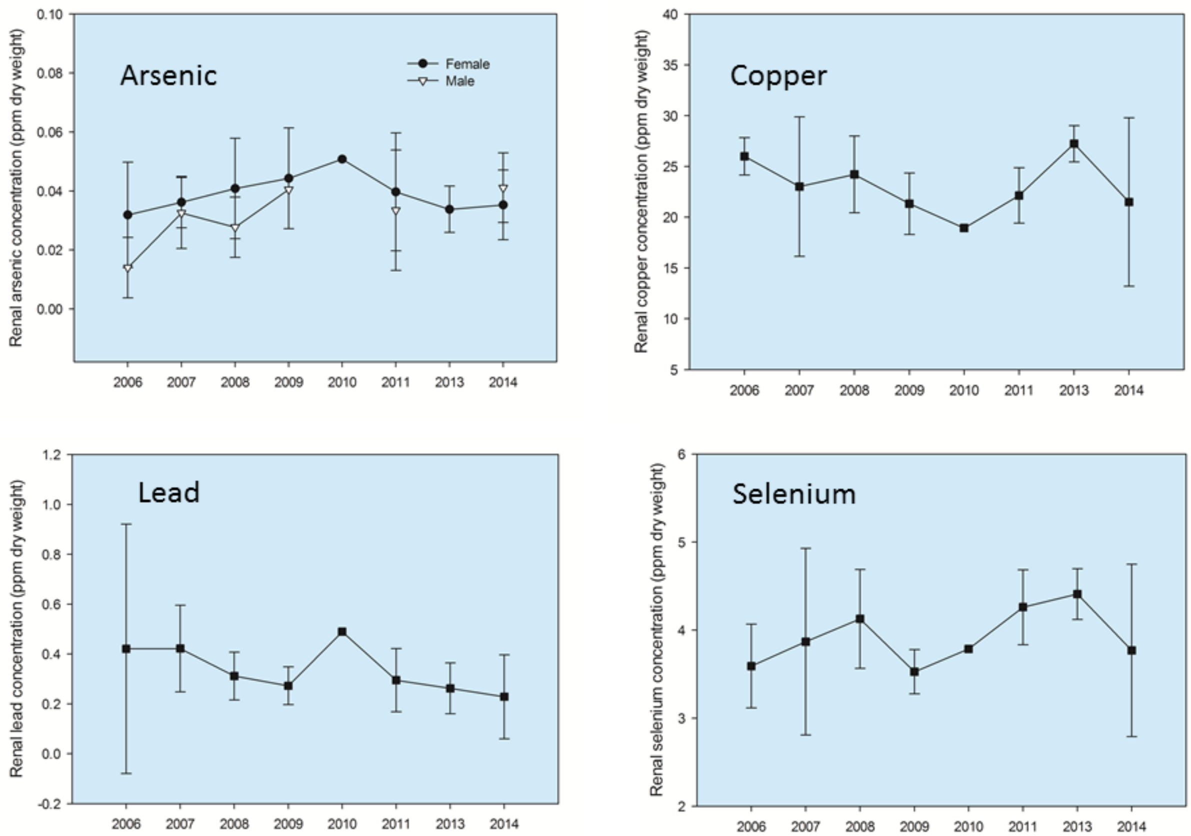
In the Beverly caribou herd, renal As was lower and renal Se was higher in 2013 than in 2008, but with only two years of data, trends cannot be inferred (neither As nor Se was measured in the 1994 and 2000 collections). Although renal Cu and Hg declined over time, both trends were driven by 1994 data. Levels of both elements have not changed since the year 2000. Although a statistical increase in renal Pb was seen in bulls, the 1994 data were all below the detection limit, and there was only one data point from 2008. The remaining data is insufficient to infer a true trend. Similarly, a statistical increase was seen in renal Cd in bulls over time as well as with age. However, with so few data (technically data from 3 years, but only one data point from 2008) it is difficult to infer a true trend. Zn did not change over time. Unfortunately, it is difficult to ascertain any true temporal trends from these data.

Table 1. Renal element concentrations (X + SE; µg·g^{-1} dry weight).

	N	Age	Arsenic	Cadmium	Copper	Lead	Mercury	Selenium	Zinc
Qamanirjuaq caribou herd; Fall-collected									
Females									
2006	7	7.3	0.03 ± 0.007	18.7 ± 5.27	26.3 ± 0.8	0.58 ± 0.31	3.37 ± 0.4	3.6 ± 0.2	104 ± 3.21
2007	10	5.1	0.04 ± 0.003	24 ± 4.96	25.1 ± 2.8	0.44 ± 0.05	5.57 ± 0.7	4.1 ± 0.43	110 ± 9.65
2008	10	8.1	0.04 ± 0.005	29.7 ± 3.72	24.4 ± 1.3	0.36 ± 0.02	4.99 ± 0.5	4 ± 0.21	106 ± 5.056
2009	4	0.5	0.04 ± 0.009	19.8 ± 7.37	21.1 ± 1.7	0.25 ± 0.03	5.32 ± 1.1	3.5 ± 0.14	95 ± 5.64
2010	1		0.05	21.5	18.9	0.49	6.69	3.8	96
2011	17	6.0	0.04 ± 0.005	21 ± 5.96	22 ± 0.7	0.3 ± 0.03	5.04 ± 0.5	4.2 ± 0.09	108 ± 2.634
2013	4	5.5	0.03 ± 0.004	31.1 ± 17.6	27.2 ± 0.9	0.26 ± 0.05	3.96 ± 0.4	4.4 ± 0.14	120 ± 7.916
2014	10	10.0	0.04 ± 0.004	28.6 ± 4.39	19.9 ± 2.1	0.27 ± 0.07	5.45 ± 0.5	3.5 ± 0.32	98 ± 11.02
Males									
2006	14	5.8	0.01 ± 0.003	14 ± 2.37	25.8 ± 0.5	0.34 ± 0.07	2.58 ± 0.2	3.6 ± 0.12	112 ± 3.734
2007	8	4.0	0.03 ± 0.004	11.5 ± 2.9	20.8 ± 0.9	0.39 ± 0.08	4.23 ± 0.6	3.6 ± 0.21	94 ± 3.649
2008	11	5.0	0.03 ± 0.003	16.8 ± 2.8	24.4 ± 1.3	0.27 ± 0.03	3.10 ± 0.5	4.1 ± 0.11	106 ± 2.603
2009	1		0.04	3.84	22.4	0.36	4.72	3.6	90
2011	2	5.5	0.03 ± 0.014	15.3 ± 2.89	22.9 ± 1.3	0.25 ± 0.09	4.77 ± 1.9	4.7 ± 0.47	110 ± 2.63
2014	10	6.9	0.04 ± 0.004	19.2 ± 3.85	23 ± 3.1	0.18 ± 0.02	5.42 ± 0.7	4.1 ± 0.28	100 ± 3.484
Beverly caribou herd; Spring-collected									
Females									
1994	5	6.2		32.9 ± 7.15	23.9 ± 0.5	0.18 ± 0.07	8.16 ± 1.3		116 ± 7.77
2000	20			55.2 ± 9.47	22.8 ± 1.7	0.63 ± 0.09	6.41 ± 0.5		126 ± 9.276
2008	10	6.3	0.06 ± 0.006	34.3 ± 7.3	20.5 ± 0.9	0.31 ± 0.03	5.71 ± 0.5	4.3 ± 0.16	105 ± 2.782
2013	6	7.83	0.04 ± 0.002	47.6 ± 7.66	21.3 ± 0.9	0.21 ± 0.02	5.71 ± 1	5.2 ± 0.22	123 ± 3.907
Males									
1994	5	7.2		29 ± 5.24	25.1 ± 1.2	0.1 ± 0.00	12.36 ± 0.5	5	119 ± 1.37
2008	1	4	0.1	30.8	20.3	0.28	7.22	4.5	105
2013	10	3.6	0.05 ± 0.004	28.2 ± 2.65	20.2 ± 0.5	0.21 ± 0.02	5.55 ± 0.4	4.9 ± 0.13	116 ± 2.786

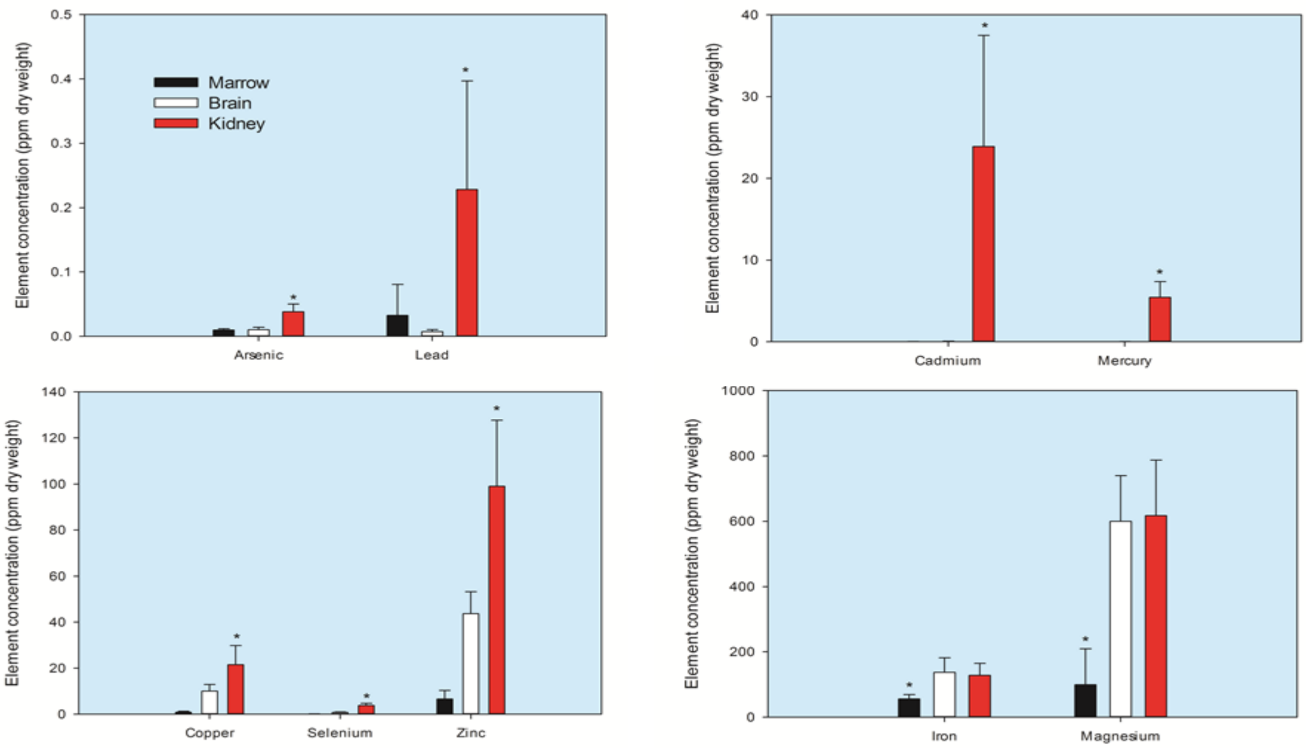
In the Qamanirjuaq caribou, As and Hg increased over time in bulls but there were no changes in cows. This seems to be an artifact of the data set, as there were no males collected in 2013, 2012 or 2010 and only 2 in 2011 and 1 in 2009. In fact As in bulls closely follows that in cows, which is not changing over time (Fig 1). Cd, Hg and Zn did not change over time in this herd while Se increased and Cu and Pb decreased slightly. These changes were slight and likely not of biological significance (Figure 1).

Figure 1. Temporal trends in renal elements in fall-collected Qamanirjuaq caribou. Note that data for Cu, Pb and Se are from both genders combined.



Marrow and brain had less As, Cd, Cu, Pb, Hg, Se and Zn than kidney (Fig. 2). There were no differences among the three tissues in Ca, although two individuals had very high Ca levels in marrow. Brain had similar amounts of Fe and Mg as kidney and both had more than marrow. There were no differences between the sexes in element concentrations in brain or marrow. This confirms that marrow and brain do not have elevated levels of contaminants, particularly when compared with kidneys, and that these tissues remain a healthy traditional food choice.

Figure 2. Element concentrations in marrow, brain and kidney from Qamanirjuaq caribou collected in the fall of 2014.



Levels of most elements measured in the Beverly and Qamanirjuaq caribou herds were not of concern toxicologically, although renal Hg and Cd concentrations may cause some concern for human health depending on the quantity of organs consumed. Yukon Health has advised restricting intake of kidney and liver from Yukon caribou, the recommended maximum varying depending on herd (e.g., a maximum of 32 Porcupine caribou kidneys/year). The health advisory confirms that heavy metals are very low in the meat (muscle) from caribou and this remains a healthy food choice.

Data collected from this program continue to provide baseline data for contaminants in Arctic caribou as well as a valuable tissue archive for legacy and emerging contaminants. The ongoing nature of this program provides security and confidence for northerners using caribou as a food source and acts as an early warning system for wildlife managers. The length and consistency of this program also provides a valuable database for exploring the dynamics of particular contaminants of concern (eg. mercury) within the terrestrial ecosystem. This program will continue to collect and analyze kidney samples from the Porcupine and Qamanirjuaq caribou herds (20 animals from each) as well as two additional herds in the coming fiscal year.

Expected Project Completion Date

This program is ongoing.

Acknowledgements

Many thanks to Yukon Environment staff: Martin Keinzler, Mike Suitor and Jane Harms for providing samples from the Porcupine caribou herd, Mary Vanderkop and Meghan Larivee for laboratory support, and Angela Milani for aging caribou teeth. I would also like to acknowledge the efforts of all hunters who have submitted samples to this program over the years – without them, this work would not be possible. A particular thank you goes to the Arviat Hunters and Trappers Association who assisted with organizing collections this year. Thanks also to Brett Elkin, GNWT for providing samples from the Beverly caribou herd. This project was funded by the Northern Contaminants Program, Indigenous and Northern Affairs Canada and administered by the Yukon Conservation Society.

References

Gamberg M, Braune B, Davey E, Elkin B, Hoekstra PF, Kennedy D, Macdonald C, Muir D, Nirwal A, Wayland M, Zeeb B. 2005. Spatial and temporal trends of contaminants in terrestrial biota from the Canadian Arctic. Sci Total Environ 351/352 :148–164.

Gamberg M. Arctic Caribou and Moose Contaminant Monitoring Program. In Synopsis of Research Conducted under the 2007/2008 Northern Contaminants Program. Indian Affairs and Northern Development. 2008: 108-113.

Community based seawater monitoring for organic contaminants and mercury in the Canadian Arctic

Surveillance communautaire de l'eau de mer en vue d'y trouver des contaminants organiques et du mercure dans l'Arctique canadien

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Abstract

This proposal addresses a knowledge gap that has been identified under the NCP "Blueprint", related to the lack of data on levels and time trends of contaminants in ocean waters. The project started in May 2014 and built on previous work in Barrow Strait near Resolute in 2011 and 2012. Seawater samples were successfully collected in May-June and in August-September 2015 using (1) passive samplers (thin plastic films) deployed for five to six week periods. Collection of smaller (1L) samples a various depths using Niskin samplers was also successful at Barrow Strait and in

Résumé

Ce projet vise à combler une lacune dans les connaissances recensée dans le plan directeur du Programme de lutte contre les contaminants dans le Nord, par rapport au manque de données sur les concentrations et les tendances temporelles des contaminants dans les eaux océaniques. Le projet lancé en mai 2014 s'articule autour des travaux réalisés en 2011 et 2012 dans le détroit de Barrows, près de Resolute. Des échantillons d'eau de mer ont été recueillis avec succès en mai et en juin et en août et en septembre 2015 à l'aide (1) d'échantillonneurs passifs (minces films

Scott Fiord near Clyde River. Analysis of stain resistant (perfluorinated) chemicals has been completed and shows that PFOS has declined to non-detectable levels since the mid-2000s. Mercury concentrations at Barrow Strait (2014-2015) remain unchanged compared to 10 years earlier (2004-05). Brominated flame retardants were also detectable at very low (picogram per liter) concentrations on the passive samplers. Ultimately our goal is to extend the existing information on contaminants in seawater at Resolute so that a time series would be developed. Results for other sites would allow comparison to test the representativeness of Barrow Strait as a sampling site.

plastiques) déployés pendant une période de cinq à six semaines. On a réussi à recueillir des échantillons de plus petit volume (c.-à-d. 1 litre, au moyen d'échantillonneurs Niskin, dans le détroit de Barrow et au fjord Scott près de Clyde River. L'analyse des concentrations en produits chimiques résistant aux taches (perfluorés) a été menée à bien; elle montre que les concentrations de sulfonate de perfluorooctane (SPFO) ont, depuis le milieu des années 2000, diminué jusqu'à n'être plus détectables. Les concentrations de mercure dans le détroit de Barrows (2014-2015) demeurent inchangées par rapport à il y a 10 ans (2004-2005). Des produits ignifuges bromés étaient aussi détectables à de très faibles (picogramme par litre) concentrations sur les échantillonneurs passifs. Notre objectif final consiste à étendre les renseignements existants sur la présence et les concentrations de contaminants dans l'eau de mer à Resolute afin qu'il soit possible d'élaborer une série chronologique. Les résultats obtenus à d'autres sites permettront d'effectuer des comparaisons afin de valider la représentativité du détroit de Barrow en tant que site d'échantillonnage.

Key messages

- Concentrations of selected POPs and mercury were measured in seawater samples from Barrow Strait near Resolute Bay NU
- Very low concentrations of brominated flame retardants were found in seawater using passive samplers (plastic films)
- Phosphorus based flame retardants were detected in seawater for the first time at Resolute
- Concentrations of PFOS are showing a declining trend based on comparisons with sampling in 2005-2008 at the same location

Messages clés

- On a mesuré les concentrations de certains polluants organiques persistants dans les échantillons d'eau de mer prélevés dans le détroit de Barrow situé près de Resolute Bay, au Nunavut.
- On a relevé des concentrations très faibles de produits ignifuges bromés dans les échantillons d'eau de mer que l'on a prélevés à l'aide d'échantillonneurs passifs (minces films plastiques).
- Des produits ignifuges à base de phosphore ont été détectés dans l'eau de mer pour la première fois à Resolute.
- Comparativement aux échantillons recueillis au même site entre 2005 et 2008, on a observé une tendance à la baisse des concentrations de SPFO.

Objectives

1. Sample seawater for hydrophobic legacy and new/emerging organic contaminants using passive methods over the spring/summer season in Barrow Strait/Lancaster Sound and other Arctic locations
2. Compare with high volume "active" water samples collected during the period of May 2015.
3. Collect seawater profiles for perfluorinated alkyl substances (PFAS) and mercury/methyl mercury using Van Dorn or Niskin samplers
4. Combine data accumulated from previous studies in order to establish temporal trends in high central Canadian Arctic seawater

Introduction

There is a relatively large amount of published seawater data for organochlorine pesticides (OCPs) in Arctic Ocean waters (Hung et al. 2013) but information is much more limited for BDEs and alternative flame retardants (AFRs) and perfluorinated alkyl substances (PFASs). Jantunen et al (2015) reported time trends and air–water exchange of organochlorine pesticides (OCPs) and current use pesticides (CUPs) from oceanographic cruises conducted between 1993 and 2013 in the archipelago and eastern Beaufort Sea. This extensive dataset showed that most legacy OCPs had declined significantly in seawater while CUPs (endosulfan, dacthal and chlorpyrifos) had not. Jantunen et al (2015) and Jantunen (2014) reported ng/L concentrations of 6 organophosphorus flame retardants (OPFRs) in samples collected during the same cruises and noted that concentration of OPFRs in Arctic waters were high compared to PBDEs, OCPs and CUPs. Morris et al (2015, 2016) determined CUPs and BFRs in seawater from Barrow Strait, Rae Strait near Gjoa Haven and Cumberland Sound and investigated bioaccumulation in the marine food web. Results showed that CUPs including endosulfan, dacthal, chlorpyrifos, and pentachloronitrobenzene, as well as BFRs including PBDEs, 2,4,6-tribromophenyl allyl ether, 1,2,3,4,5-pentabromobenzene and pentabromotoluene were detectable in the marine food chain with the highest levels in invertebrates and arctic cod. Morris et al (2015) detected dissolved BDE 47 and BDE 99 in the range of 1.0 – 5.0 pg/L in seawater of Barrow Strait during spring melt, about 10 to 100x higher than reported by Möller et al. (2011) .

Organophosphate flame retardants (OPFRs) are another group of AFRs with arctic accumulation potential. Möller et al. (2012) recently reported the first occurrence of OPFRs in the atmosphere over the Arctic Ocean and the North Pacific proving that they undergo long-range atmospheric transport toward the Arctic. Jantunen (2014) reported OPFRs in air samples at up to 400 pg m-3 and OPFRs in the range of 14-36 ng/L, where TCEP >TCPP >TPhP > TDCPP > EHDPP.

Recent papers have provided new data for PFOS and other PFASs in Canadian Arctic seawater and nearby seas (Hung et al. 2013). PFOA, PFHpA and PFHxA were the major PFASs in the waters of the Canadian Archipelago, Beaufort and Chukchi Seas (Benskin et al. 2012). Other shorter chain PFASs, which are degradation products of replacements for long chain (8 or more carbon chains) have not been determined in Canadian Archipelago waters.

The overall effect of ice cover and snow/ice melt on inputs of the hydrophobic organics as well as PFASs, is still not entirely clear, and how current use semi-volatile and less volatile contaminant concentrations are influenced by melt water is relatively unexplored.

Mercury concentrations in Canadian arctic seawater and adjacent seas have been extensively reviewed recently (Chételat et al. 2012, Kirk et al. 2012). Kirk et al. (2012) determined the concentrations of mercury species in relation to depth profiles (0 and up to 660 m) in Lancaster Sound. Total mercury (THg) at the Barrow Strait site declined with depth from 0.45 ng/L at the surface to 0.26 ng/L at 322 m, with monomethyl Hg (MMHg) representing a large portion (35%) of the THg at depth. High proportions of methylated Hg (includes both MMHg and dimethyl Hg (DMHg), a toxic and volatile form of mercury) were found in all deep waters i.e. below 100 m in Lancaster Sound, northern Baffin Bay and Hudson Strait. Time trends for mercury in seawater are not available to our knowledge. However the three sampling years in the mid-2000s (2004, 2005 and 2007) in Barrow Strait represent the start of a time series which this project is building on.

Activities in 2015-2016

Field and laboratory work: Seawater samples were successfully collected in Barrow Strait in May-June (May 7-June 10 under ice) and in August-September (Aug 7-Sept 28 open water) during 2015 using passive polyethylene membrane (PEM) samplers. Collection of smaller (0.5-1L) samples at various depths using Niskin samplers for analysis of total mercury (includes all forms of mercury in a sample) and methyl mercury, OPFRs and per-/polyfluorinated substances (PFASs) was also successful at Barrow Strait (May and August) and in Scott Fiord near Clyde River (September). Planned collection at Nain was delayed due to logistical constraints. A large volume (~300L through XAD resin column/filter system) water sample was collected in Barrow Strait in May 2015 however the pump failed (probably due to freezing) and the exact volume of the sample is unknown. The work at Resolute/Barrow Strait was performed by Peter Amaraulik. Passive samplers were not installed at Cambridge Bay or at Clyde River/Scott fiord due to failure to be delivered by air cargo despite extensive tracking by team members.

Capacity Building: The field work was conducted by Peter Amaraulik and his son Jeffrey. They consulted with the other team members by phone prior to sampling. Peter utilized the laboratory at the Polar Continental Shelf Program base in Resolute to prepare for field work, and to preserve and store samples.

Communications: A summary of project activities during 2015 and preliminary results was prepared for the Resolute Bay HTA in English and Inuktitut.

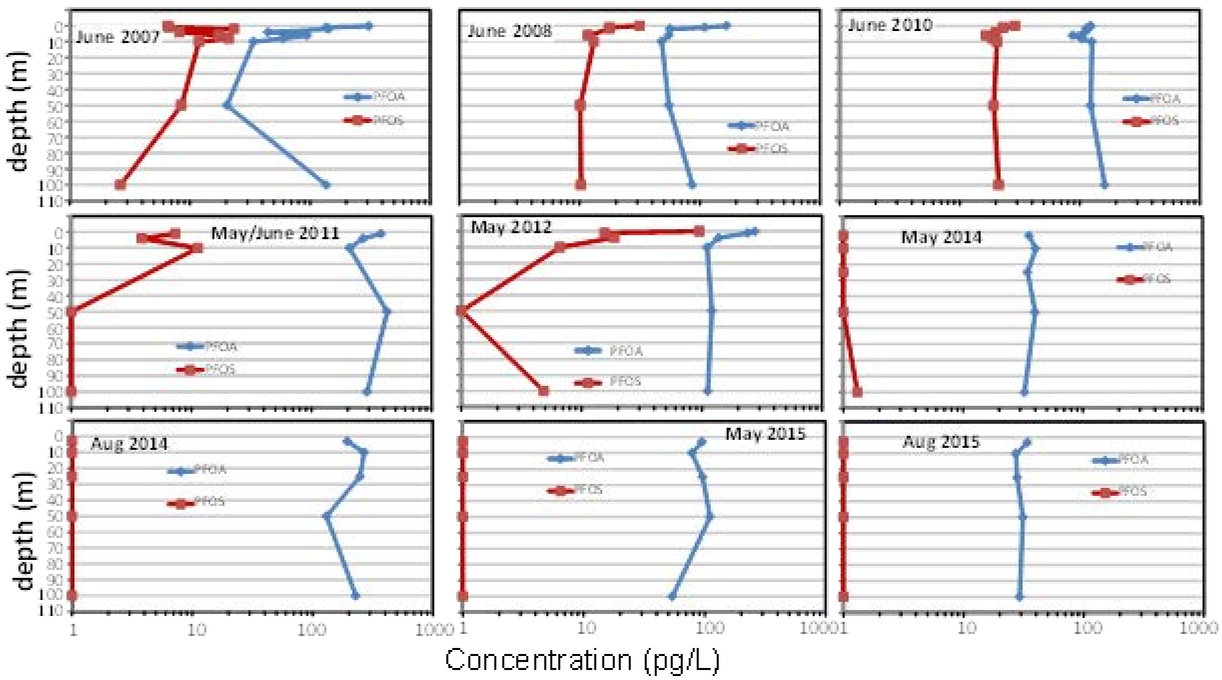
Traditional Knowledge Integration: Although traditional knowledge integration is not formally part of the project the success of the project depends heavily on the community field team's knowledge of the ice and water conditions in the area. The long term trends in ice conditions are of interest to the project and may help explain the results.

Results

PFAS profiles were determined in samples collected in May and compared with previous years (Figure 1). The profiles of PFOA and PFOS are shown because as of 2007 they were the major PFASs in seawater although other perfluorinated carboxylates with C4 to C10 carbon chains were also detected. As of 2014, PFOS has been undetectable in seawater (<5 pg/L). All sampling times and depths are shown so that possible seasonal variation is taken into account. In most cases, the May/June sampling time shows higher concentrations in surface water and samples at 1-2 m depth while this is generally not seen in July or August. We attribute this to snow and ice melt which injects PFASs into the upper ocean. However for 2014 and 2015 the sampling took place under colder conditions where there was no ice melt in May. This may explain the lack of a profile. PFOA concentrations were also higher in August 2014 than in August 2015 for reasons that are not entirely clear. Sea ice persisted all summer in 2014 but Barrow Strait was ice free as of the end of July in 2015, and this may have affected concentrations.

Polybrominated diphenyl ethers (PBDEs) were determined in passive samplers deployed in August-September 2015. Results for the May-June deployment and for XAD resin extracts of seawater collected in May 2015 are pending. PBDE congeners 2, 47 and 99 were detectable

Figure 1. Depth profiles of PFOS and PFOA in seawater from Barrow Strait (2007-2015).



in the PEMs at low pg/L levels (Table 1). Blanks in PEMs were non-detectable for BDE 2 and 99, and ~ 10% of measured BDE-47. Results for 2012 and 2014 deployments, both conducted in May-June under the sea ice, are also shown in Table 1. BDE 47 has been consistently detected each year, however the concentrations in the 2015 samples were higher than in the previous years. It's possible that levels of PBDEs are higher in open water summer conditions compared to under the ice. The shorter deployment time in 2014 (21 days) compared to 2012 and 2015 (40-50 days) may have been insufficient time to achieve detectable level.

PCBs were readily detectable in the August-September 2015 PEMs at pg/L concentrations (Table 1). Concentrations of trichlorobiphenyls (18 and 28; 1.4-1.5 pg/L) were similar to measurements in the early 2000s in Baffin Bay and the Southern Beaufort Sea by Carizzo and Gustafsson (2011) (0.5-0.7 pg/L) who used high volume extraction on polyurethane foam taken during an oceanographic cruise.

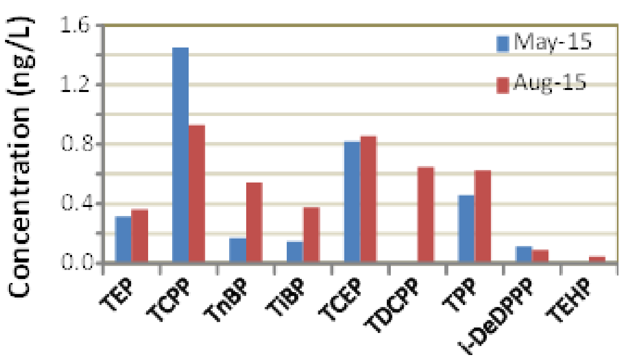
HCBz and α-HCH were also detected in the 2015 samples as well as in 2012 (Table 1). Concentrations of HCBz were similar to the concentrations of the large volume samples reported by Wong et al (2011) for samples collected in Baffin Bay and the Beaufort Sea (5.1-6.4 pg/L). However, α-HCH concentrations determined for the PEMs were much lower than reported by Wong et al (628-1013 pg/L).

Nine OPFRs were detected at low concentrations ranging from <0.01 to 1.5 ng/L in seawater from Barrow Strait (Figure 2). Eleven other OPFRs were determined in the same sample extracts but not detected. The only other OPFR results for the Arctic Ocean are from Jantunen (2014) and Jantunen et al (2015) who reported relatively high levels of total OPFRs (14-36 ng/L) observed from ship-based sampling in the Arctic archipelago. Those concentrations are comparable to measurements in the eastern North Sea (Bollmann et al. 2012). While the concentrations of OPFRs determined in this study are much lower than Jantunen (2014) and Jantunen et al (2015) they are still very much higher than perfluorinated substances or BFRs in seawater.

Table 1. Comparison of PBDE and PCB congener concentrations (pg/L) in passive (PEM) water samplers (Lohmann unpublished data)

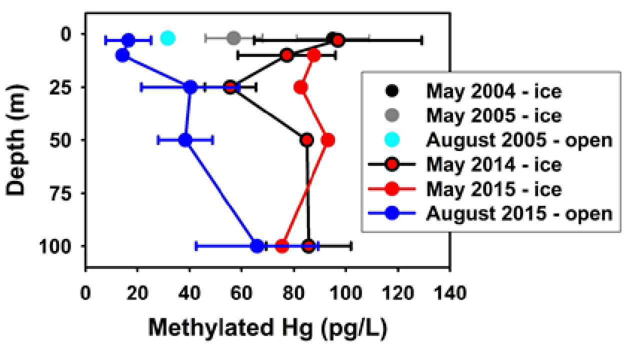
Sampler	PEM	PEM	PEM #1	PEM #2	PEM #1	PEM #2
Time	Apr-May '12	Apr-May '12	May-Jun '14	May-Jun '14	Aug-Sep '15	Aug-Sep '15
BDE-2	0.50	0.45	<0.05	<0.05	0.55	0.61
BDE-8	0.13	0.14	<0.05	<0.05	<0.05	<0.05
BDE-15	0.35	0.3	<0.05	<0.05	<0.05	<0.05
BDE-28	0.24	0.21	<0.05	<0.05	<0.05	<0.05
BDE-49	0.065	0.068	<0.05	<0.05	<0.05	<0.05
BDE-47	0.096	0.096	0.097	0.32	0.45	0.47
BDE-100	0.055	0.057	<0.05	<0.05	<0.05	<0.05
BDE-99	0.15	0.13	<0.05	<0.05	0.51	0.56
BDE-154	0.11	0.11	<0.05	<0.05	<0.05	<0.05
BDE-153	0.14	0.13	<0.05	<0.05	<0.05	<0.05
BDE-183	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
PCB-8	0.96	0.89	0.057	0.14	0.34	0.27
PCB-18	0.18	0.17	<0.1	<0.1	0.77	0.86
PCB-28	0.12	0.12	<0.1	<0.1	0.63	0.65
PCB-52	0.12	0.12	<0.1	<0.1	2.50	2.54
PCB-101	0.04	0.03	<0.1	<0.1	1.12	1.18
PCB-138	0.01	0.02	<0.1	<0.1	0.31	0.31
PCB-153	0.01	0.01	<0.1	<0.1	0.44	0.49
α-HCH	75.9	78.9	na	na	96.9	106
HCBz	9.32	9.20	na	na	4.2	4.4

Figure 2. Surface trends in seawater from Barrow Strait, 3 m depth in May (blue) and August (red) 2015 samples. TBPO, TPrP, TPPO, TXP, DTBPPP, TBDPP, TEEDP, EHDPP, TOTP, T2iPPP, TTBP were <LOD



Under ice concentrations of methylated mercury (contains both methylmercury and dimethyl mercury) in May 2014 and 2015 are shown in Figure 3 and are compared to results from 2004 and 2005. Open water and under ice measurements of methylmercury concentrations in August 2015 were similar to previous results for Barrow Strait and the Canadian arctic archipelago (Kirk et al. 2012). Concentrations of methylated Hg in surface waters during the open water season are lower than those observed under ice in both 2005 and 2015. This seasonal difference is likely due to photo-degradation of monomethyl Hg and volatilization of dimethyl Hg during the open water season (Kirk et al. 2012). Alternatively, higher under ice concentrations of methylated Hg in spring may reflect elevated monomethyl and dimethyl Hg production due to enhanced microbial activity during spring/May algal blooms. Future measurements will include both methylated Hg and monomethyl Hg measurements so that seasonal production and loss mechanisms of monomethyl Hg and dimethyl Hg can be better understood at this site.

Figure 3. Methyl mercury profiles in Barrow Strait (2014-15) and comparison with earlier measurements.



Discussion and Conclusions

The results of the study to date, combined with previous work at Barrow Strait by Morris et al. (2015) illustrate the challenges and opportunities of Arctic seawater monitoring from nearby communities. Using the ice platform, depth profiles for PFASs, OPFRs, and mercury/ methylmercury were relatively easy to obtain from the same sample location as previous years. However, for the less soluble substances such as PBDEs and PCBs much larger volumes are needed and these are best achieved using passive samplers which provide time average concentrations of the dissolved phase. Deployment times in 2015 (35-44 days) seem to have been adequate for PBDEs because they yielded similar concentrations to results in 2012 (50 days) while shorter times in 2014 (21 days) yielded lower concentrations and more non-detects.

Several new results from this study were surprising (1) non-detectable concentrations of PFOS and (2) relatively high concentrations of OPFRs. These results demonstrate that bans on the use of PFOS are having in impact globally and that the Arctic Ocean has a large inventory of OPFRs far larger than for the brominated flame retardants or PCBs. However, method detection limits for OPFRs remain relatively high compared to other compounds, due to laboratory blank issues. Thus further work will be useful to confirm these measurements and understand seasonal and annual variations.

Expected Project Completion Date

An ongoing project is planned in order to develop temporal trend information.

Acknowledgments

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References

Benskin, J. P., D. C. G. Muir, B. F. Scott, C. Spencer, A. O. De Silva, H. Kylin, J. W. Martin, A. Morris, R. Lohmann, G. Tomy, B. Rosenberg, S. Taniyasu and N. Yamashita. 2012. Perfluorinated compounds in the Arctic and Atlantic Oceans. Environ. Sci. Technol. 46(11): 5815-5823.

Bollmann, U. E., A. Möller, Z. Xie, R. Ebinghaus and J. W. Einax. 2012. Occurrence and fate of organophosphorus flame retardants and plasticizers in coastal and marine surface waters. Water Research. 46(2): 531-538.

Carrizo, D. and O. Gustafsson. 2011. Distribution and inventories of polychlorinated biphenyls in the polar mixed layer of seven pan-arctic shelf seas and the interior basins. Environ. Sci. Technol. 45(4): 1420-1427.

Chételat, J., M. Amyot, B. Braune, T. Brown, M. Evans, A. Fisk, A. Gaden, C. Girard, A. Hare, J. Kirk, I. Lehnherr, R. Letcher, L. Loseto, R. Macdonald, B. McMeans, D. Muir, A. Poulain, K. Reimer, K. Sheldon and G. Stern. 2012. Marine Environment. In Chételat, J., B. Braune (eds.), Mercury in Canada's North. Ottawa ON, Aboriginal Affairs and Northern Development Canada, pp. 159-221.

Hung, H., P. Kurt-Karakus, L. Ahrens, T. Bidleman, M. Evans, C. Halsall, T. Harner, L. Jantunen, S. C. Lee, D. Muir, M. Shoeib, G. Stern, E. Sverko, Y. Su, P. Vlahos and H. Xiao (2013). Occurrence and Trends in the Physical Environment. Chapter 3. In D. C. G. Muir, P. Kurt-Karakas and J. E. Stow (eds.), Canadian Arctic Contaminants Assessment Report On Persistent Organic Pollutants - 2013. Ottawa ON: Aboriginal Affairs and Northern Development Canada, pp. 147-272.

Jantunen, L. (2014). Polycyclic Aromatic Compounds, Flame Retardants and Other Persistent organic pollutants in air in the Canadian archipelago. In Synopsis of Research Conducted under the 2013–2014 Northern Contaminants Program. Ottawa ON, Aboriginal Affairs and Northern Development Canada: pp. 329-339.

Jantunen, L. M., A. Gawor, F. Wong, T. F. Bidleman, F. Wania, G. A. Stern, M. Pucko and H. Hung. 2015. Organophosphate Ester Flame Retardants and Plasticizers in the Canadian Arctic. Presented at the Society of Environmental Toxicology and Chemistry, Salt Lake City, UT.

Jantunen, L. M., F. Wong, A. Gawor, H. Kylin, P. A. Helm, G. A. Stern, W. M. J. Strachan, D. A. Burniston and T. F. Bidleman. 2015. 20 Years of Air–Water Gas Exchange Observations for Pesticides in the Western Arctic Ocean. Environ. Sci. Technol. 49 (23): 13844–13852.

Kirk, J. L., I. Lehnherr, M. Andersson, B. M. Braune, L. Chan, A. P. Dastoor, D. Durnford, A. L. Gleason, L. L. Loseto, A. Steffen and V. L. St. Louis. 2012. Mercury in Arctic marine ecosystems: Sources, pathways and exposure. Env. Res. 119: 64-87.

Möller, A., R. Sturm, Z. Xie, M. Cai, J. He and R. Ebinghaus. 2012. Organophosphorus flame retardants and plasticizers in airborne particles over the Northern Pacific and Indian Ocean toward the polar regions: Evidence for global occurrence. Environ. Sci. and Technol. 46(6): 3127-3134.

Möller, A., Z. Xie, M. Cai, G. Zhong, P. Huang, M. Cai, R. Sturm, J. He and R. Ebinghaus (2011). Polybrominated diphenyl ethers vs alternate brominated flame retardants and dechloranes from East Asia to the arctic. Environ. Sci. and Technol. 45(16): 6793-6799.

Morris, A. D., D. C. G. Muir, K. R. S. Solomon, R. J. Letcher, A. T. Fisk, B. McMeans, M. McKinney, C. Teixeira, X. Wang, M. Duric and P. Amarualik (2015). Distribution of organohalogen flame retardants in seawater and trophic transfer in ringed seal (Pusa hispida) food chains from the Canadian arctic. Manuscript in prep.

Morris, A. D., D. C. G. Muir, K. R. S. Solomon, R. J. Letcher, A. T. Fisk, B. McMeans, M. McKinney, C. Teixeira, X. Wang, M. Duric and P. Amarualik (2016). Current use pesticides in the Canadian Arctic marine environment and polar bear-ringed seal food chains. Environ. Toxicol. Chem. In press.

Wong, F., L. M. Jantunen, M. Pućko, T. Papakyriakou, R. M. Staebler, G. A. Stern and T. F. Bidleman. 2011. Air-water exchange of anthropogenic and natural organohalogens on international polar year (IPY) expeditions in the canadian arctic. Environ. Toxicol. Chem. 45(3): 876-881.

Investigation of the toxic effects of mercury in landlocked Arctic Char

Enquête sur les effets toxiques du mercure chez l'omble chevalier dulcicole

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Abstract

In northern Canada and especially Nunavut, mercury (Hg) concentrations can be high in predatory fish, including landlocked arctic char (*Salvelinus alpinus*). An analysis of data from landlocked char in northern Canada and Greenland indicates that 30% of the populations surveyed exceed toxicity thresholds for Hg in fish. In 2015, we collected landlocked char from "NCP focal ecosystem" lakes on Cornwallis Island to build upon our previously funded NCP work aimed at determining if landlocked Arctic char are indeed experiencing toxicity. Collections were conducted in cooperation with the char "core" monitoring project led by Derek Muir. The lakes sampled (Small, North, Amituk) span a gradient of Hg contamination, allowing for the comparison

Résumé

Dans le Nord du Canada et particulièrement au Nunavut, les concentrations de mercure peuvent être élevées chez les poissons prédateurs, y compris chez l'omble chevalier dulcicole (*Salvelinus alpinus*). L'analyse des données sur l'omble chevalier dulcicole du Nord du Canada et du Groenland révèle que les seuils de toxicité pour le mercure sont dépassés chez 30 % des populations étudiées. En 2015, nous avons prélevé des ombles chevaliers dans des lacs d'un « écosystème d'intérêt pour le Programme de lutte contre les contaminants dans le Nord (PLCN) » à l'île Cornwallis afin de renforcer notre travail dans le cadre du PLCN déjà financé visant à déterminer si l'omble chevalier dulcicole subit réellement

of biological endpoints in char with low Hg concentrations to char with high Hg concentrations. Preliminary results suggest that increasing Hg exposure leads to higher levels of lipid peroxidation (measured as thiobarbituric acid reactive substances or TBARS) and lower activities of superoxide dismutase (SOD) in the livers of Arctic char. No such correlation was found for either lipid peroxidation or SOD in Arctic char brains, however. Determinations of glutathione peroxidase (GSH-PX) activities in livers and brains are ongoing, and may explain the observed differences, despite the similar Hg concentrations in the tissues. Our work is novel in that it goes beyond documenting Hg concentrations in fish and will provide critical knowledge concerning the status of fish health.

des effets toxiques. L'échantillonnage a été effectué en collaboration avec l'équipe du projet de surveillance de base de l'omble chevalier, dirigée par Derek Muir. Les résultats obtenus pour les lacs échantillonnés (Small, North, Amituk) indiquent un gradient de contamination par le mercure, permettant la comparaison de paramètres biologiques entre les ombles chevaliers présentant une faible concentration de mercure et ceux présentant une forte concentration de mercure. Les résultats préliminaires laissent entendre qu'une exposition accrue au mercure mène à des niveaux plus élevés de la peroxydation lipidique (mesurée sous forme de substances réactives à l'acide thiobarbiturique ou TBARS) et à une baisse des activités de la superoxyde dismutase (SOD) dans le foie de l'omble chevalier. Aucune corrélation de la sorte ne s'est révélée pour la peroxydation lipidique ou la SOD dans le cerveau de l'omble chevalier, cependant. Les déterminations des activités du glutathion peroxydase (GSH-PX) dans le foie et le cerveau se poursuivent, et peuvent expliquer les différences observées, malgré les concentrations de mercure similaires dans les tissus. Notre travail est novateur en ce sens qu'il fait plus que documenter les concentrations de mercure chez les poissons et apportera des connaissances essentielles en ce qui concerne l'état de santé des poissons.

Key messages

- We sampled landlocked arctic char from "NCP focal ecosystem" lakes (Small, North, Amituk) near Resolute Bay, Nunavut, to determine effects of mercury on the char.
- Mercury concentrations in char from all of the lakes, except Small Lake, exceed values known from laboratory studies to cause effects on fish.
- Preliminary results suggest that increasing Hg exposure leads to higher levels of lipid peroxidation (measured as TBARS) and lower activities of superoxide dismutase (SOD) in the livers of Arctic char, but not in the brains.

Messages clés

- Nous avons effectué l'échantillonnage d'ombles chevaliers dulcicoles dans des lacs d'un « écosystème d'intérêt pour le Programme de lutte contre les contaminants dans le Nord (PLCN) » (Small, North, Amituk) près de Resolute Bay, au Nunavut, afin de déterminer les effets du mercure sur cette espèce.
- Les concentrations de mercure mesurées dans les ombles chevaliers de tous les lacs, sauf le lac Small, dépassent les valeurs connues entraînant des effets sur les poissons, d'après des études en laboratoire.

- Les résultats préliminaires laissent entendre qu'une exposition accrue au mercure mène à des niveaux plus élevés de la peroxydation lipidique (mesurée sous forme de TBARS) et à une baisse des activités de la superoxyde dismutase (SOD) dans le foie de l'omble chevalier, mais pas dans leur cerveau.

Objectives

The **long-term objective** of this research project is to better understand whether ecologically relevant exposures to Hg are impacting the health of Arctic fish and wildlife by focusing here on Arctic char as a sentinel species. This research will provide critical knowledge concerning the status of fish health in the North and help towards the derivation of species-specific protective guidelines. In doing so, the research goes beyond simply documenting Hg concentrations in fish. Further, "the health of northern Aboriginal populations is intimately linked to the health of Arctic ecosystems" (NCP Blueprint 2015/16), and thus the proposed work has direct relevance to human and ecosystem health.

Here, the **short-term goals** objectives are:

1. Study the toxicity of Hg in landlocked char from "NCP focal ecosystem lakes" on Cornwallis Island.
2. Provide this information to the Hamlet of Resolute Bay (Qausuittuq) and to the Niqiit Avatittinni Committee (Nunavut) on a timely basis.

Introduction

Hg is a priority contaminant for NCP because concentrations of Hg in edible muscle of predatory fish from lakes in northern Canada usually exceed the Health Canada guideline of 0.2 ppm wet wt. for subsistence consumption (Lockhart et al., 2005). Anthropogenic emissions of Hg to the atmosphere, notably fossil fuel combustion, have led to increased atmospheric Hg deposition in even the most remote ecosystems, e.g., the Canadian High Arctic (Muir et al., 2009). In aquatic ecosystems, microbes transform Hg into methylmercury (MeHg) which biomagnifies in food webs, resulting in high concentrations in predatory fish.

A growing body of evidence suggests that Hg concentrations regularly found in predatory fish, in e.g., northern Canada, may also be toxic to the fish. Recent analyses of the available data for Hg toxicity in fish by our team and others indicate that effects are likely to occur at whole-body concentrations (wet wt.) exceeding 0.2 ppm (Beckvar et al., 2005), or 0.3 ppm (Dillon et al., 2010; Sandheinrich and Wiener, 2011). Equivalent concentrations in edible muscle are 0.33 and 0.5 ppm wet wt., respectively, and dietary mercury concentrations effects can occur starting at 0.2 ppm (Depew et al., 2012). According to these thresholds, 12 of 40 (or 30% of) landlocked char populations sampled in northern Canada and Greenland are at risk for Hg toxicity.

To investigate the effects of Hg on landlocked char, we collected char in 2011 and 2012 from four "NCP focal ecosystem" lakes (Small, 9-mile, North, Amituk) near Resolute Bay, NU. Collections were conducted in cooperation with the char "core" monitoring project led by Co-Investigator Muir and a separate NCP-sponsored food web project led by Kidd and Muir (e.g., see new findings published by (Lescord et al., 2015). The four lakes sampled span a gradient of Hg contamination, allowing for the comparison of biological endpoints in char with low Hg concentrations to char with high Hg concentrations.

We tested a series of hypotheses concerning Hg-exposure associated changes in char reproduction, liver anatomy and physiology, and general health. Furthermore, moving beyond simple measures of total Hg (Hg_T) in bulk liver tissue, we measured Hg in operationally defined subcellular fractions to determine how it was distributed in Arctic char liver cells and if differences existed in the subcellular distribution of Hg for Small and Amituk Lake char (comparison of low and high-Hg char).

Total Hg was distributed similarly in liver cells of char from both lakes; sensitive compartments contributed to 73 and 61% of the contributions in fish livers from Small and Amituk. This suggests, that at low (Small Lake) and high (Amituk Lake) concentration **Hg is not effectively detoxified** in the livers of these fish (Barst et al., 2016). Data indicate possible subtle effects on reproduction, as the number of eggs per ripe female (relative fecundity) was lower at high Hg concentration. Effects on the liver were more pronounced – at low Hg concentration hepatic tissue was pathologically normal, but at high Hg concentration (Amituk char) inflammation, in the form of hepatic fibrosis, was prevalent (Barst et al., 2016).

Our results from 2011 and 2012 suggest an inefficient detoxification of MeHg in the livers of Arctic char. As a result, we hypothesized that a significant fraction of MeHg may be reaching downstream target organs, i.e. the brain, to elicit toxic effects. Accordingly, in 2015 with funds from NCP we sampled brains of Arctic char from "NCP focal ecosystem" lakes, to test a suite of hypotheses related to Hg neurotoxicity. The results reported below are preliminary, but are the first steps in going beyond documenting Hg concentrations to provide knowledge concerning the status of fish health.

Activities in 2015-2016

To investigate the hepato- and neurotoxic effects of Hg on landlocked char, we collected char (n=53) in 2015 from three "NCP focal ecosystem" lakes (Small, North, Amituk) near Resolute Bay, NU. Similar to previous years, collections were conducted in cooperation with the char "core" monitoring project led by Muir, and thus Arctic char tissues were divided between projects. The lakes sampled are known to span a gradient of Hg contamination, allowing for the comparison of biological endpoints in char with low Hg concentrations to char with high Hg concentrations. Arctic char livers and brains were collected for Hg determination and for analyses of endpoints relating to oxidative stress.

Capacity Building: The project depends on the help of local people from Resolute Bay. Since 2005, Debbie Iqaluk has worked on the char "core" monitoring project, enabling the collection of char from all targeted lakes on Cornwallis Island in a wide range of weather and ice conditions. In the field, Debbie has helped to collect, dissect, and assess the health of char. She previously received training in dissection and anatomical examination of fish (from Köck). Muir has been involved with Iqaluit College and thus students are familiar with our work.

Communications: Muir has presented reports and posters to the Resolute Bay Hamlet office and the HTA for the current char projects in the lakes of Cornwallis Island (i.e., the "core" monitoring project led by Muir and this project).

Preliminary results of this project have also been presented at the 2015 NCP results workshop (Vancouver BC).

Traditional Knowledge Integration: Fish collection relies on the knowledge and experience of local people working on the project, as has been true for the char "core" monitoring project for a number of years. Also, traditional knowledge is used for initial assessment of fish health (e.g., Does that fish look healthy? Is that an unusual parasite burden? Is that a normal looking liver?).

Results

Summary data for fish size, condition, and Hg content in muscle, liver, and brain are given in **Table 1.** Total Hg concentrations in selected brain regions (telencephalon, optic lobe, cerebellum) are presented in **Table 2.**

The progress and preliminary results relating to biological endpoints are given in **Table 3.** Individuals from each lake except Small exceed the toxicity threshold of Beckvar et al. (2005; 0.3 ppm wet wt. in muscle), but only char from Amituk exceed the threshold of Dillon et al. (2010; 0.5 ppm wet wt. in muscle). Liver HgT concentrations were one to two times higher than muscle Hg concentrations – to a maximum of 3.1 ppm wet wt in an individual from Amituk Lake. Similar to previous years' results, MeHg was the predominant form of Hg in Arctic char liver (mean = 92 %). To determine if HgT concentrations were similar among brain regions (telencephalon, optic lobe, cerebellum), select brain regions from eight individuals were dissected and regions were analyzed separately (Table 2). Total Hg concentrations were similar among Arctic char brain regions, and therefore the remaining optic lobes were used for analysis of oxidative stress biomarkers, while the other regions were used for Hg determinations. Brain HgT concentrations followed a similar trend as muscle and liver concentrations across the three lakes (Small < North < Amituk). Brain and liver HgT were significantly correlated, and the ratio between the two approached unity with increasing liver Hg. Similar to livers, the majority of Hg measured in the brains of Arctic char was in the form of MeHg (mean= 88 %).

The results of analyses for oxidative stress biomarkers are presented in **Figure 1**. To date, TBARS have been measured in the livers of all of the Arctic char collected in 2015. TBARS in brain and SOD activities in both tissues have been analyzed in a subset. Data indicate increasing levels of lipid peroxidation with increasing HgT concentration in char livers. No such correlation was found for TBARS and HgT in the brains of Arctic char, however the activity of SOD was negatively correlated with HgT in livers, but not in brain.

Table 1. Summary data for fork length, mass, and concentrations of total mercury (HgT) in edible muscle, liver, and brain of char collected from "NCP focal ecosystem" lakes.

				HgT (ppm wet wt) muscle			HgT (ppm wet wt) liver			HgT (ppm wet wt) brain		
Lake	n	Fork Length (cm)	Mass (g)	mean	SE	range	mean	SE	range	mean	SE	range
Small	15	34.9	309.3	0.14	0.014	0.07 - 0.27	0.28	0.037	0.09 - 0.62	0.17	0.019	0.08 - 0.35
North	18	36.6	428.7	0.23	0.017	0.12 - 0.39	0.44	0.042	0.23 - 0.75	0.23	0.030	0.13 - 0.54
Amituk	20	42.1	628.9	1.23	0.058	0.79 - 1.7	1.98	0.107	1.07 - 3.08	1.43	0.102	0.85 - 2.51

Table 2. Total mercury concentrations (ppm wet weight) in brain regions (telencephalon, optic lobe, and cerebellum) of landlocked Arctic char collected from “NCP focal ecosystem” lakes.

Lake/Fish ID	Brain region	HgT (ppm wet weight)	Mean	Standard deviation
Small Lake #1	Optic lobe	0.091	0.09	0.002
	Cerebellum	0.088		
	Telencephalon	0.090		
Small Lake #2	Optic lobe	0.165	0.17	0.014
	Cerebellum	0.191		
	Telencephalon	0.168		
Small Lake #3	Optic lobe	0.059	0.06	0.004
	Cerebellum	0.055		
	Telencephalon	0.052		
North Lake #1	Optic lobe	0.172	0.18	0.013
	Cerebellum	0.189		
	Telencephalon	0.165		
North Lake #2	Optic lobe	0.207	0.21	0.006
	Cerebellum	0.215		
North Lake #3	Optic lobe	0.524	0.53	0.010
	Cerebellum	0.538		
Amituk Lake #1	Optic lobe	1.708	1.66	0.071
	Cerebellum	1.608		
Amituk Lake #2	Optic lobe	2.365	2.29	0.103
	Cerebellum	2.219		

Figure 1. Oxidative stress biomarkers in the livers (filled circles) and brains (non-filled circles) of landlocked arctic char from "NCP focal ecosystem" lakes in relation to total mercury (ppm wet weight). Upper panels are scatterplots of total mercury versus thiobarbituric acid reactive substances (TBARS) in liver (A) and brain (C). Lower panels are scatterplots of total mercury versus superoxide dismutase (SOD) activity in liver (B) and brain (D).

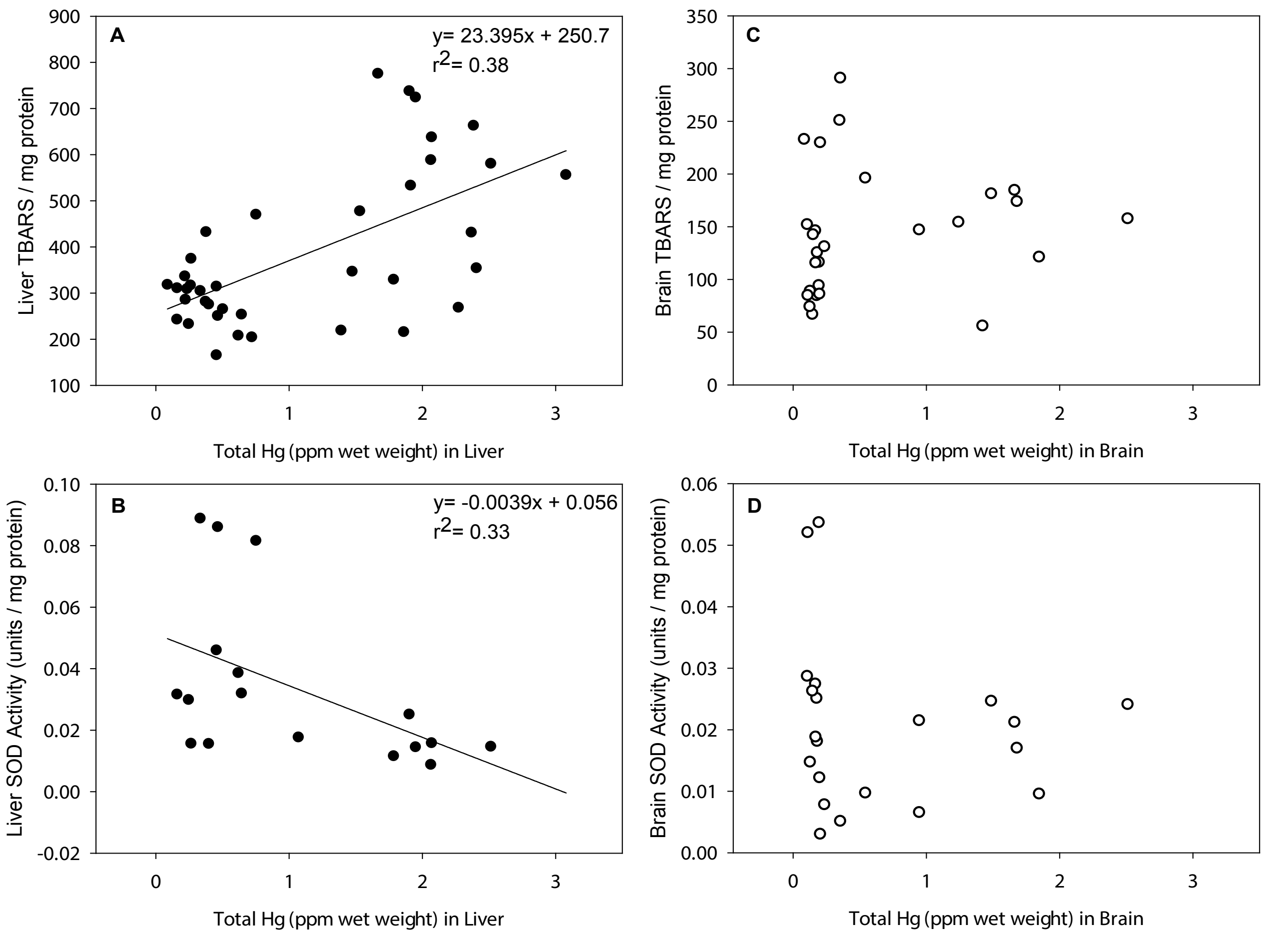

Table 3. Progress and preliminary results for hypotheses designed to determine hepato- and neurotoxicity of Hg in landlocked Arctic char.

Aims and hypotheses	Analysis	Preliminary result/ Notes
Aim 1. Measure mercury in Arctic char tissues		
H1: Concentrations of HgT will be positively correlated among liver, brain, and muscle	Completed	Concentrations of HgT are correlated among liver, brain, and muscle. Liver HgT: Brain HgT approaches unity with increasing liver HgT.
H2: MeHg will comprise the majority of HgT in livers	Completed	MeHg comprises the majority of liver HgT (mean = 92 %).
H3: MeHg will comprise the majority of HgT in brains	Completed	MeHg comprises the majority of brain HgT (mean = 88 %).
Aim 2. Characterize mercury distribution within Arctic char brain		
H1: In brains, inorganic Hg and MeHg will be primarily bound to cytosolic metal binding proteins	In progress	Planned activities for 2016 include sampling of Arctic char to increase mass for subcellular work.
H2: Above threshold concentrations MeHg and inorganic Hg will spill over into metal sensitive subcellular pools	In progress	Planned activities for 2016 include sampling of Arctic char to increase mass for subcellular work.
H3: there will be no differences across the brain regions.	Completed	Concentrations of HgT are similar across brain regions (telencephalon, optic lobe, cerebellum).
Aim 3. Assess associations between mercury exposures and effects-based measures		
H1: The relative weight of the brain will decrease with increasing concentrations of inorganic Hg and MeHg	Completed	Brain weights are not correlated with Hg concentrations.
H2: oxidative stress biomarkers (SOD, GSH-Px, TBARS) will significantly correlate with brain Hg levels	In progress	Brain SOD activities and TBARS level are not correlated with HgT in optic lobes. Liver SOD decrease with increasing HgT. Liver TBARS levels are positively correlated with HgT. Future analysis of GSH-Px may explain observed differences between tissues.
H3: receptor levels of dopamine and GABA will negatively relate to brain Hg concentrations	In progress	Planned activities for 2016 include sampling of Arctic char to increase mass for receptor work.
H4: Pathologies will be positively correlated with inorganic Hg and MeHg in brain.	In progress	Histological analysis planned for June 2016.

Discussion and Conclusions

Our NCP-funded work from 2011 and 2012 suggests that landlocked Arctic char from "NCP focal ecosystem" lakes are not effectively detoxifying MeHg in their livers. Since MeHg is the predominate form of Hg in char livers there is no indication of a conversion of MeHg to inorganic Hg via demethylation. Furthermore, Hg is largely found in sensitive subcellular pools of Arctic char liver from both high- and low-Hg lakes, demonstrating a lack of activation of defence mechanisms (Barst et al., 2016). This apparent lack of detoxification led us to hypothesize that a significant fraction of Hg may exit the liver in the bloodstream and circulate to sensitive downstream target organs such as the brain. This appears to be substantiated by our most recent work, which shows that the ratio of HgT in liver to brain approaches unity as concentrations of Hg increase in char tissues. As MeHg is able to easily cross the blood brain barrier, a lack of detoxification in the liver likely facilitates MeHg's entry into the brain.

Relative to other organisms, fish have elevated levels of polyunsaturated fatty acids (PUFAs), potentially making them more sensitive to lipid peroxidation (Di Giulio and Hinton, 2008). The analysis of TBARS is a widely accepted indicator of lipid peroxidation (Berntssen et al., 2003). The positive correlation between liver HgT concentration and TBARS suggests that Hg plays a role in the production of lipid peroxides in Arctic char livers. The negative correlation with SOD activity and HgT in char liver is consistent with higher levels of TBARS in this organ. Together these measures indicate that with higher Hg exposure the redox defence system in the livers of Arctic char may be affected. Future analysis of GSH-Px, a selenium-dependent enzyme and important player in redox defence, may provide additional support for this claim. The lack of correlation between HgT and TBARS in the brains of Arctic char was surprising given the similar concentrations of Hg in liver and brains of char with the highest Hg concentrations (Amituk Lake). A study by Berntssen et al. (2003), reported decreased activities of SOD and GSH-Px in the brains of juvenile Atlantic salmon (Salmo salar) fed diets enriched with MeHg. The authors also noted increased lipid peroxidative products (measured as TBARS) in brains of fish fed the highest dose of MeHg. Mean Hg concentrations in brains of arctic char from Amituk Lake exceed those reported by Berntssen et al. (2003). It is possible that juvenile fish, like those used by Berntssen et al. (2003) are more susceptible to MeHg toxicity than adult fish (as is often the case for other species). Nevertheless, the lack of correlation between HgT in brain and TBARS suggests that Hg levels are not sufficient enough to cause lipid peroxidation. Once again, the future analysis of GSH-Px may provide an explanation as to why Hg and both SOD activity and TBARS are not correlated – GSH-Px activity may be elevated in char brains with high Hg concentration, thus compensating for the lack of change in TBARS and SOD. Finally, although Hg concentrations were near equivalent in liver and brains of Amituk char, differences in PUFA levels between the two tissues may result in differences in how these organs are affected by Hg.

As outlined in Table 2, we have several hypotheses which are currently being tested, will be addressed shortly, or would benefit from additional sample mass for analysis. The latter include hypotheses related to the subcellular distribution of Hg and receptor levels of dopamine and GABA. The assessment of the subcellular distribution of Hg in Arctic char tissues is novel to our NCP-funded work and provides useful information about exposure, beyond bulk tissue analysis. PI-Basu's lab has published dozens of studies in fish (e.g., perch, zebrafish, goldfish) and fish-eating wildlife (e.g., polar bears, narwhals, pilot whales, mink, otters, loons, eagles) to show that MeHg exposure can disrupt brain neurochemistry (e.g., neurotransmitter systems including GABA and dopamine), particularly in systems that control reproduction and animal behavior (reviewed by Basu 2015). As recent literature reviews by our project team and others (Crump and Trudeau, 2009; Scheuhammer et al., 2007; Tan et al., 2009; Basu and Janz, 2014) point to reproduction as the biological process most susceptible to Hg toxicity, further investigation of how the aforementioned receptors relate to Hg exposure in landlocked Arctic char is warranted.

Expected Project Completion Date

July 2016

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References

Barst, B.D., Rosabal, M., Campbell, P.G., Muir, D.G., Wang, X., Köck, G., Drevnick, P.E., 2016. Subcellular distribution of trace elements and liver histology of landlocked Arctic char (Salvelinus alpinus) sampled along a mercury contamination gradient. Environmental Pollution 212, 574-583.

Basu, N. 2015. Applications and Implications of Neurochemical Biomarkers in Environmental Toxicology. Environmental Toxicology and Chemistry. 34: 22-29.

Basu, N., Janz, D. 2014. Organometal(loid)s. Organic Chemical Toxicology of Fishes. 33: 141-194.

Beckvar, N., Dillon, T.M., Read, L.B., 2005. Approaches for linking whole-body fish tissue residues of mercury or DDT to biological effects thresholds. Environmental Toxicology and Chemistry 24, 2094-2105.

Berntssen, M., Aatland, A., Handy, R., 2003. Chronic dietary mercury exposure causes oxidative stress, brain lesions, and altered behaviour in Atlantic salmon (Salmo salar) parr. Aquatic Toxicology 65, 55-72.

Crump, K., Trudeau, V., 2009. Mercury induced reproductive impairment in fish. Environmental Toxicology and Chemistry 28, 895-907.

Depew, D.C., Basu, N., Burgess, N.M., Campbell, L.M., Devlin, E.W., Drevnick, P.E., Hammerschmidt, C.R., Murphy, C.A., Sandheinrich, M.B., Wiener, J.G., 2012. Toxicity of dietary methylmercury to fish: Derivation of ecologically meaningful threshold concentrations. Environmental Toxicology and Chemistry 31, 1536-1547.

Di Giulio, R.T., Hinton, D.E., 2008. The toxicology of fishes. CRC.

Dillon, T., Beckvar, N., Kern, J., 2010. Residue-based mercury dose–response in fish: An analysis using lethality-equivalent test endpoints. Environmental Toxicology and Chemistry 29, 2559-2565.

Lescord, G.L., Kidd, K.A., Kirk, J.L., O'Driscoll, N.J., Wang, X., Muir, D.C., 2015. Factors affecting biotic mercury concentrations and biomagnification through lake food webs in the Canadian high Arctic. Science of the Total Environment 509, 195-205.

Lockhart, W., Stern, G., Low, G., Hendzel, M., Boila, G., Roach, P., Evans, M., Billeck, B., DeLaronde, J., Friesen, S., 2005. A history of total mercury in edible muscle of fish from lakes in northern Canada. Science of the Total Environment 351, 427-463.

Muir, D., Wang, X., Yang, F., Nguyen, N., Jackson, T., Evans, M., Douglas, M., Kock, G., Lamoureux, S., Pienitz, R., 2009. Spatial trends and historical deposition of mercury in eastern and northern Canada inferred from lake sediment cores. Environmental Science & Technology 43, 4802-4809.

Sandheinrich, M., Wiener, J., 2011. Methylmercury in freshwater fish: recent advances in assessing toxicity of environmentally relevant exposures. Environmental Contaminants in Biota: Interpreting Tissue Concentrations 2, 169-190.

Scheuhammer, A.M., Meyer, M.W., Sandheinrich, M.B., Murray, M.W., 2007. Effects of environmental methylmercury on the health of wild birds, mammals, and fish. AMBIO: A Journal of the Human Environment 36, 12-19.

Tan, S.W., Meiller, J.C., Mahaffey, K.R., 2009. The endocrine effects of mercury in humans and wildlife. Critical Reviews in Toxicology 39, 228-269.

Spatial variation in Canadian Arctic prey fish communities and contaminant levels: Assessment of candidate POPs, selenium and fatty acids

Variation spatiale des communautés de poissons-proies et des concentrations de contaminants dans l'Arctique canadien : Évaluation des polluants organiques persistants, du sélénium et des acides gras candidats

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Abstract

This project assesses contaminant and nutrient levels in small marine fish and invertebrates near coastal Nunavut communities in the low, mid-, and high Arctic ecosystems. Samples were obtained in 2012 and 2014 through community collections in Arviat and Resolute Bay and during a trawl conducted in Clyde River in 2013. Samples included arctic cod, sculpin, Northern shrimp, amphipods and a few other fish species, including increasingly present sub-Arctic fishes, capelin and sandlance. Levels of legacy (PCBs, organochlorine pesticides, total and methylmercury) and newer (flame

Résumé

Ce projet évalue les niveaux de contaminants et de nutriments dans les petits poissons et invertébrés marins et près des collectivités côtières du Nunavut dans les écosystèmes du BasArctique, du centre de l'Arctique et de l'Extrême-arctique. On a obtenu des échantillons en 2012 et en 2014 au moyen de collectes communautaires à Arviat et à Resolute Bay et pendant un relevé au chalut effectué à Clyde River en 2013. Les échantillons comportaient des morues polaires, des chabots, des crevettes nordiques, des amphipodes et quelques autres espèces de poisson, dont

retardants, short-chain chlorinated paraffins, polychlorinated naphthalenes) contaminants, as well as nutrients (selenium, lipid and essential fatty acids), were measured and compared among species and regions. Variation in levels of mercury, PCBs and organochlorines were low among regions, while flame retardants were very low to not detectable in all regions. Subsequent comparisons among species indicated that sculpin and Northern shrimp showed the highest mercury, PCB and organochlorine levels. While methylmercury was the predominant form of mercury (≥ 83%), total mercury levels were generally low and selenium:mercury molar ratios were high. Arctic cod showed higher mercury levels than capelin and sand lance, but similar or slightly lower levels of PCBs and most organochlorines relative to these sub-Arctic fishes. If important sources of community food, such as Arctic char and ringed seals, feed on sub-Arctic fishes instead of Arctic cod, this change in diet will likely have limited influence on Hg, PCB and organochlorine levels and no influence on levels of selenium in community foods. Detailed analysis of this inter-specific variation is currently underway for short-chain chlorinated paraffin and polychlorinated naphthalene contaminants as well as for essential fatty acid as additional nutrients.

les poissons subarctiques de plus en plus présents, le capelan et le lançon. Les niveaux de contaminants anciens (BPC, pesticides organochlorés, mercure total et méthylmercure) et nouveaux (produits ignifuges, paraffines chlorées à chaîne courte, naphtalènes polychlorés), ainsi que de nutriments (sélénium, lipides et acides gras essentiels), ont été mesurés et comparés entre les espèces et les régions. La variation dans les niveaux de mercure, de BPC et d'organochlorés était faible dans les régions, tandis que les niveaux des produits ignifuges étaient très faibles, voire indétectables dans toutes les régions. Les comparaisons subséquentes entre les espèces ont indiqué que le chabot et la crevette nordique affichaient les niveaux de mercure, de BPC et d'organochlorés les plus élevés. Même si le méthylmercure était la principale forme de mercure (supérieure ou égale à 83 %), les concentrations de mercure total étaient généralement faibles et les rapports molaires sélénium:mercure étaient élevés. La morue polaire affichait des niveaux de mercure plus élevés que le capelan et le lançon, mais des niveaux semblables ou légèrement plus faibles de BPC et de la plupart des organochlorés par rapport à ces poissons subarctiques. Si des sources importantes d'aliments communautaires, tels que l'omble chevalier et les phoques annelés, se nourrissent de poissons subarctiques au lieu de morues polaires, ce changement alimentaire aura probablement une influence limitée sur les niveaux de mercure, de BPC et d'organochlorés et aucune influence sur les niveaux de sélénium dans les aliments communautaires. Une analyse détaillée de cette variation intraspécifique est en cours pour les contaminants que sont les paraffines chlorées à chaîne courte et les naphtalènes polychlorés, ainsi que pour les acides gras essentiels comme nutriments additionnels.

Key messages

- Legacy contaminant levels were similar for a given species collected in low, mid- and high eastern Canadian Arctic regions. For example, sculpin (Cottidae) collected near Arviat, Clyde River and Resolute Bay showed no significant differences in tissue PCB and organochlorine concentrations.
- Among species, Northern shrimp and sculpin showed the highest levels of contaminants, including total mercury, methylmercury, PCBs, and organochlorine pesticides.
- Levels of newer flame retardant contaminants, including polybrominated diphenyl ethers, pentabromoethylbenzene, hexabromobenzene and Dechlorane Plus, were low to not detectable in all species and regions.
- While methylmercury was the predominant form of mercury in all samples, total mercury levels were generally low and selenium:mercury molar ratios were high.
- Sub-Arctic capelin and sand lance had similar or lower levels of mercury, but similar or higher levels of PCBs and organochlorines, relative to Arctic cod. Therefore, the levels of these contaminants in community foods, such as Arctic char, ringed seal and beluga whale, might only be slightly influenced if community foods eat these sub-Arctic fish instead of Arctic cod.

Messages clés

- Les niveaux de contaminants anciens étaient semblables pour une espèce donnée recueillie dans les régions du Bas-Arctique, du centre de l'Arctique et de l'Extrême-Arctique canadien. Par exemple, des chabots (*Cottidae*) prélevés à proximité d'Arviat, de Clyde River et de Resolute Bay n'ont montré aucune différence notable pour ce qui est des concentrations de BPC et d'organochlorés dans les tissus.
- Parmi les espèces, la crevette nordique et le chabot affichaient les niveaux les plus élevés de contaminants, dont le mercure total, le méthylmercure, les BPC et les pesticides organochlorés.
- Les concentrations de produits ignifuges contaminants nouveaux, dont les polybromodiphényléthers, le pentabromoéthylbenzène, l'hexabromobenzène et le Déchlorane Plus étaient de faibles à indétectables chez toutes les espèces et dans toutes les régions.
- Même si le méthylmercure était la principale forme de mercure dans tous les échantillons, les concentrations de mercure total étaient généralement faibles et les rapports molaires sélénium:mercure étaient élevés.
- Le capelan et le lançon subarctiques affichaient des niveaux de mercure similaires ou plus faibles, mais des niveaux de BPC et d'organochlorés similaires ou plus élevés, comparativement à la morue polaire. Par conséquent, les niveaux de ces contaminants dans les aliments communautaires, tels que l'omble chevalier, le phoque annelé et le béluga, pourraient seulement subir une légère influence si les aliments communautaires mangent ces poissons subarctiques au lieu de la morue polaire.

Objectives

- Measure levels of legacy and emerging persistent organic pollutants in marine forage fish and invertebrates in low, mid, and high Arctic communities.
- Measure levels of nutrients, including selenium, lipids and essential fatty acids in these marine prey species.
- Provide feedback to the participating communities of Arviat, Clyde River and Resolute Bay on the levels of these contaminants and nutrients among species and regions.

Introduction

Arctic marine ecosystems are changing in response to rapid warming and loss of sea ice (Post et al. 2013). Reported ecological responses include the northward range expansion of sub-Arctic and temperate marine species (Wassmann et al. 2011). Marine forage fish communities, in particular, have shifted from Arctic to sub-Arctic species in regions of the low to mid-Canadian Arctic. Arctic cod (Boreogadus saida), a keystone species within Arctic marine ecosystems (Craig et al. 1982), is becoming less common, while sub-Arctic capelin (Mallotus villosus), sandlance (Ammodytidae) and/or herring (Clupea harengus) are now more common (Gaston et al. 2003; Gaston et al. 2009; Provencher et al. 2012).

Arctic and sub-Arctic forage fish species may show variation in contaminant levels as a function of trophic position, habitat use, migration, lipid content, body size or diet (Borgå et al. 2004). Significant differences in the levels of PCBs, organochlorine (OC) pesticides, polybrominated diphenyl ethers (PBDEs), polyfluoroalkyl substances (PFASs) and total mercury (THg) were found in discarded forage fish at a thick-billed murre (Uria lomvia) colony from a single location in the low eastern Canadian Arctic (Braune et al. 2014). These discarded fishes included Arctic cod, capelin, sandlance and several benthic species. To assess the nutritional consequences of changing forage fish communities for key NCP monitoring species, comprehensive spatial and temporal comparisons of contaminant and nutrient levels among the Arctic and sub-Arctic forage species are necessary.

In this project, we worked with local fishers and Hunters and Trappers Organizations (HTOs) to carry out extensive sampling of forage species in multiple 'focal' marine ecosystems in Nunavut. We reported on THg levels in this dataset and used carbon and nitrogen isotope ratios to explore factors contributing to THg variation among species. Here, we report on results for methylmercury (MeHg), PCBs, OCs, and newer and emerging flame retardants including PBDEs, pentabromoethylbenzene (PBEB), hexabromobenzene (HBBz) and Dechlorane Plus (DP), and for the micronutrient, selenium (Se). We are also currently analyzing extracts for several candidate persistent organic pollutants (POPs), including short-chain chlorinated paraffins (SCCPs) and polychlorinated naphthalenes (PCNs), and for essential fatty acids as additional nutrients. Overall, our findings will provide knowledge as to how spatial variation in climate-associated ecological changes may modulate spatial variation in contaminant accumulation in key NCP monitoring species, such as ringed seal. In addition, through concomitant analysis of essential fatty acids and Se, we will put contaminant results in a broader context of the overall nutritional value of a changing forage base. This knowledge will lead to a better understanding of the implications of this forage base shift on the health of fish-feeding organisms regularly harvested in Arctic communities.

Activities in 2015-2016

Sample collections

A total of 128 whole forage fish and pools of invertebrates were sampled in previous years in Arviat, Clyde River, and Resolute Bay, NU. All sampling was completed and samples shipped to the laboratory by the Fall 2014, with other samples collected in 2012-2013 as well. To augment sample collections, we worked again this year with the Arviat HTO Secretary Manager, Hilda Panigoniak, to try to collect Arctic cod in this region. Project team member, Nigel Hussey, also worked with the Clyde River HTO to try to collect capelin. Already processed samples used in the various analyses are now being archived in the McKinney Lab at -80°C with backup power and wired temperature monitors.

Laboratory analysis

Last year (2014-2015), we completed analysis of THg (Center for Environmental Sciences and Engineering, University of Connecticut), carbon and nitrogen stable isotope ratios (Fisk Lab, University of Windsor) and DNA barcoding (Canadian Center for DNA Barcoding, University of Guelph). This year (2015-2016), MeHg (Center for Environmental Sciences and Engineering, University of Connecticut), 40 PCB congeners and 19 OC pesticides (Organics Analysis Laboratory, University of Windsor), 19 PBDE congeners, syn- and anti-DP, HBBz and PBEB flame retardants (Tomy Lab, University of Manitoba), and Se (Center for Environmental Sciences and Engineering, University of Connecticut) analyses were performed. The organic contaminant extracts have been shipped to Ed Sverko's Lab (NLET, EC Burlington), where SCCP and PCN analysis on extracts from Arviat samples is currently underway. A suite of 70 fatty acids is also currently being analyzed (McKinney Lab, University of Connecticut).

Capacity Building

As mentioned previously, on-going work this year to augment the sample collections was coordinated with and again led by the HTOs. During our meeting with the Arviat HTO last year, back-and-forth discussions occurred regarding the forage fish community composition in the region, the timing of collections and community fishing activities. Again this year, we shipped sampling kits, instructions and a cooler to the Arviat HTO. HTO Secretary Manager Panigoniak made a number of attempts to fish them through the ice. Similar connections were made through team member Hussey in an effect to have community collections of capelin in Clyde River.

Communications

To coordinate collection of additional samples, PI McKinney communicated regularly with the Arviat HTO, and team member Hussey coordinated with the Clyde River HTO. Results from this year were communicated to all three communities through a one-page Visual Summary and a single-paragraph Plain-Language Summary, which were translated into Inuktitut and approved in advance by the Nunavut Environmental Contaminants Committee (NECC). In addition to the Visual Summaries having been sent to each HTO, we are exploring the possibility of posting them on community Facebook pages. Team member Sara Pedro visited the community of Arviat in April 2016. During the visit, she gave 3 presentations (including slides translated into Inuktitut) at John Arnalukjuak High School, 1 presentation at the Nunavut Arctic College Campus, and a presentation to Arviat HTO board members. At the 2015 NCP Results Workshop, a poster presentation was made on the results of the project. Furthermore, oral presentations were used to communicate results at a number of conferences (see NCP Performance Indicators).

Traditional Knowledge Integration

TK was used in the original and on-going sample collection efforts. Local community members led the sample collections in Arviat and Resolute Bay, and TK from the Nunavut Coastal Resource Inventories (NCRI) and/or local fishers informed the selection of forage species to target in each community. During this and last year's visits to Arviat, discussions with the HTO board members included recent local observations of forage fish communities, as well as the types of fish that local fishers consider important for future monitoring (such as Arctic char).

Results

THg, MeHg and Se

All 124 fish and four invertebrate pools were analyzed for THg concentrations last year (Figure 1, top panel), as published in the NCP 2014-2015 Synopsis Report (NCP 2015). This year, MeHg and Se concentrations were also determined (Table 1). The proportion of MeHg to THg was high, with a minimum of 83% (Resolute Bay amphipods), indicating that THg concentrations were a reasonable proxy for MeHg concentrations in this study. Thus, we subsequently examined THg concentrations. Concentrations were generally similar for a given species collected in two or more regions, whereas concentrations varied among species. Concentrations of THg were highest in sculpin and Northern shrimp and lowest in amphipods. The intermediate levels of THg found in Arctic cod were similar to those found in sand lance, but higher than those found in capelin ($p < 0.05$). In contrast to THg concentrations, the range of Se concentrations across all species and locations was small (0.29-1.32 µg g-1 ww). The Se:Hg molar ratio exceeded 1 in all species and locations, with a minimum ratio of 6.9 found in Northern shrimp from Clyde River.

Figure 1. Arithmetic mean (±SE) wet weight total mercury (THg; top panel) and lipid weight ΣPCB (middle panel) and ΣOC pesticide (bottom panel) concentrations among marine forage fish and invertebrates species collected in Nunavut from 2012-2014. Significant differences among species are represented by different letters.

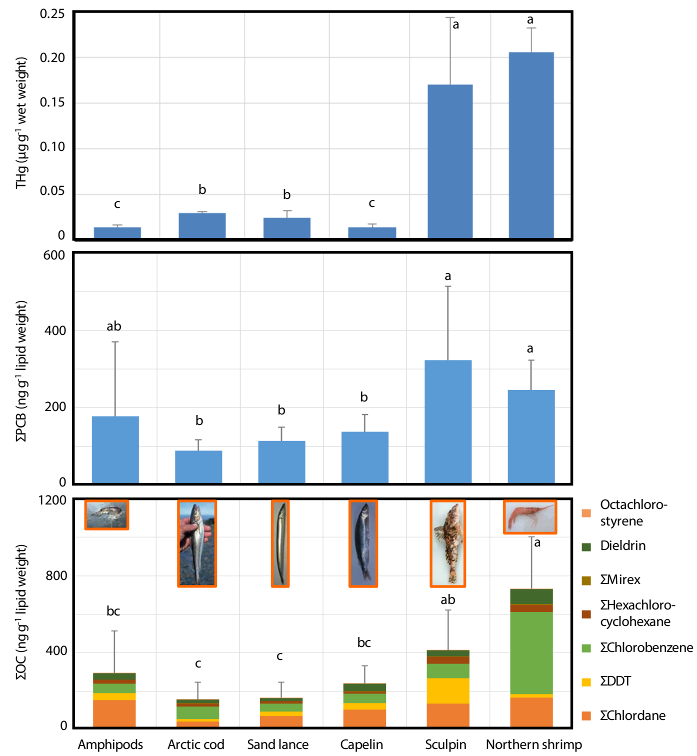

Table 1. Arithmetic mean (±SE) wet weight (ww) total mercury (THg) concentrations, proportions of methylmercury (MeHg) to THg, selenium (Se) concentrations, and Se:Hg molar ratios in marine forage fish and invertebrates collected in 3 Nunavut communities in 2012-2014.

Species	N	Length (mm)	THg (µg g^{-1} ww)	MeHg (%)	Se (µg g^{-1} ww)	Se:Hg molar ratio
Arctic cod						
Clyde River	20	142 ± 8	0.032 ± 0.002	103 ± 2	0.43 ± 0.01	37 ± 3
Resolute Bay	20	148 ± 3	0.029 ± 0.001	115 ± 3	0.56 ± 0.02	53 ± 4
Sculpin						
Arviat	10	196 ± 10	0.130 ± 0.019	98 ± 5	0.58 ± 0.03	15 ± 3
Clyde River	10	127 ± 8	0.273 ± 0.030	93 ± 3	0.69 ± 0.08	7.9 ± 1.5
Resolute Bay	10	148 ± 9	0.108 ± 0.014	105 ± 4	0.52 ± 0.01	14 ± 2
Capelin						
Arviat	11	104 ± 3	0.014 ± 0.001	91 ± 3	0.50 ± 0.02	96 ± 5
Sandlance						
Arviat	13	96 ± 3	0.025 ± 0.002	89 ± 4	1.15 ± 0.16	122 ± 15
Northern shrimp						
Clyde River	10	N/A	0.206 ± 0.008	98 ± 3	0.55 ± 0.02	6.9 ± 0.4
Amphipods						
Arviat	1*	N/A	0.018	107	1.00	141
Clyde River	1*	N/A	0.015	138	1.20	209
Resolute Bay	2*	N/A	0.012	83	1.32	291
Greenland cod						
Arviat	10	305 ± 21	0.142 ± 0.028	96 ± 4	0.41 ± 0.02	9.8 ± 1.6
Cisco						
Arviat	5	352 ± 8	0.096 ± 0.020	119 ± 7	0.31 ± 0.03	10.3 ± 2.3
Goiter blacksmelt						
Clyde River	4	108 ± 10	0.014 ± 0.002	145 ± 12	0.29 ± 0.03	55 ± 4

*Number of pools

PCBs and OC Pesticides

Due to the small mass of some samples, some individuals of the same species and sampling location were pooled to achieve a mass of ~2.5g for analysis of all pooled and individual samples. Some congeners and compounds were detected within each contaminant group, such that ΣPCB, ΣCHL, ΣDDT, ΣClBz, ΣHCH were reportable in all 90 of these pooled/individual samples (Figure 1, middle and bottom panels). Similar to THg, ΣPCB and ΣOC concentrations were generally not significantly different within species among the three regions for species sampled in more than one region (Arctic cod, amphipods, sculpin). As well, ΣPCB and ΣOC concentrations among species tended to be highest in Northern shrimp and sculpin. In contrast to THg, though, amphipods showed intermediate ΣPCB and ΣOC levels and Arctic cod, capelin and sand lance were found to have the lowest levels. Concentrations of ΣPCB and ΣOC did not differ in sand lance and capelin relative to Arctic cod. However, concentrations of some specific groups of OCs, like Σchlordane and ΣDDT, were significantly higher ($p < 0.05$) in capelin (but not in sand lance) than in Arctic cod.

PBDE, HBBz, PBEB, and DP

Levels of PBDEs (including BDE209), HBBz, PBEB, and DP isomers were usually low or below the detection limits in the forage fish and amphipods (Table 2). The only flame retardant contaminant detected in more than 70% of individuals in any species was ΣPBDE. In this case, mean concentrations of ΣPBDE were in the low ng g^{-1} lipid weight range for capelin and Greenland cod, but the detection rate was <70% for all other species. PBEB was detected in one sculpin and one Greenland cod, both from Arviat, but not in any other samples. HBBz and DP were not detected in any samples at any location.

SCCPs and PCNs

To evaluate the possibility of SCCPs and PCNs as contaminants in these forage species, an analysis of these compounds is currently underway in a subset of 24 of the organic contaminant extracts of samples from Arviat only.

Fatty Acids

An extensive suite of 70 fatty acids commonly detected in marine species, including essential fatty acids, is currently being evaluated in prepared lipid extracts of all fish and invertebrate samples from all three communities.

Discussion and Conclusions

For most contaminants monitored, there appeared to be limited variation in concentrations for individual species sampled in more than one of the regions representing the low, mid and high eastern Canadian Arctic. On the other hand, the detected contaminants (Hg, PCBs, OCs, PBDEs) showed significant variation among species. Northern shrimp and sculpin showed the highest levels of THg, MeHg, PCB, and OCs. Substantially higher levels of THg and MeHg were also found in sculpin than in capelin, but not in Northern shrimp, sampled in West Greenland in 2003-2004 (Rigét et al. 2007). Conversely, in northern Hudson Bay samples from 2007-2009, capelin and sculpin were found to have lower THg levels than Arctic cod (Braune et al. 2014). We found that levels of newer flame retardant contaminants were

Table 2. Arithmetic mean (min, max) lipid weight (lw) concentrations of Σ-polybrominated diphenyl ether (ΣPBDE), pentabromoethylbenzene (PBEB), hexabromobenzene (HBBz) and ΣDechlorane Plus (ΣDP) in marine forage fish and invertebrates collected in three Nunavut communities in 2012-2014.

Species	N	ΣPBDE (ng g-1 lw)	PBEB (ng g-1 lw)	HBBz (ng g-1 lw)	ΣDP (ng g-1 lw)
Arctic cod	28	ND (0.00, 63.6)	ND	ND	ND
Capelin	6	12.9 (0.0,17.4)	ND	ND	ND
Sand lance	4	ND (0-30.6)	ND	ND	ND
Amphipod	4	ND (0.0,303)	ND	ND	ND
Sculpin	24	ND (0.0,329)	ND (0.0,4.5)	ND	ND
Northern shrimp	6	ND	ND	ND	ND
Greenland cod	10	39.7 (1.5, 188)	ND (0.0,5.3)	ND	ND
Cisco	5	ND (0.0, 11.1)	ND	ND	ND
Goiter blacksmelt	3	ND	ND	ND	ND

*Total number of samples analyzed as pools and individuals low to not detectable in all species and regions, reasonably similar to the results for PBDEs in the northern Hudson Bay study (Braune et al. 2014). The authors noted that fish size may be a confounding factor in these prey fish studies. Our data on fish length, as well as nitrogen and carbon stable isotope ratios, will be used to further evaluate factors influencing contaminant variation among species.

Unlike for contaminants, concentrations of Se showed little variation among species. This finding is consistent with homeostatic regulation of Se concentrations, given that it is an essential micronutrient (Burger and Gochfeld 2011). Here, we found that Se:Hg molar ratios were high (≥6.9). It has been suggested that the molar ratio of Se:Hg may be more important in assessing Hg risks than Hg concentrations alone, as mercury is an irreversible inhibitor of selenoenzymes (Ralston and Raymond 2010).

At least in this study, Hg levels were somewhat lower in sub-Artic capelin and sand lance relative to Arctic cod, while organic contaminants generally showed the reverse pattern. Overall, these results suggested that consuming sub-Arctic fish instead of Arctic cod may only have a small influence on Hg, PCB and OC levels in important community foods, such as Arctic char, ringed seal and beluga whale.

Expected Project Completion Date

All THg, MeHg, PCB, OC, flame retardant and Se analyses are complete. We are currently processing the previously prepared extracts for SCCPs and PCNs, and the samples for fatty acids. Results of these analyses are expected in the summer of 2016. A draft of the manuscript from the 2014-2015 project is complete and is expected to be submitted in the summer of 2016, while the results of the 2015-2016 project are expected to be submitted as a manuscript in early 2017. Additional evaluation of the implications of these findings for contaminant and nutrient levels in the meat and blubber of ringed seals, an important traditional food, is planned for 2016-2017. All additional aspects of this project will be available once Sara Pedro completes her PhD, expected in May 2018.

Project website

Further research on the impacts of changing ecological interactions on contaminant exposures in Arctic marine species, including this NCP project, can be located at mckinneylab.weebly.com.

Acknowledgments

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References

Borgå, K., A.T. Fisk, P.F. Hoekstra and D.C.G. Muir. 2004. Biological and chemical factors of importance in the bioaccumulation and trophic transfer of persistent organochlorine contaminants in arctic marine food webs. Environ Toxicol Chem. 23: 2367-2385.

Braune, B.M., A.J. Gaston, K.H. Elliott, J.F. Provencher, K.J. Woo, M. Chambellant, S.H. Ferguson and R.J. Letcher. 2014. Organohalogen contaminants and total mercury in forage fish preyed upon by thick-billed murres in northern Hudson Bay. Mar Pollut Bull. 78: 258-266.

Burger, J. and M. Gochfeld. 2011. Mercury and selenium levels in 19 species of saltwater fish from New Jersey as a function of species, size, and season. Sci Total Environ. 409: 1418-1429.

Craig, P.C., W.B. Griffiths, L. Haldorson and H. Mcelderry. 1982. Ecological studies of arctic cod (Boreogadus saida) in Beaufort Sea coastal waters, Alaska. Can J Fish Aquat Sci. 39: 395-406.

Gaston, A.J., D.F. Bertram, A.W. Boyne, J.W. Chardine, G. Davoren, A.W. Diamond, A. Hedd, W.A. Montevecchi, J.M. Hipfner, M.J. Lemon, M.L. Mallory, J.F. Rail and G.J. Robertson. 2009. Changes in Canadian seabird populations and ecology since 1970 in relation to changes in oceanography and food webs. Environ Rev. 17: 267-286.

Gaston, A.J., K. Woo and J.M. Hipfner. 2003. Trends in forage fish populations in Northern Hudson Bay since 1981, as determined from the diet of nestling thick-billed murres Uria lomvia. Arctic. 56: 227-233.

NCP. 2015. Synopsis of Research conducted under the 2014–2015 Northern Contaminants Program. Ottawa: Aboriginal Affairs and Northern Development Canada. pp. 1-479.

Post, E., U.S. Bhatt, C.M. Bitz, J.F. Brodie, T.L. Fulton, M. Hebblewhite, J. Kerby, S.J. Kutz, I. Stirling and D.A. Walker. 2013. Ecological consequences of sea-ice decline. Science. 341: 519-524.

Provencher, J.F., A.J. Gaston, P.D. O'Hara and H.G. Gilchrist. 2012. Seabird diet indicates changing Arctic marine communities in eastern Canada. Mar Ecol Prog Ser. 454: 171-182.

Ralston, N.V.C. and L.J. Raymond. 2010. Dietary selenium's protective effects against methylmercury toxicity. Toxicology. 278: 112-123.

Rigét, F.F., P. Moller, R. Dietz, T.G. Nielsen, G. Asmund, J. Strand, M.M. Larsen and K.A. Hobson. 2007. Transfer of mercury in the marine food web of West Greenland. J Environ Monit. 9: 877-883.

Wassmann, P., C.M. Duarte, S. Agusti and M.K. Sejr. 2011. Footprints of climate change in the Arctic marine ecosystem. Global Change Biol. 17: 1235-1249.

Metal loading and retention in Arctic tundra lakes during spring runoff

Charge et rétention des métaux dans les lacs de la toundra arctique durant le ruissellement printanier

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Abstract

Detailed hydrologic and hydrochemical sampling was conducted over the 2014 and 2015 spring snowmelt periods at a small lake near Iqaluit, NU to quantify and track snow and snowmelt trace metal burdens and downstream fluxes. Concentrations of total and methylmercury in snowpack and snowmelt were consistent with other sub-Arctic and Arctic field studies and demonstrate the important role of snow and snow hydrology in coupling atmospheric sources of mercury to surface waters. Differences in snow accumulation between years and/or other chemical and physical processes operating on the snowpack likely contributed to the large between-year differences in observed concentrations and enrichment of THg in melt water exiting the snowpack. Natural hydrologic tracers, including electrical conductivity and $\delta^{18}O$, were also used

Résumé

On a procédé à des échantillonnages hydrochimiques et hydrologiques détaillés au cours des périodes de fonte des neiges aux printemps 2014 et 2015 sur un petit lac près d'Iqaluit, au Nunavut, afin de quantifier et de suivre les charges de métaux traces dans la neige et la fonte des neiges ainsi que les flux en aval. Les concentrations de mercure total et de méthylmercure dans le manteau neigeux et la fonte des neiges étaient conformes à celles observées dans d'autres études sur le terrain en région arctique et subarctique et démontrent le rôle important de la neige et de l'hydrologie de la neige quand vient le temps d'associer les sources atmosphériques de mercure aux eaux de surface. Les différences entre les accumulations de neige d'une année à l'autre ou d'autres processus chimiques et physiques actifs sur le manteau neigeux ont probablement contribué

to help understand sources of water in inflowing and outflowing streams of the study lake and point to substantial mixing of snowmelt water with ground or soil water in the catchment prior to entering the lake, but limited mixing between streamflow and lake water prior to discharging from the lake.

aux grandes différences entre les années dans les concentrations observées de mercure total (HgT) et l'enrichissement en mercure total dans l'eau de fonte qui sort du manteau neigeux. Des traceurs hydrologiques naturels, y compris la conductivité électrique et $\delta^{18}O$, ont également été utilisés pour aider à comprendre les sources d'eau des cours d'eau entrant et sortant du lac à l'étude et pour signaler le mélange important de l'eau provenant de la fonte des neiges avec l'eau du sol ou du sous-sol dans le bassin versant avant d'entrer dans le lac, mais le mélange limité entre l'écoulement fluvial et l'eau du lac avant qu'ils se déversent du lac.

Key messages

- Snowmelt was found to be an important source of total and methyl-mercury in surface waters at an intensively sampled lake and its watershed near Iqaluit, NU;
- Observed total mercury concentrations in meltwater leaving the snowpack were found to be higher than concentrations in bulk samples taken from the snowpack prior to the onset of melt, particularly in 2015;
- Snowmelt isotopic and chemical composition was highly augmented by ground and soil water during the spring freshet periods in 2014 and 2015 but did not appreciably impact meltwater concentrations of total and methyl-mercury concentrations leaving the snowpack, whereas lead (Pb) concentrations were low in streamflow relative to snowmelt and cadmium (Cd) concentrations were largely below analytical detection limits;
- Lake outflow concentrations of total mercury, methyl-mercury and lead largely tracked inputs from inflowing streams, consistent with the dynamics of natural conservative tracers (specific conductivity and $\delta^{18}O$

Messages clés

- La fonte des neiges s'est avérée une source importante de mercure total et de méthylmercure dans les eaux de surface dans un lac ayant fait l'objet d'échantillonnages intensifs et son bassin versant près d'Iqaluit (Nunavut).
- Il a été déterminé que les concentrations de mercure total observées dans l'eau de fonte quittant le manteau neigeux étaient plus élevées que celles mesurées dans les échantillons en vrac prélevés dans le manteau neigeux avant le début de la fonte, en particulier en 2015.
- La composition isotopique et chimique de l'eau de fonte des neiges a été augmentée par l'eau du sol et du sous-sol au cours des périodes de crue printanière de 2014 et de 2015, mais n'a pas eu d'impact notable sur les concentrations de mercure total et de méthylmercure dans l'eau de fonte qui quittent le manteau neigeux, tandis que les concentrations de plomb (Pb) étaient faibles dans l'écoulement fluvial par rapport à la fonte des neiges, et les concentrations de cadmium (Cd) étaient largement inférieures aux limites de détection analytiques.
- Les concentrations de mercure total, de méthylmercure et de plomb au point de déversement du lac correspondaient en grande partie aux apports des cours d'eau qui s'y jettent, ce qui est conforme aux dynamiques des traceurs conservateurs naturels (conductivité spécifique et $\delta^{18}O$).

Objectives

The overarching objectives of this two year project study were: (1) to accurately quantify snowmelt fluxes of trace metals to surface waters in the vicinity of Iqaluit, NU, including comprehensive water and metal mass balances in one nearby lake; and (2) to continue developing local capacity for hydrometric, geochemical and limnological sampling and monitoring techniques required to monitor snowmelt fluxes of trace metals from terrestrial to aquatic environments, in collaboration with Nunavut Research Institute (NRI) and Nunavut Arctic College (NAC), Iqaluit, NU. The information collected will contribute to the important, long-term objective of understanding and predicting how climate and ecosystem changes will affect trace metal fate, transport and food web bioaccumulation in Arctic freshwaters. The specific scientific questions of the project are:

1. What are trace metal loads in snowpack just prior to spring snowmelt in Arctic tundra watersheds on Southern Baffin Island and what fraction of this load is mobilized by the spring freshet?

2. What is the fate of trace metal loads from the melting snowpack? What fraction of the snowmelt trace metal load to the watershed is lost through (a) terrestrial watershed sequestration; and/or (b) export via the lake outflow?

3. How much do snowmelt loads contribute to total metal loads in Arctic tundra lakes during the annual water year (onset of spring melt to fall freeze-up)

Introduction

Long-range atmospheric transport deposits toxic metals in Arctic ecosystems that are far away from the industrial activities and high-density urban centres that emit them. Three particularly toxic metals, mercury (Hg), lead (Pb), and cadmium (Cd,) are regulated by international treaties such as the Heavy Metals Protocol of the United Nations Economic Commission for Europe and the Minamata Convention on Mercury of the United Nations Environment Programme. In conjunction with those efforts, the Northern Contaminants Program (NCP) conducts research and monitoring to track the impact and fate of these metals in the environment and the effectiveness of international treaties.

Considerable information has been collected over the last 15 years on Hg concentrations in Arctic snow because of the discovery of atmospheric mercury depletion events (AMDEs) (e.g., Dommergue et al. 2005, St. Louis et al. 2005, 2007; Poulain et al. 2007, Steffen et al. 2008). This research has shown that snowpack is a significant reservoir of Hg from atmospheric deposition. Methyl-mercury (MeHg) can also be found at relatively high concentrations in Arctic snow (St. Louis et al. 2005, 2007). Much less information is available on Arctic snowpack loads for other metals such as Pb and Cd, which remain metals of international concern. More recent research has also focused on the release of Hg from glacier melt (Zdanowicz et al. 2013) including to Lake Hazen (St. Louis et al. 2013). However, due to the logistical challenges and high frequency of sampling required, snowmelt delivery of metals to aquatic ecosystems has not been adequately studied. In the Canadian Arctic, it remains unclear how snowmelt contributes to the metal loads of lakes because of a lack of hydrological measurements taken in tandem with metal concentrations. Detailed, labour-intensive measurements of snowpack storage, snowmelt inputs and lake water storage and losses are required. Research on snowmelt contributions of trace metals to Arctic lakes is fundamental to understanding of how climate change will impact the delivery of metals to aquatic food webs. The present study was initiated to help fill these scientific and monitoring gaps and contribute to an improved understanding of the role of snow hydrology in trace metal dynamics in Arctic tundra lakes and their watersheds.

Activities in 2015-2016

Field Activities

The 2015 spring field season began in April and built on knowledge and experience from the 2014 season. We conducted spring snow surveys throughout the "Lake 1" watershed near Iqaluit NU, with considerable help from NAC ETP students (see Capacity Building). Depth integrated snow samples were collected for mercury and other trace metal analysis using clean sampling protocols. We took frequent top (just below ice layer) and bottom (~3 m above sediments) water column samples from Lake 1 while the lake ice was still traversable. Stream inflow and outflow sampling was conducted every two to three days over the peak melt period. All metal analysis was conducted on unfiltered water samples and we also measured major ions and total organic carbon (DOC) in filtered samples (0.5 µm retention pre-combusted GFF) and other basic water quality parameters (pH, specific conductance or SpC, temperature). All samples were also analyzed for stable isotopes of water (d^{18}O and deuterium). Level logging pressure transducers were deployed to gauge lake and stream levels. The main inflowing and outflowing streams were gauged for discharge on water sampling days and that data will be used in conjunction water level data for establishing stage-discharge relations and hydrographs for the melt period.

Capacity Building

The project has presented many opportunities for collaboration with NAC ETP students. Over the 2014 and 2015 field seasons, at least ten past or present ETP students were directly engaged in field activities associated with this project including snow surveying, water sampling and streamflow gauging (please see acknowledgements for names of individuals). In 2015, M. Richardson participated as a volunteer instructor in the ETP spring field camp at Crazy Lake and helped to develop a new module on snow surveying. He also participated in the NCP supported fall contaminants workshops in October 2014 and 2015. In each year, this included a lecture on physical environmental pathways of metal contaminants, complementing the largely biological focus of the training workshop. A field exercise was also conducted in which ETP students learned the basics of streamflow discharge gauging using direct measurement as well as indirect tracer-based methods.

Communications

Details of this project have been communicated locally through M. Richardson's participation in the 2015 ETP spring field camp at Crazy Lake and the ETP fall contaminants workshop in 2014 and 2015. The project findings will also be communicated through the NCP synopsis reporting and results workshops, presentations at scientific conferences and publications in scientific journals. These documents will be made available to NRI, NAC and the Amarok Hunters and Trappers Association of Iqaluit.

Traditional Knowledge Integration

During the 2014 and 2015 field programs, many individuals proved invaluable to project fieldwork in the hilly precarious terrain around Iqaluit, thanks to their strong and diverse land skills and mechanical abilities. On various occasions they helped plan the most efficient and safe routes to access the various sampling lakes throughout the melt season, modifying routes frequently as needed to account for changing conditions on the ground. They repaired equipment, serviced snowmobiles, ATVs, and qamutik, maintained ice augers and other key equipment, and prepared and deployed zodiac boats for open water sampling. Their skill and experience operating ATVs also enabled them to safely access to sampling sites during the summer, navigating around and through precarious boulder fields.

Results

End of season snow conditions in the Lake 1 basin were lower in 2014 (SWE=130 cm) compared to 2015 (SWE=176 cm) (**Table 1**). The onset of spring melt was delayed in 2015 by about 10 days compared to 2014, according to the Water Survey of Canada spring/summer hydrographs for the Apex River watershed (hydrographs not shown). The freshet period was also more protracted in 2015, possibly due to the higher SWE conditions in that year (Table 1).

Snowmelt THg concentrations increased from the pre-melt snowpack by a factor of two in 2015, whereas snowmelt concentrations were approximately equal to pre-melt snowpack concentrations in 2014. MeHg concentrations in pre-melt snowpack were approximately equal in 2014 and 2015 (0.030 and 0.035 ng L^{-1}, respectively). Snowmelt MeHg concentrations were similar to snowpack concentrations in 2014, but increased almost threefold relative the pre-melt snowpack conditions in 2015 (Table 1).

Boxplots showing the distributions of SpC, $d^{18}O$, THg, MeHg, DOC and Pb in Lake 1 water (at depth), Lake 1 outflow, Lake 1 ice, snowmelt and streamflow are shown in Figure 1. The most important observations to note in this figure are as follows:

- Streamflow entering Lake 1 had a fundamentally different chemical and isotopic signature then the melting snowpack, including higher SpC, less negative $d^{18}O$ and higher DOC concentration, indicating substantial mixing of snowmelt with "old" water (groundwater) residing within the catchment prior to the snowmelt period;

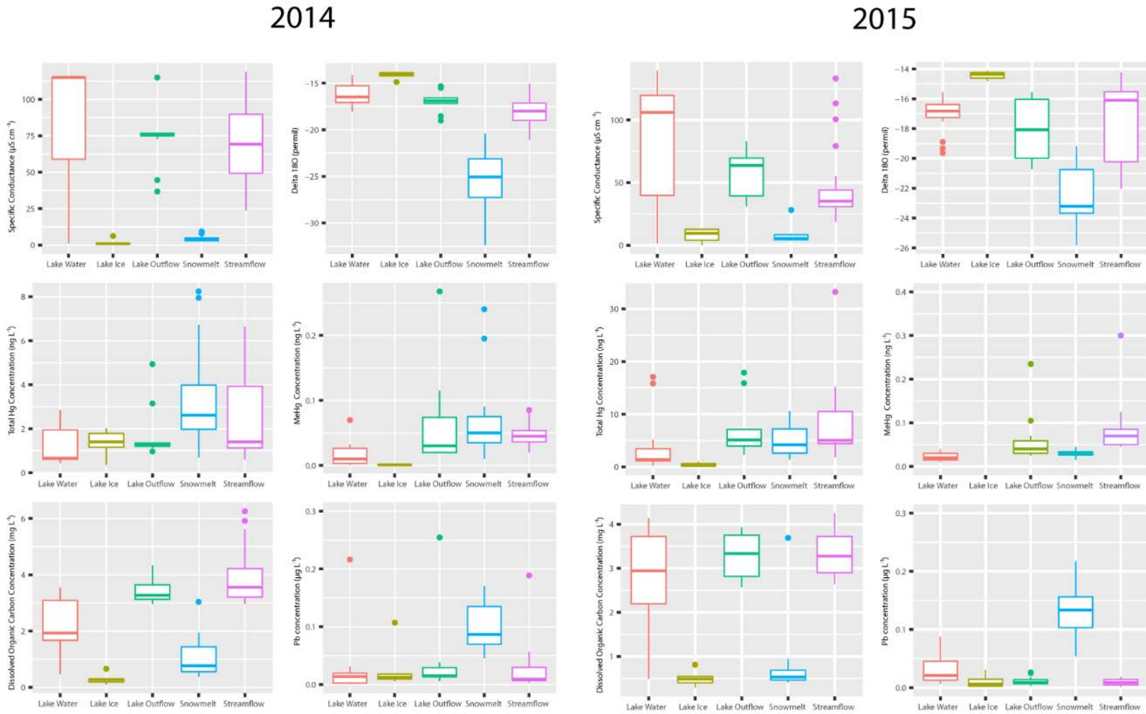
- Concentrations of THg and MeHg in snowmelt were approximately equal to concentrations in streams, lake water and Lake 1 outflow. Concentrations of Pb in snowmelt were considerably higher that any concentrations observed in downstream surface waters;

- SpC and concentrations of all chemical analytes in cored lake ice were very low and for MeHg, below detection limits. Melting lake ice therefore has a strong ability to dilute lake water and/or lake 1 outflow during the melt period especially considering the volume fraction of ice relative to the entire water column at Lake 1 (i.e. ~ 2 m of ice and a mean depth of ~ 6 m).

Table 1 Hydrologic conditions (SWE and freshet dates) and Hg (THg and MeHg) conditions for the Iqaluit, NU study site in 2014 and 2015. Freshet dates were approximated from the WSC Apex River hydrographs and are based on the onset of flow in the Apex River and the inflection point at the end of the spring melt hydrograph recession.

Year and Freshet Dates	SWE (mm)	Freshet start date	Freshet end date	Total precipitation over freshet period (mm)	Mean THg and MeHg concentrations (ng L^{-1}) in pre-melt Snowpack		Mean THg and MeHg concentrations in snowmelt (ng L^{-1})	
					THg	MeHg	THg (sd)	MeHg(sd)
2014 (May 26th to July 10th)	130	May 26th	July 10th	112	3.2 (0.57)	0.035 (0.01)	3.6 (2.95)	0.09 (0.07)
2015 (June 5th to July 31st)	176	June 5th	July 31st	134.5	2.27 (1.26)	0.03 (0.017)	4.97 (3.06)	0.03 (0.012)

Figure 1 Boxplots showing the chemical and isotopic composition of lake water, lake ice, lake inflow, streams and snowmelt over the 2014 (left) and 2015 (right) melt periods. Note difference y-axis scales between years, and notably higher THg concentrations in snowmelt, lake inflows and outflows.



SpC and d[18]O are useful as natural tracers to determine end member contributions to streamflow, which will be used in conjunction with hydrometric monitoring to develop a complete metal mass balance for the 2015 field season. We do not include results for Cd since most samples were below detection limit. A summary of other trace metals analyzed is not provided here, for brevity, but will be the subject of subsequent analyses and will be included in the Polar Data Catalogue.

Chemical and isotopic characteristics of the Lake 1 outflow tracked those of the inflowing streams very closely over the melt period in both 2014 and 2015 (Figure 2). This was observed not only for SpC and d[18]O which are useful conservative hydrologic tracers, but also metal contaminants of concern, notably THg and Pb, both of which decreased in concentration over the melt period in the lake inflows and outflow.

Two-component end member mixing analysis (EMMA) (Hooper et al. 1990) was used to quantify relative contributions of "old" water (soil and groundwater) to the streams flowing into Lake 1 over the melt period using both d[18]O and SpC as independent tracers. During the early melt period, snowmelt comprised ~62% to 88% of streamflow, decreasing steadily to baseflow conditions (assumed 100% groundwater) by the end of July (data not shown). The results strongly corroborate the distinct difference in hydrochemical and isotopic signature of snowmelt vs streamflow shown in Lake 1. Figure 3 indicates that snowmelt is an important contributor to THg and MeHg in streams since observed concentrations increase with increasing snowmelt fraction. This plot also shows that DOC is also higher in streamwater when the snowmelt fraction is highest.

Figure 2 Times series of d18O (top row), SpC (second row), THg (third row) and Pb (bottom right) for Lake 1 inflows (turquoise triangles) and outflow (red circles) for 2014 (left panels) and 2015 (right panels). Apex River WSC hydrographs are shown as a reference for the timing and magnitude of the melt period (bottom row). The lake outflow isotopic and chemical composition closely traces that of inflowing streams throughout the melt period.

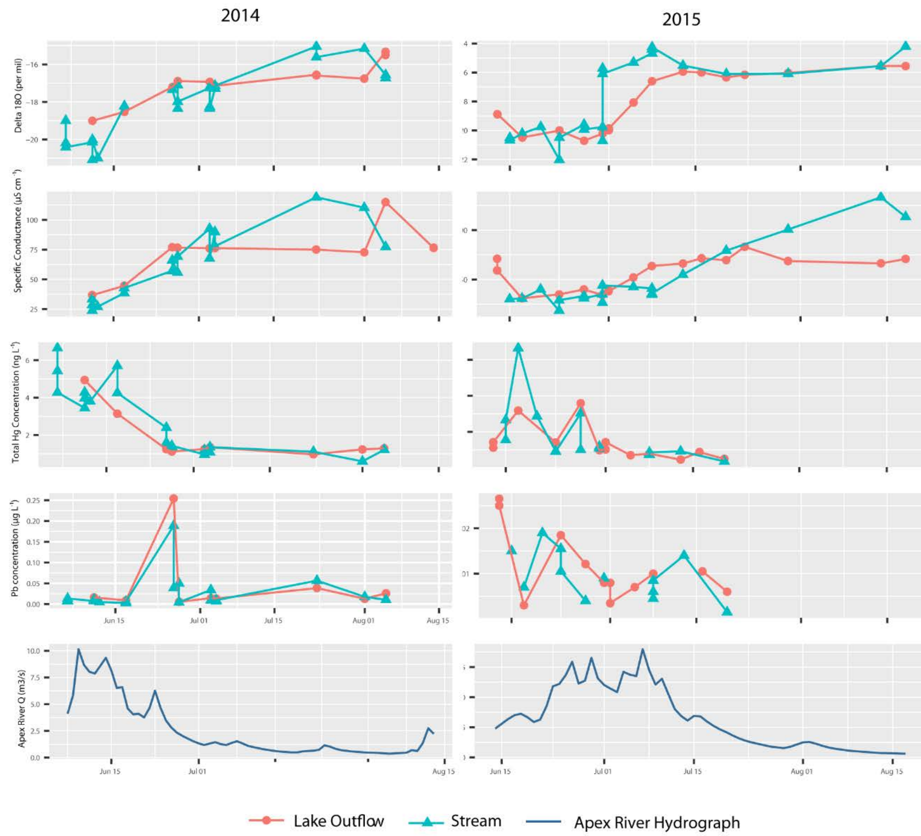
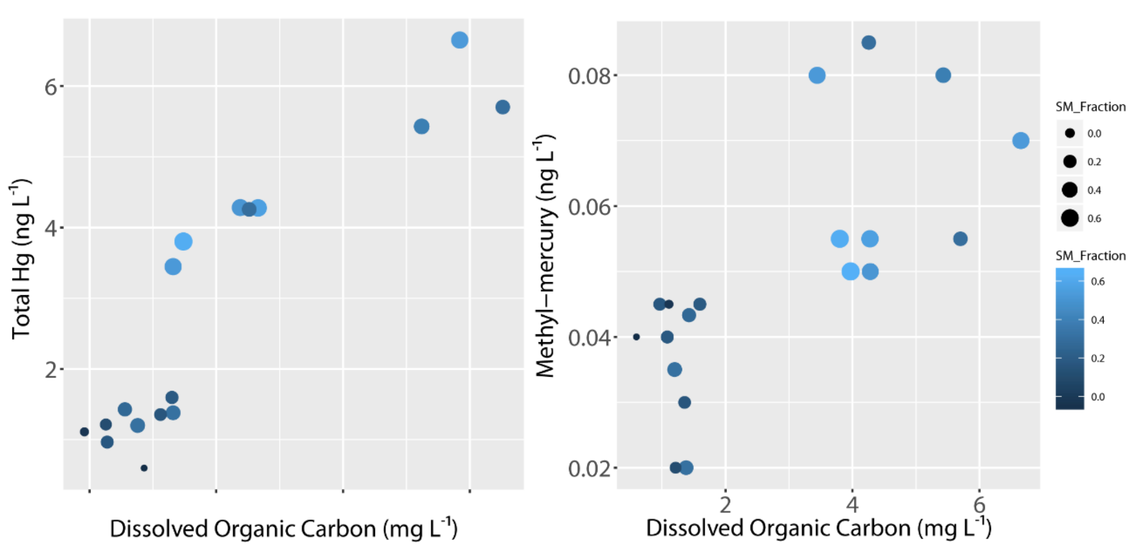


Figure 3 THg (left) and MeHg (right) vs DOC and proportion of snowmelt in streamwater (SM_Fraction). Increasing fraction of snowmelt streamwater is indicated by increasing dot size and decreasing colour intensity.



Discussion and Conclusions

The concentrations of THg and MeHg in snowpack and snowmelt water are consistent with reported ranges for other sub-Arctic and Arctic study sites (Durnford and Dastoor 2011, Dommergue et al. 2003, Emmerton et al. 2013, Lahoutifard et al. 2013). Previous researchers have observed increasing THg in coastal Arctic snowpacks during polar spring as a result of AMDEs and this phenomenon may have contributed to the inter-annual differences in snowpack THg in the present study, as well as the observed high levels of THg and MeHg in snowmelt water. High concentrations in early snowmelt pulses such as those observed here can also occur due to preferential enrichment of THg in the meltwater (St. Louis et al. 2005). Thus, complex physical and chemical processes affect Hg cycling above and within melting snowpacks and may depend on hydrologic or meteorological factors such as snow accumulation and/or timing and magnitude of melt rates. For example, snow accumulation and melt conditions were different in 2014 vs 2015 in this study and may have caused differences in the partitioning of snowpack Hg burdens between leaching via meltwater and re-emission to the atmosphere. Dommergue and Dastoor (2003) note that in a shallower snowpack, a greater proportion of the THg burden is likely to be emitted to the atmosphere rather than exit via meltwater, and this may have limited snowmelt THg enrichment in 2014 (SWE=130 cm) compared to 2015 (SWE=176 cm).

The elevated THg concentrations in snowmelt were propagated downstream along the drainage network, including the Lake 1 outflow which is somewhat surprising given our observations of substantial differences in streamflow chemical and isotopic composition relative to the melting snowpack. Other studies have shown similar changes in the chemical and isotopic composition of snowmelt during the spring freshet in Arctic watersheds, including the Apex River watershed (Obradovic and Sklash 1986). This has been attributed to mixing of new melt water with near surface soil and groundwater. While SpC and $d^{18}O$ tracers clearly show large augmentation of the meltwater signature during passage into the surface drainage network, THg and MeHg were not substantially different and our results demonstrate that snowmelt is an important source of THg and MeHg to surface waters. The elevated DOC concentrations in streamflow during the early melt period relative to snowmelt (Figure 3) inputs may play a role in limiting sorption of snowmelt Hg to soil particles in the active layer and facilitating transport of the snowpack Hg burden to downstream water bodies.

The close tracking of Lake 1 outflow isotopic and chemical composition is also consistent with findings by Semkin et al. (2005) and Bergman and Welch (1984). Both of those studies demonstrated that a significant fraction of snowmelt runoff entering Arctic tundra lakes over the spring melt period can bypass the water column in a thin layer below the ice surface and discharge via the outflow. Subsequent analysis of our data using end member mixing analysis (EMMA) will allow us to estimate the relative contributions of snowmelt to the lake water column vs outflow discharge over the 2015 melt season since we have detailed hydrometric gauging data for the lake inflow and outflow. The preliminary results reported here show that snowmelt water and runoff can have high concentrations of THg but inputs to lakes largely bypass the water column, likely making its way to the marine environment in Frobisher Bay. These findings imply that snow and snowmelt processes likely play an important role in coupling atmospheric sources of Hg pollution to the marine environment in Arctic coastal regions and warrant further analysis of terrestrial-marine interactions during the spring melt period.

Expected Project Completion Date:

All field and analytical work is complete. Data analysis and reporting will continue until Spring of 2017.

Acknowledgments

We are grateful for the NCP funding that supported this work, as well as other granting agencies including NSERC, Polar Knowledge Canada and ArcticNet that helped to fund synergistic activities. We would like to thank all of the following ETP students who helped with field activities and/or played other important supporting roles: Ted Irniq (2013 ETP graduate), Joeffrey Okalik, Mathew Gardiner Keenan “Nooks” Lindell, Angulalik Pedersen, Peter Aqqaq, Randy Hinanik, Alex Kilabuk, Sean Noble-Nowdluk, Tony Lee and Nash Panniuq. We also thank ETP instructors Jason Carpenter and Daniel Martin for supporting this work and staff at NRI: Rick Armstrong and Mary-Ellen Thomas. Team member John Chételat also contributed valuable insight and text to this report. Dominic Belanger (Marc Amyot lab) and Madjid Hadioui (Kevin Wilkinson lab) performed mercury and trace element analyses, respectively. Finally, this project would not have been possible without the intensive field sampling and laboratory efforts of Jessica Peters (2014 and 2015), Electra Skaarup (2014) and Keegan Smith (2015).

References

Bergmann, M. A. and H. E. Welch. 1985. Spring meltwater mixing in small Arctic lakes. Canadian journal of fisheries and aquatic sciences. 42(11): 1789-1798.

Dommergue, A., C. P. Ferrari, P. A. Gauchard, C. F. Boutron, L. Poissant, M. Pilote, P. Jitaru and F. C. Adams. 2003. The fate of mercury species in a sub-arctic snowpack during snowmelt. Geophysical Research Letters. 30(12): 1621.

Durnford, D. and A. Dastoor. 2011. The behavior of mercury in the cryosphere: A review of what we know from observations. *J. Geophys. Res. Atmos.* 116(D6).

Emmerton, C.A., J.A.,Graydon, J.A. Gareis, V.L. St. Louis, L.F.Lesack, J.K. Banack, F Hicks, and J. Nafziger. 2013. Mercury export to the Arctic Ocean from the Mackenzie River, Canada. *Environ. Sci. Technol.* 47(14): 7644-7654.

Hooper, R. P., N.Christophersen, and N.E. Peters.1990. Modelling streamwater chemistry as a mixture of soilwater end-members—An application to the Panola Mountain catchment, Georgia, USA. *J. Hydrol.* 116(1): 321-343.

Kirk, J. L., V. L. St. Louis and M. J. Sharp. 2006. Rapid reduction and reemission of mercury deposited into snowpacks during atmospheric mercury depletion events at Churchill, Manitoba, Canada. *Environ. Sci. Technol.* 40(24): 7590-7596.

Lahoutifard, N., M. Sparling and D. Lean. 2005. Total and methyl mercury patterns in Arctic snow during springtime at Resolute, Nunavut, Canada. *Atmos. Environ.*. 39(39): 7597-7606.

Loseto, L. L., D. R. Lean and S. D. Siciliano. 2004. Snowmelt sources of methylmercury to High Arctic ecosystems. *Environ. Sci. Technol.* 38(11): 3004-3010.

Louis, V. L. S., H. Hintelmann, J. A. Graydon, J. L. Kirk, J. Barker, B. Dimock, M. J. Sharp and I. Lehnherr. 2007. Methylated mercury species in Canadian high Arctic marine surface waters and snowpacks. *Environ. Sci. Technol.* 41(18): 6433-6441.

Obradovic, M. M., and M. G. Sklash. (1986). An isotopic and geochemical study of snowmelt runoff in a small Arctic watershed. *Hydrol. Process.* 1(1): 15-30.

Poulain, A. J., E. Garcia, M. Amyot, P. G. Campbell and P. A. Ariya. 2007. Mercury distribution, partitioning and speciation in coastal vs. inland High Arctic snow. *Geochim. Cosmochim. Acta.* 71(14): 3419-3431.

Semkin, R. G., G. Mierle and R. J. Neureuther. 2005. Hydrochemistry and mercury cycling in a High Arctic watershed. *Sci. Total Environ.* 342(1): 199-221.

Steffen, A., T. Douglas, M. Amyot, P. Ariya, K. Aspmo, T. Berg, J. Bottenheim, S. Brooks, F. Cobbett, A. Dastoor, A. Dommergue, R. Ebinghaus, C. Ferrari, K. Gardfeldt, M. E. Goodsite, M. D. Lean, A. J. Poulain, C. Scherz, H. Skov, J. Sommar, and C. Temme. 2008. A synthesis of atmospheric mercury depletion event chemistry in the atmosphere and snow. *Atmos. Chem. Phys.*8: 1445-1482.

St. Louis, V. L., M. J. Sharp, A. Steffen, A. May, J. Barker, J. L. Kirk, D. J. Kelly, S. E. Arnott, B. Keatley and J. P. Smol. 2005. Some sources and sinks of monomethyl and inorganic mercury on Ellesmere Island in the Canadian High Arctic. *Environ. Sci. Technol.* 39(8): 2686-2701.

St. Louis, V.L. 2013. Quantifying contaminant loadings, water quality and climate change impacts in the world's largest lake north of 74° latitude (Lake Hazen, Quttinirpaaq National Park, Northern Ellesmere Island, Nunavut). In: Synopsis of research conducted under the 2012-2013 Northern Contaminants Program. Aboriginal Affairs and Northern Development Canada, Government of Canada. pp. 317-325.

Stern, G. A., R. W. Macdonald, P. M. Outridge, S. Wilson, J. Chételat, A. Cole, H.

Hintelmann, L. L. Loseto, A. Steffen and F. Wang. 2012. How does climate change influence arctic mercury? *Sci. Total Environ.* 414: 22-42.

Zdanowicz, C., E. M. Krüemmel, D. Lahoutifard, Lean, A. Poulain, E. Yumvihoze, J. Chen and H. Hintelmann. 2012. Accumulation, storage and release of atmospheric mercury in a glaciated Arctic catchment, Baffin Island, Canada. *Geochim. Cosmochim. Acta.* 107:316-335.

Persistent organic pollutants in a Canadian Archipelago: Air, Water and Sediment

Polluants organiques persistants dans l'air, l'eau et les sédiments de l'archipel canadien

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Abstract

Since 2007, we have collected yearly samples in the Canadian Archipelago from on board the CCGS Amundsen as a part of ArcticNet. These samples include air, water, sediment and zooplankton. This project targets persistent organic pollutants and new and emerging compounds of concern, including pesticides, flame retardants, plasticizers, perfluorinated compounds and fossil fuel related compounds. Some of these compounds have been banned by national and international organizations, others are under consideration. It is important to continue to monitor compounds after they have been banned to observe the effectiveness of regulations. It is also equally important to screen and monitor for suspected new compounds that could pose a threat to the arctic. We have also started a water monitoring network utilizing passive water samplers in the archipelago attached to moorings and buoys and is being expanded to cover an east to west transect in the Canadian Arctic. This consistent sampling in the

Résumé

Depuis 2007, nous recueillons des échantillons annuels dans l'archipel canadien à bord du NGCC *Amundsen* dans le cadre d'ArcticNet. Ces échantillons comprennent l'air, l'eau, les sédiments et le zooplancton. Ce projet cible les polluants organiques persistants et les composés nouveaux et émergents préoccupants, y compris les pesticides, les produits ignifuges, les plastifiants, les composés perfluorés et les composés liés aux combustibles fossiles. Certains de ces composés ont été interdits par des organismes nationaux et internationaux; d'autres sont à l'étude. Il est important de continuer à surveiller les composés une fois qu'ils ont été interdits afin d'observer l'efficacité des règlements. Il est tout aussi important de dépister et de surveiller les nouveaux composés soupçonnés susceptibles de représenter une menace pour l'Arctique. Nous avons également lancé un réseau de surveillance de l'eau employant des échantillonneurs passifs de l'eau dans l'archipel, joints à des dispositifs d'ancrage

archipelago has enables us to develop trends for pesticides in air and water and some flame retardants and plasticizers in air. Our general conclusions are compounds currently being used are remaining constant or increasing in concentration where compounds that have been banned are decreasing in arctic air and water. International regulations have been effective at decreasing concentrations of banned chemicals in the arctic but replacement compounds that we have little knowledge of are now being found in the arctic environment.

et à des bouées, qui est en pleine expansion afin de couvrir un transect est-ouest dans le Canada arctique. Cet échantillonnage uniforme dans l'archipel nous a permis de développer des tendances pour les pesticides dans l'air et dans l'eau et certains produits ignifuges et plastifiants dans l'air. Nous en concluons sommairement que les composés actuellement utilisés demeurent constants ou sont à la hausse sur le plan des concentrations lorsque les concentrations des composés qui ont été bannis diminuent dans l'air et l'eau arctiques. Les règlements internationaux sont efficaces pour ce qui est de diminuer les concentrations des produits chimiques bannis dans l'Arctique, mais des composés de remplacement sur lesquels nous disposons de peu de connaissances se retrouvent désormais dans l'environnement arctique.

Key messages

- Flame retardants that have replaced the regulated or banned flame retardants are being found in arctic air and water at levels that exceed the banned compounds by orders of magnitude.
- Trends of organophosphate flame retardants and plasticizers in Canadian arctic air have remained constant over the past seven years, with one exception.
- Arctic communities are local point sources for some organophosphate flame retardants and plasticizers.
- Rivers deliver organophosphate flame retardants and plasticizers to the Canadian Arctic.

Messages clés

- Les produits ignifuges qui ont remplacé les produits ignifuges réglementés ou bannis se trouvent dans l'air et l'eau arctiques à des niveaux qui excèdent les composés bannis de plusieurs ordres de grandeur.
- Les tendances des produits ignifuges et des plastifiants à base d'organophosphate dans l'air du Canada arctique demeurent stables depuis les sept dernières années, à une exception près.
- Les collectivités de l'Arctique sont des sources ponctuelles locales pour certains produits ignifuges et plastifiants à base d'organophosphate.
- Les rivières apportent les produits ignifuges et les plastifiants à base d'organophosphate au Canada arctique.

Objectives

The objectives of this project are:

- to continue measuring levels and trends of persistent organic pollutants (POPs) in Canadian arctic air and water;
- to develop a passive water monitoring program for POPs in the Canadian Arctic and
- to screen for new and emerging compounds of concern in the Canadian arctic.
- These objectives were completed by carrying out multi-media (i.e. air, water and sediment) sampling in the Canadian Archipelago in the summer of 2015 as a part of ArcticNet.

Introduction

Contamination of the Canadian arctic ecosystem with man-made chemicals has been well documented for air, water and sediments but time and location trends are not well established especially for new and emerging compounds of concern. The four types of chemicals we study are 1) pesticides, 2) flame retardants and plasticizers, 3) fluorine containing compounds and 4) fossil fuel related compounds. The first three types are also called persistent organic pollutants (POPs) as they do not easily breakdown in the environment, are carbon based and are detrimental to the environment and humans. The major concern with POPs is that they are taken up by arctic biota including fish, seals and whales so when traditional foods are eaten, northerners are exposed to POPs. For the pesticides, flame retardants, plasticizers and fluorinated compounds there are two types: those that are still registered for use and the ones that have been banned so they are no longer used. We plan to measure both types, this monitoring is key to evaluating the effectiveness of national and international regulations.

Although the pesticides, flame retardants, plasticizers and fluorinated compounds are not produced nor used in high quantities in the north, they are found in every part of the Canadian arctic environment. They are transported globally through air and water currents that originate from the southern areas where these chemicals are intensely used.

Fossil fuel related compounds are produced when gas, diesel and oil are burned and when oil and gas is extracted from the earth. There are a few small sources of fossil fuel related compounds in the arctic, such as northern communities that produce their electricity from fossil fuel burning (Iqaluit's sole source of electricity is from diesel fuel), from ships travelling through the north-west passage, and oil exploration, but most are transported from the south. As ship traffic and oil exploration increases in sub-arctic and arctic regions, levels of these compounds are also expected to increase so it is important to establish current concentrations so future levels can be compared.

Our group has been conducting research on pesticides in the arctic since the early 1990s. Over the years the types of compounds investigated has expanded as new chemicals enter the market. Since 2007, we have teamed with ArcticNet to collect air, water, zooplankton and sediment samples in the Canadian Archipelago and will continue each summer. Through a complementary study, archived arctic cod samples are being analyzed for the same compounds. This data will provide information on how these POPs are transported to the north and once there, how they are introduced into the arctic food chain.

We have developed pesticide trends in air and water and trends of organophosphate esters in air in the Canadian Archipelago. We continue to work on developing trends for flame retardants, fluorinated compounds and fossil fuel related compounds in arctic air and water.

Activities in 2015-2016

Air and water samples were collected on board the CCGS Amundsen in the eastern Canadian Archipelago during the summer of 2015, this was a follow-up cruise to annual cruises since 2007. The passive water samples deployed on the moorings in 2014 were successfully retrieved from all sites in the Beaufort Sea. Passive water samples were also redeployed at four stations at varying depths at different locations in the Beaufort Sea. Sediment samples were taken in all regions of the Canadian Archipelago; half of these samples have been archived for future analysis.

All 2015 samples have been extracted and processed but analysis is ongoing. Methods were developed for an expanded list of organophosphate esters, taking guidance from the latest Chemicals Management Plan lists.

Air samples from 2013-2015 have been passed on to the Hazardous Air Pollutants Lab and Organic Analysis Labs for perfluorinated compound and polycyclic aromatic compound analysis. Analysis is on-going.

Alternate passive water sampling techniques were also investigated to reduce the cost and to align our sampling techniques with the Global Water Monitoring network being developed (AQUA-GAPS Lohmann and Muir, 2010). Currently solid phase membrane devices (SPMDs) are being used but they are expensive and extraction and processing can be problematic due to the use of triolein as the accumulating substance. After successful trials, in the summer of 2016, we will deploy SPMDs, poly-ethylene (PE) and silicon rubber (poly dimethyl siloxane (PDMS)) strips in the sampling cage, with the hope of eliminating the SPMDs in the summer of 2017.

Several papers were published in peer reviewed journals that included data produced from NCP funding, please see table below for details.

Communication with Local Communities and Capacity Building

In February 2014 and again in January 2016, Sandy Steffen, Hayley Hung and I visited Iqaluit and gave a presentation on our work to the students at Nunavut Arctic College. This presentation included a summary of our results and a hands-on demonstration of how air and water are sampled, processed and analyzed. I also demonstrated how to determine percent moisture in an Arctic Ocean sediment sample and had every student weigh and document the sediment for the moisture content. Additionally, we met with NECC in Iqaluit to discuss this project and how to integrate a northern student into the project.

While in Iqaluit, I interviewed northern students who were interested in participating in the ArcticNet cruise in the summer if 2016. Daniel Taukie was chosen; he will receive a special project credit from the college for this work. He is currently having trouble getting federal security clearance but we hope to be able to clear this issue up soon. He has a strong understanding of traditional knowledge and has extensive field work experience. Daniel and my other student Jimmy Truong, will also be on the Amundsen with members of the schools on board program, which includes nine students and their teachers from aboriginal communities across Canada.

I have also prepared an information brochure to be translated and distributed to northern communities, NECC has reviewed the document.

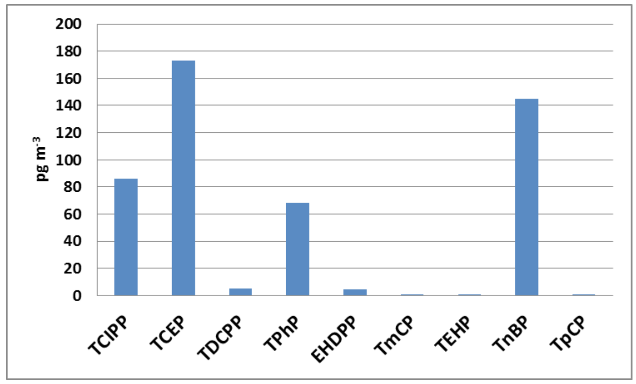
Results

Trend analysis of legacy and current use pesticides in arctic air and water and the state of air-water gas exchange between 1993-2013 was published in Environmental Science and Technology (Jantunen et al. 2015) and was discussed in last year's synopsis report. In this report I will discuss the temporal and spatial trends of organophosphate esters (OPEs) in arctic air and report concentrations of OPEs in arctic water.

Occurrence and Levels of OPEs in Air

Trend and spatial analysis was completed for the organophosphate flame retardants in Arctic air between 2007-2013 in the Canadian Archipelago (Suhring et al., EST in press). Organophosphate esters (OPEs) are both flame retardants and plasticizers; they are high production volume compounds and have been identified by this study in arctic air, water, snow and zooplankton. Comparing the levels of OPEs in the environment, indoor and outdoor, the OPEs are much more mobile than the brominated flame retardants (BFRs). This is indicated by the levels of OPEs in indoor environments i.e. dust and air, that are orders of magnitude higher than the BFRs (Brommer and Harrad, 2015; Dobson et al., 2012) even though the source products were treated with a similar mass. This order of magnitudes higher levels of OPEs is maintained in the urban outdoor environment (Shoeib et al., 2014) and remote regions including the Canadian Arctic.

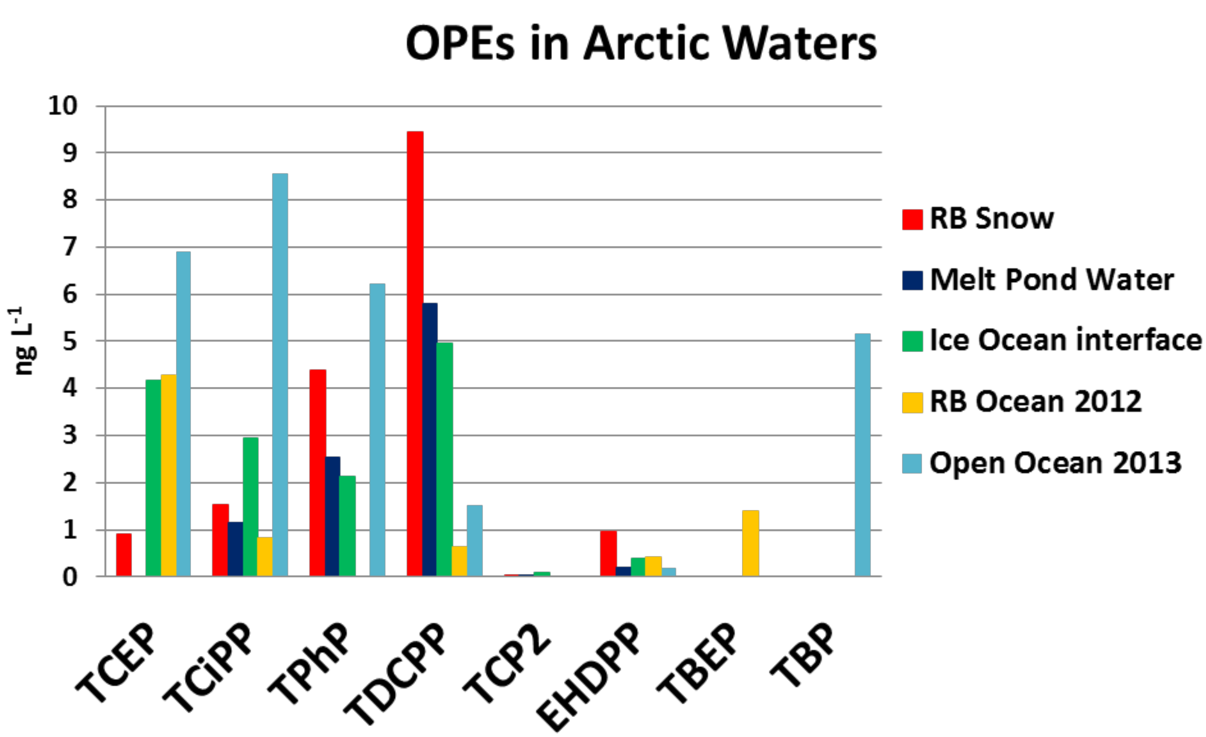
Figure 1: Average concentrations (pg m^{-3}) of OPEs in the particle fraction of air samples from the Canadian Arctic (2007–2013).



Occurrence and Levels of OPEs in Water and Snow

Samples were collected at Resolute Bay (RB) in 2012 that included air, water, melt pond water and open ocean water (Figure 2). Also in Figure 2 are water data from ArcticNet in 2013. A more extensive list of OPEs was detected in higher frequency in arctic water compared to air. OPEs are very soluble compared to classic

Figure 2: OPEs in Arctic water and snow from Resolute Bay (RB) and ArcticNet 2013.



chlorinated compounds; this may explain the high levels in arctic water. Samples that had been previously extracted were retrieved from the archive; unfortunately the blanks are too high for the samples to be usable so a retrospective analysis is not possible. The high levels of several compounds in the snow and the melt pond water, i.e. TCiPP, TPhP, TDCPP and EHDPP indicate that these OPEs are effectively scavenged from the air by precipitation to the surface of the ocean. There is also a very strong correlation between OPE concentrations in the snow and melt pond water, where there is no correlation between the concentrations in snow/ melt pond and in Arctic Ocean water.

Discussion and Conclusions

Trends of OPEs in Air

Good spatial coverage was made in the Canadian archipelago from 2007-2013 (Figure 3). OPEs in air were detected in the particle phase; being sorbed to particles increases the atmospheric half-life and increases the mobility of the OPEs (Liu et al. 2014).

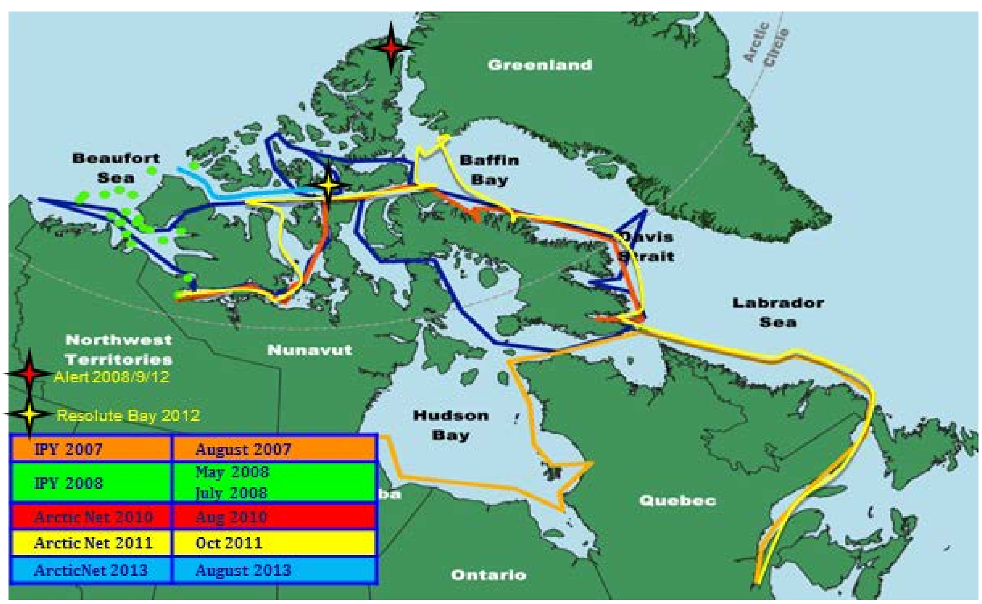
Temporal and Spatial Trends Non-Chlorinated OPEs in Arctic Air

Our study found that most non-chlorinated OPEs identified in arctic air have diffuse sources with no geographical trend, likely resulting from long range atmospheric transport from source regions in the south including North America, Europe and Asia. The exceptions are TnBP and EHDPP, where highest levels were found at the land based stations. We postulate that the likely source of TnBP and EHDPP is the local airport; these compounds were also found at high abundance in air samples taken at a land-based station in the Norwegian Arctic (Salamova et al. 2014). TPhP was the only OPE with a significant temporal trend; the levels of TPhP have drastically increased in the two most recently reported years resulting in a doubling time of ~1 year. Once data from 2014-2015 is added, this trend will be reassessed.

Temporal and Spatial Trends of Chlorinated-OPEs in Arctic Air

Several cruises started or ended in Quebec City so for chlorinated OPEs the highest levels were close to this source region and declined with increasing latitude. Localized elevated

Figure 3: Amundsen cruise track, 2007-2013.



air concentrations around the river mouths of the Nelson and Churchill suggest water-based transport to the arctic with volatilization once the fresh water mixes with the saline water because organic compound are less soluble in saline water than fresh water due to the salting out effect (Schwartzenbach et al., 1993). This is aligned with the higher persistence (POV) in water and therefore higher characteristic travel distance (CTD) in water of Cl-OPEs compared to non-CL OPEs (Table 1). Cl-OPE concentrations seemed to be constant or decreasing, however that could be an artefact of dilution due to increased river discharge.

OPE concentrations were of the same order of magnitude as those reported by Salamova et al. (2014) and Svalbard, Möller et al. (2012) in the arctic ocean north of Alaska, with concentrations ranging from non-detect to 585 pg $m^{-3.}$

This work has identified a class of flame retardants in the arctic environment at very high levels compared to their brominated counterparts. Since the air samples are collected in such as way retrospective trends were able to be done on archived air samples. We will continue this work in 2016-2017, expanding our list of screening compounds.

Expected Project Completion Date

Analysis of the 2015 samples in air, water, sediment and passive water samples for organophosphate and pesticides should be completed by December 2016. The PFAS analysis in air samples should also be completed by December 2016. PACs in air should be completed by March 2017.

Acknowledgments

NCP has been acknowledged in the papers published and the multiple presentations given, oral and poster format at workshops and international conferences.

References

Brommer, S., and S. Harrad. 2015. Sources and human exposure implications of concentrations of organophosphate flame retardants in dust from UK cars, classrooms, living rooms, and offices. Environ. Int. 83: 202-207.

Dodson, R.E., Perovich, L.J., Covaci, A., Van den Eede, N., Ionas, A.C., Dirtu, A.C., Brody, J.G., Rudel, R.A. 2012. After the PBDE Phase-Out: a broad suite of flame retardants in repeat house dust samples from California. Environ. Sci. Technol. 46: 13056–13066.

Klasmeier, J., M. Matthies, M. Macleod, K. Fenner, M. Scheringer, M. Stroebe, A.C. Le Gall, T. McKone, D. Van De Meent and F. Wania. 2006. Application of multimedia models for screening assessment of long-range transport potential and overall persistence. Environ. Sci. Technol. 40: 53-60.

Liu, Y., J. Liggio, T. Harner, L. Jantunen, M. Shoeib, S.M. Li. 2014. Heterogeneous OH initiated oxidation: a possible explanation for the persistence of organophosphate flame retardants in air. Environ. Sci. Technol. 48: 1041–1048.

Lohmann, R., and D. Muir. 2010. Global aquatic passive sampling (AQUA-GAPS): Using passive samplers to monitpr POPs in the waters of the world. Environ. Sci. Technol. 447: 860-864.

Möller, A., R. Sturm, Z. Xie, M. Cai, J. He, AND R. Ebinghaus. 2012. Organophosphorus flame retardants and plasticizers in airborne particles over the Northern Pacific and Indian Ocean toward the Polar Regions: evidence for global occurrence. Environ. Sci. Technol. 46: 3127–3134.

Salamova, A., M. H. Hermanson, and R. A. Hites. 2014. Organophosphate and halogenated flame retardants in atmospheric particles from a European Arctic site. Environ. Sci. Technol. 48: 6133–6140.

Schwartzenbach, R., P. Gschwend, and D. Imboden. 1993. Environmental Organic Chemistry, 1st ed. J. Wiley and Sons Publishers, New York, p.228.

Shoeib, M., L. Ahrens, L. Jantunen, and T. Harner. 2014. Atmospheric concentrations of organobromine, organochlorine and organophosphorus flame retardants in Toronto, Canada, Atmos. Environ. 140-147.

Wegmann, F., L. Cavin, M. MacLeod, M. Scheringer, and K. Hungerbuhler. 2009. The OECD software tool for screening chemicals for persistence and long-range transport potential. Environ. Modell. Softw. 24: 228-237.

Mercury and trace metal concentrations, and their effects on health indicators in a northern marine bird

Concentrations de mercure et de métaux à l'état de traces et effets sur les indicateurs de santé chez un oiseau marin nordique

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Abstract

Northern common eider ducks (*Somateria mollissima borealis*) are an important harvested species across northern Canada, as well as a circumpolar bio-indicator. This project investigated variation and long term trends of mercury (Hg; a priority contaminant for NCP) and other trace metal concentrations in common eider blood, and how these trace elements are associated with indicators of bird health and reproduction. We undertook this study at East Bay Island, near the community of Coral Harbour, Nunavut, where Environment and Climate Change Canada (ECCC) has a long-term study program to monitor eiders. Blood samples were taken from 193 breeding females over two years (2013/14) and analysed for trace elements (e.g., Hg, lead (Pb)), and three physiological health indices (corticosterone, triglycerides

Résumé

L'eider à duvet du Nord (*Somateria mollissima borealis*) fait l'objet d'une pêche importante partout dans le Nord et constitue un bioindicateur circumpolaire. Ce projet a étudié les variations et les tendances à long terme du mercure (Hg; un contaminant préoccupant pour le Programme de lutte contre les contaminants dans le Nord [PLCN]) et les concentrations d'autres métaux à l'état de traces dans le sang de l'eider à duvet, et la façon dont ces éléments à l'état de traces sont associés aux indicateurs de santé et de reproduction des oiseaux. Nous avons entrepris cette étude à l'île de la baie Est, près de la communauté de Coral Harbour, au Nunavut, où Environnement et Changement climatique Canada (ECCC) offre un programme d'étude à long terme afin de surveiller les eiders. Des échantillons de sang ont été prélevés sur 193 femelles reproductrices

and immunoglobulin Y). Post-capture, all sampled females were then monitored through behavioural observations to track reproductive success. We were uniquely positioned to compare contemporary Hg data (2013/14) with historical (1997/98) blood Hg data collected from the same colony. We found female eiders had significantly lower blood Hg concentrations in 2013/14 than in 1997/98, with significant annual variation. This suggests that Hg uptake in this region is highly variable between years, making interpretation of long-term trends from these few data points difficult. When blood Hg and Pb concentrations were compared with levels of corticosterone, triglycerides and immunoglobulin Y, only Hg and corticosterone were found to be significantly correlated, with a negative relationship found between Hg and corticosterone. Lastly, we experimentally manipulated parasite loads and compared blood Hg levels to study their combined effects on reproduction. We found that parasite burden influenced breeding, however no significant interactions occurred with Hg. The findings of this research are being used to better understand the drivers of eider duck health, reproduction and survival, all important metrics to consider for this harvested and managed species. Importantly, this project also contributes to the circumpolar research efforts of eiders and their environmental contaminants (i.e. Norway, Greenland, Iceland and Canada in particular), and is feeding information into two Arctic Council working groups (CAFF and AMAP).

sur deux ans (2013-2014) et analysés afin de détecter la présence d'éléments à l'état de traces (p. ex. mercure, plomb et trois indices de santé physiologique [corticostérone, triglycérides et immunoglobine Y]). Après la capture, toutes les femelles échantillonnées ont ensuite été surveillées au moyen d'observations comportementales afin de suivre le succès de la reproduction. Nous étions particulièrement bien placés pour comparer les données contemporaines sur le mercure (2013-2014) avec les données historiques sur le mercure dans le sang (1997-1998) recueillies dans la même colonie. Nous avons constaté que les eiders femelles avaient des concentrations de mercure dans le sang nettement inférieures en 2013-2014 par rapport à 1997-1998, accompagnées d'une variation annuelle considérable. Cela donne à penser que l'absorption de mercure dans cette région est hautement variable d'une année à l'autre, ce qui rend difficile l'interprétation des tendances à long terme à partir de ces quelques points de données. Lorsque l'on a comparé les concentrations de mercure et de plomb dans le sang avec les niveaux de corticostérone, de triglycérides et d'immunoglobine Y, seuls le mercure et la corticostérone se sont avérés étroitement corrélés, et un lien négatif s'est révélé entre le mercure et la corticostérone. Enfin, nous avons manipulé de façon expérimentale des charges de parasites manipulées et comparé les concentrations de mercure dans le sang afin d'étudier leurs effets combinés sur la reproduction. Nous avons découvert que la charge parasitaire influait sur la reproduction; aucune interaction importante n'est toutefois survenue avec le mercure. Les résultats de cette recherche sont utilisés afin de mieux comprendre les facteurs de santé, de reproduction et de survie de l'eider à duvet, toutes des mesures importantes à prendre en compte pour cette espèce prélevée et gérée. Il convient de souligner que ce projet contribue également aux efforts de recherche circumpolaires sur les eiders et leurs contaminants environnementaux (c.-à-d. la Norvège, le Groenland, l'Islande et le Canada en particulier) et transmet des renseignements à deux groupes de travail du Conseil de l'Arctique (CAFF et AMAP).

Key messages

- While we found eider ducks in 2013/14 had significantly lower levels of blood Hg concentrations compared to the same colony in 1997/98, the large inter-annual variation makes interpreting long-term trends based on a few data points difficult.
- Blood Hg and Pb concentrations did not significantly vary with most of the physiological health markers analysed (corticosterone, triglycerides and immunoglobulin Y).
- We found a significant negative correlation between blood Hg concentrations and corticosterone levels.
- Although, reducing parasite loads experimentally increased the breeding propensity of female eiders arriving in low condition and/or late arriving female eiders, we found no association with reproductive metrics or survival to blood Hg concentrations. This suggests that Hg is not a driver of reproductive timing or success in northern common eider ducks at East Bay Island.

Messages clés

- Bien que nous ayons découvert que les eiders à duvet du Nord de 2013-2014 présentaient des niveaux de mercure dans le sang beaucoup plus faibles par rapport à la même colonie en 1997-1998, la grande variation d'une année à l'autre rend difficile l'interprétation des tendances à long terme en fonction de quelques points de données.
- Les concentrations de mercure et de plomb n'ont pas beaucoup changé avec la plupart des indicateurs de santé physiologique analysés (corticostérone, triglycérides et immunoglobuline Y).
- Nous avons constaté une forte corrélation négative entre les concentrations de mercure dans le sang et les niveaux de corticostérone.
- Même si la réduction des charges parasitaires a augmenté à titre expérimental la propension à la reproduction des eiders femelles qui arrivent faibles ou des eiders femelles ou qui arrivent tardivement, nous n'avons relevé aucune association entre les mesures de la reproduction ou la survie et les concentrations de mercure dans le sang. Cela laisse entendre que le mercure n'est pas un facteur du moment ou du succès de la reproduction chez les eiders à duvet du Nord à l'île de la baie Est.

Objectives

This project had four main objectives:

1. Compare contemporary eider duck blood Hg levels taken at East Bay Island in 2013 and 2014 to samples taken at the same breeding colony in 1997 and 1998 to give an indication of long-term trends in Hg burdens.
2. Examine blood Hg concentrations in eider ducks to determine the level of inter-annual variation (2013 and 2014).
3. Investigate how blood Hg and other trace metal concentrations (e.g., lead) in eider ducks relate to physiological health indicators that are measured in the blood plasma.
4. Investigate how blood Hg may interact with endoparasites to affect reproduction in eiders through an experimental manipulation of breeding females on East Bay Island.

Introduction

Although natural sources of Hg have changed little over the last 150 years, anthropogenic sources have increased dramatically due to industrialization (Dietz et al., 2009) with approximately 5000 tons of Hg being released into the environment annually (Liu et al., 2012). Since the mid-1970s, marine birds have been examined for Hg across the Canadian North, and have been used to detect trends and potential effects on wildlife (Mallory and Braune, 2012; Mallory et al., 2012). Additionally, marine birds have been used to assess the effects of Hg toxicity (Braune et al., 2012; Meyer, 2005).

Importantly, Hg can affect wildlife indirectly through declines in health and condition, which then can negatively influence breeding effort and success. Wild birds may exhibit neurological and physical changes with increasing Hg levels. For instance, in wild adult common loons (Gavia immer), Scheuhammer et al. (2008) found neurological changes in brain receptors and enzymes in birds that had high concentrations of Hg. Thus, Hg can potentially impact a range of behaviours including foraging and migration given that Hg affects the central nervous system of an animal. Mercury can affect wildlife indirectly through declines in health and condition, because of its negative impacts on biota, which then can deleteriously influence breeding effort and success. Additionally, contaminants that affect changes in brain chemistry have been linked with changes in baseline levels of corticosterone levels (produced in the adrenal gland) in birds (Love et al., 2003). This suggests that Hg concentrations could influence corticosterone levels and other biomarkers as Hg is known to cross the blood-brain barrier (Wiener et al., 2003), and be found at high levels in some Arctic marine birds (Provencher et al., 2014).

Northern common eider ducks (Somateria mollissima borealis; mitiq; hereafter eider duck) are an important indicator and harvested species hunted across Northern Canada. The aim of this project was to contribute to our knowledge of long-term trends and variability in Hg in this important subsistence harvested marine bird species. We also aimed to broaden our knowledge of the effects of Hg and other metals on eider duck health, and investigate how cumulative impacts may be affecting northern marine birds. We focus on how trace elements vary with three commonly used biometrics, including corticosterone (a stress related hormone; Hennin et al., 2016), triglycerides (Hennin et al., 2016), and immunoglobulin Y (an indicator of immunity on birds; Bourgeon et al., 2006; Legagneux et al., 2014)long-lived species face trade-offs between survival and reproduction. The cost of reproduction, which is defined as the negative effect of current parental investment on chances of adult survival and future reproduction, may affect immune function, possibly through hormonal changes. In this study, components of acquired immunity and plasma corticosterone levels of female eiders (Somateria mollissima.This work is integrated into long-term studies at East Bay Island, in northern Hudson Bay, which allow us to capitalize on previous work focusing on the environmental and physiological drivers of eider reproduction and survival (Descamps et al., 2009; Hennin et al., 2014; Love et al., 2010) and the flexibility to respond to inter-annual variation in these cues. Determining which cues are linked to reproductive timing, what these cues are predicting and understanding the fitness consequences of variation in timing, is therefore of paramount interest to evolutionary and applied ecologists, especially in the face of global climate change. We investigated inter-annual relationships between climatic variation and the timing of reproduction in Canada's largest breeding population of Arctic common eiders (Somateria mollissima.

Activities in 2015-2016

Field and Analytical work

All field components of this project were carried out prior to 2015-2016. Briefly, during the 2013 and 2014 field seasons at the East Bay Island eider breeding colony, a total of 193 blood samples were collected from eiders as part of J. Provencher's PhD research and the long-term monitoring program at East

Bay Island by the research team. Whole blood samples are currently housed in the National Wildlife Specimen Bank at the National Wildlife Research Center in Ottawa. In both 2013 and 2014, blood plasma samples from the same females have been analyzed for corticosterone, triglycerides and immunoglobulin Y concentrations at the University of Windsor. Further, breeding metrics (lay date, clutch size, etc.) from 2013 and 2014 were also collected from these same birds to assess reproduction and survival within the sampling year in relation to metrics obtained from both whole blood and blood plasma. Subsequently, in 2014 and 2015, band-reading was conducted at East Bay Island to identify banded eiders that have returned from previous years, allowing us to estimate year-to-year survival.

During 2015/16, NCP supported the analysis of trace elements in the blood samples from the 2014 season (n=120). Trace element analyses were completed by RPC Laboratories (Fredericton, New Brunswick; Table 1; also shows detection limits), with a total of 32 trace elements examined in female eider blood. For the same female eider ducks, blood was also analyzed at the University of Windsor for corticosterone, triglycerides and immunoglobulin Y.

Communications

In the fall of 2015, J. Provencher co-led the wildlife contaminants workshop in Iqaluit as part of the Nunavut Arctic College's Environmental Technology Program supported by the Northern Contaminants Program. Early results from this study, as well as other marine bird projects under the northern marine bird group, were presented during the workshop.

Lastly, during March 2016, our research team visited the two nearby communities to East Bay Island, and those communities which have contributed to J. Provencher's thesis work (Coral Harbour and Cape Dorset). Project leaders G. Gilchrist and J. Provencher discussed this project during these community updates, along with the results to date. These community meetings were also used as an opportunity for new students joining the group to learn about community consultations, and for the researchers to share regionally-relevant research with the students of local schools.

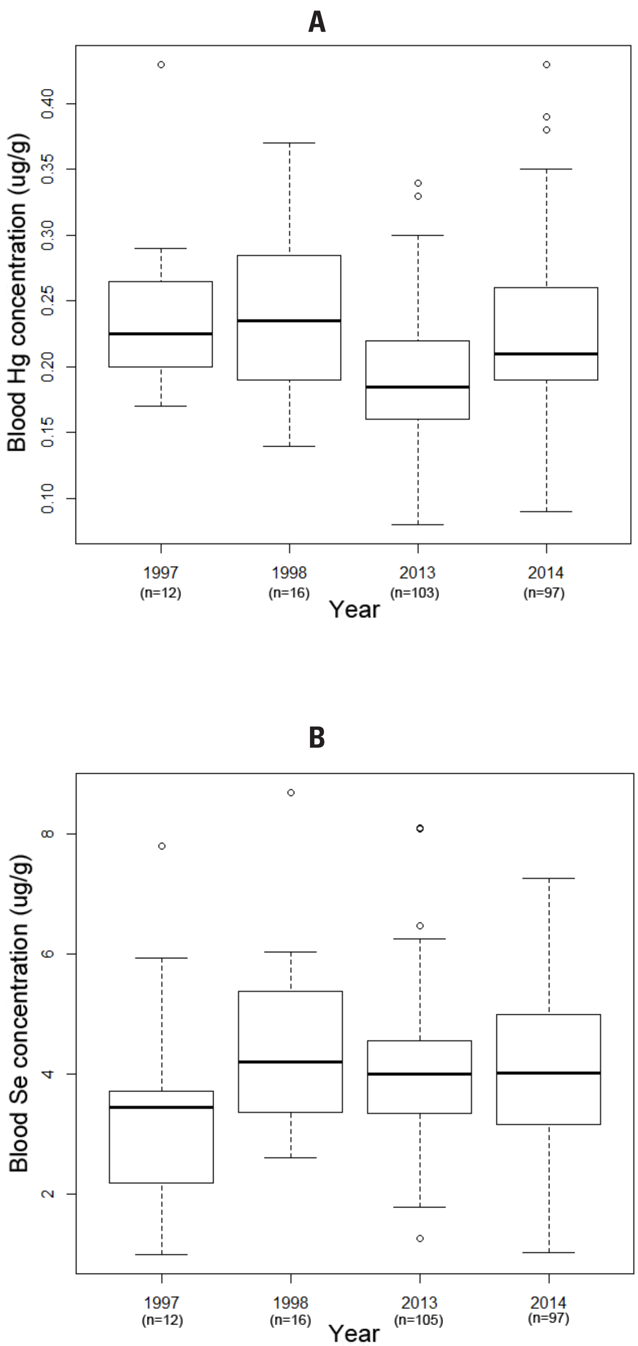
Results

We found that female eider ducks had relatively low or normal levels of many blood trace elements, including Hg and Pb (**Table 1).** While we found that in general blood Hg levels were significantly lower in eiders examined in 1997/98 as compared to 2013/14 (GLM - $F_{1,229} = 7.06$, $p = 0.008$), we also found significant inter-annual variation in Hg concentrations (GLM – $F_{3,227} = 8.69$, $p < 0.0001$; Fig 1A). We found no differences in blood selenium (Se) concentrations between the two time periods (GLM – $F_{1,229} = 0.03$, $p = 0.85$), nor any significant inter-annual variation in blood Se levels (GLM – $F_{3,227} = 1.36$, $p = 0.26$; Fig 1B).

Table 1. Essential and non-essential elements in female common eider blood collected from a breeding colony in northern Hudson Bay (n=193). Geometric means, 95% confidence intervals (CI), minimum detected values, and maximum detected values are given along with the detection limits. The numbers of birds with concentrations above the detection limits are given under n. All concentrations are given in $ug{\cdot}g^{-1}$ dry weight (dw). NA indicates where values were unavailable due to low sample sizes.

Elements	Detection limit dw ($ug{\cdot}g^{-1}$)	n	Geometric mean (95% CI) ($ug{\cdot}g^{-1}$)	Minimum, Maximum levels ($ug{\cdot}g^{-1}$)
Essential elements				
Aluminum	0.5	8	NA	0.5, 3.1
Calcium	2	193	135 (6)	41, 246
Chromium	0.05	71	NA	0.05, 0.12
Cobalt	0.005	2	NA	0.006, 0.006
Copper	0.05	193	0.47 (0.1)	0.23, 0.70
Iron	1	193	548 (4.9)	464, 647
Lithium	0.005	132	NA	0.005, 0.130
Magnesium	0.5	193	87.3 (0.8)	72.0, 98.1
Manganese	0.05	156	0.08 (0.006)	0.05, 0.23
Molybdenum	0.005	193	0.023 (0.001)	0.012, 0.083
Nickel	0.05	0	NA	NA
Potassium	1	193	2136 (20)	1750, 2540
Selenium	0.05	193	3.96 (0.18)	1.01, 8.11
Sodium	2	193	1694 (15)	1420, 1930
Zinc	0.1	193	7.4 (0.1)	5.1, 12.2
Non-essential elements				
Antimony	0.005	15	NA	0.005, 0.036
Arsenic	0.05	186	0.18 (0.01)	0.05, 0.85
Barium	0.05	108	na	0.05, 0.64
Beryllium	0.005	0	NA	NA
Bismuth	0.05	0	NA	NA
Boron	0.05	169	0.12 (0.01)	0.05, 0.50
Cadmium	0.0005	184	0.0023 (0.0002)	0.0005, 0.0108
Lead	0.005	154	0.008 (0.0008)	0.005, 0.043
Mercury	0.01	193	0.20 (0.008)	0.08, 0.43
Rubidium	0.005	193	1.054 (0.019)	0.703, 1.460
Silver	0.005	48	NA	0.005, 0.019
Strontium	0.05	191	0.54 (0.05)	0.05, 2.04
Tellurium	0.005	1	NA	0.009
Thallium	0.005	0	NA	NA
Tin	0.005	9	NA	0.006, 0.030
Uranium	0.005	0	NA	NA
Vanadium	0.05	3	NA	0.05, 0.19

Figure 1. Blood concentrations in female eider ducks at East Bay Island, Nunavut, in the 1990s and again in 2013/14 of mercury (Hg; A), and selenium (Se; B).



To date, we have examined the relationships between four trace elements (Cd, Hg, Pb and Se) and three commonly used biometric measures in birds (corticosterone, triglycerides and immunoglobulin Y) using a combination of Akaike's Information Criterion and path analysis (see publications for more details). For most of the relationships tested, we have found no significant relationships between any of the trace elements and the biometric measures when considered singularly, or jointly. We did find a negative relationship between corticosterone and Hg (GLM - $F_{6,183} = 3.37$, $p = 0.05$).

While the remainder of the analysis is still being completed as part of J. Provencher's PhD thesis, we provide a brief summary of the early results to date. Blood Hg concentrations did not significantly vary with breeding propensity, clutch size or survival in female eider ducks at East Bay Island. Additionally, even when blood Hg concentrations were taken into account with experimentally manipulated parasite burdens (via the use of an anti-parasite drug administered to female eiders upon their arrival at the breeding colony), no significant effects were found. Final reports and manuscripts outlining these results will be submitted for publication during the summer of 2016 as planned.

Discussion and Conclusions

While we did find that contemporary eiders had lower levels of blood Hg than individuals sampled in the late 1990s, the significant inter-annual variation that we also detected makes the interpretation of these relatively few data points difficult. Our findings emphasize the need for long term monitoring of Hg to use regular intervals that allow for inter-annual differences and long term trends to be considered (Riget et al., 2011)freshwater and terrestrial ecosystems with the purpose of generating a 'meta-analysis' of temporal trend data collected over the past two to three decades, mostly under the auspices of the Arctic Monitoring and Assessment Program (AMAP.

Interestingly, we found low levels of Cd in blood from eiders breeding at the East Bay colony. This is in contrast to other work that has shown that eiders from this colony can have high levels of Cd (Mallory et al., 2014). Cadmium is known to be accumulated by bivalves, which likely explains why seaducks often have higher-than expected levels of Cd (Puls, 1994), as has been found in eider ducks that feed heavily on bivalves (Lovvorn et al., 2013; Mallory et al., 2014). Since

Cd has been detected at high levels in the livers (a tissue that often reflects weeks to months before sampling) of East Bay Island eiders, Cd accumulation may occur before the eiders arrive in the region. In this study, we used blood which reflects signatures that represent exposure in the hours to days before the sampling period, suggesting that Cd accumulation may show seasonal variation. There may also be large inter-annual variation in Cd exposure due to environmental conditions, or bivalves may differ in their importance in the eider duck diet throughout the year leading to seasonally fluctuating Cd levels.

We found that neither Hg nor Pb significantly varied with triglycerides or immunoglobulin Y. This suggests that Hg and Pb either do not influence these metrics, or that eiders experience Hg and Pb concentrations below levels that are likely to trigger an effect that is detectable. While we found no significant correlation between Pb and corticosterone, we did find a significant negative correlation between Hg and corticosterone. This suggests that higher Hg concentrations in the blood are associated with baseline corticosterone levels in female eiders in the early breeding season. This supports other studies that have found that Hg may be an endocrine disruptor in wild birds (Jayasena et al., 2011). While Hg concentrations are not particularly high in northern eider ducks, these results suggest that Hg may have effects on the endocrine system at concentrations well below known effect levels.

The analyses will continue on the data that this project has already made available. In particular, we will be further exploring how Hg and Pb relate to breeding metrics of the birds, including condition and arrival timing on the colony, known precursors to breeding success (see Descamps et al., 2011). These analyses will allow us to explore the indirect relationships that Hg may have on breeding traits that ultimately affect breeding success.

Expected Project Completion Date

This project is expected to be completed by August 2016, as this is the expected completion date for J. Provencher's PhD dissertation. All manuscripts related to this project are expected to be submitted for publication by August 2016.

Project website (if applicable)

You can find more information about this and other projects at one of the co-leads website (jenniferprovencher.com) and through Twitter at @jenni_pro.

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References

Bourgeon, S., Cruscuolo, F., Le Maho, Y., Raclot, T., 2006. Phytohemagglutinin response and immunoglobulin index decrease during incubation fasting in female common eiders. Physiol. Biochem. Zool. 79, 793–800. doi:10.1086/504609

Braune, B.M., Scheuhammer, A.M., Crump, D., Jones, S., Porter, E., Bond, D., 2012. Toxicity of methylmercury injected into eggs of thick-billed murres and arctic terns. Ecotoxicology 21, 2143–2152.

Descamps, S., Bety, J., Love, O.P., Gilchrist, H.G., 2011. Individual optimization of reproduction in a long-lived migratory bird: a test of the condition-dependent model of laying date and clutch size. Funct. Ecol. 25, 671–681. doi:10.1111/j.1365-2435.2010.01824.x

Descamps, S., Gilchrist, H.G., Bety, J., Buttler, E.I., Forbes, M.R., 2009. Costs of reproduction in a long-lived bird: large clutch size is associated with low survival in the presence of a highly virulent disease. Biol. Lett. 5, 278–281. doi:10.1098/rsbl.2008.0704

Dietz, R., Outridge, P., Hobson, K.A., 2009. Anthropogenic contributions to mercury levels in present-day Arctic animals - A review. Sci. Total Environ. 407, 6120–6131.

Hennin, H.L., Legagneux, P., Bety, J., Williams, T.D., Gilchrist, H.G., Baker, T.M., Love, O.L., 2014. Pre-breeding energetic management in a mixed-strategy breeder. Oecologia 177, 235–243. doi:10.1007/s00442-014-3145-x

Hennin, H.L., Wells-Berlin, A.M., Love, O.P., 2016. Baseline glucocorticoids are drivers of body mass gain in a diving seabird. Ecol. Evol. 6, 1702–1711.

Jayasena, N., Frederick, P.C., Larkin, I.L. V, 2011. Endocrine disruption in white ibises (Eudocimus albus) caused by exposure to environmentally relevant levels of methylmercury. Aquat. Toxicol. 105, 321–7. doi:10.1016/j.aquatox.2011.07.003

Legagneux, P., Berzins, L.L., Forbes, M., Harms, N.J., Hennin, H.L., Bourgeon, S., Gilchrist, H.G., J., Soos, C., Love, O.P., Foster, J.T., Descamps, S., Burness, G., 2014. No selection on immunological markers in response to a highly virulent pathogen in an Arctic breeding bird. Evol. Appl. 7, 765–773. doi:10.1111/eva.12180

Liu, G., Cai, Y., O'Driscoll, N., Feng, X., Jiang, G., 2012. Overview of mercury in the environment, in: Liu, G., Cai, Y., O'Driscoll (Eds.), Environmenta; Chemistry and Toxicology of Mercury. Wiley, Hoboken, New jersey.

Love, O.P., Gilchrist, H.G., Descamps, S., Semeniuk, C.A.D., Bety, J., 2010. Pre-laying climatic cues can time reproduction to optimally match offspring hatching and ice conditions in an Arctic marine bird. Oecologia 164, 277–286. doi:10.1007/s00442-010-1678-1

Love, O.P., Shutt, L.J., Silfies, J.A., Bortolotti, G.R., Smits, J.E.G., Bird, D.M., 2003. Effects of dietary PCB exposure on adrenocorticol function in captive American kestrels (Falco sparverius). Ecotoxicology 12, 199–208.

Lovvorn, J.R., Raisbeck, M.F., Cooper, L.W., Cutter, G.A., Miller, M.W., Brooks, M.L., Grebmeier, J.M., Matz, A.C., Schafer, C., 2013. Wintering eiders acquire exceptional Se and Cd burdens in the Bering Sea: physiolocal and oceanographic factors. Mar. Ecol. Prog. Ser. 489, 245–261.

Mallory, M.L., Allard, K.A., Braune, B.M., Gilchrist, H.G., Thomas, V.G., 2012. New longevity record for Ivory Gulls (Pagophila eburnea) and evidence of natal philopatry. Arctic 65, 98–101.

Mallory, M.L., Braune, B., Robertson, G., Gilchrist, H.G., Mallory, C.D., Forbes, M.R., Wells, R., 2014. Increasing cadmium and zinc levels in wild common eiders breeding along Canada's remote nothern coastline. Sci. Total Environ. 476, 73–78.

Mallory, M.L., Braune, B.M., 2012. Tracking contaminants in seabirds of Arctic Canada: Temporal and spatial insights. Mar. Pollut. Bull. 64, 1475–1484. doi:10.1016/j.marpolbul.2012.05.012

Meyer, M.W., 2005. Evaluating the impact of multiple stressors on common loon population demographics - an integrated laboratory and field approach. USEPA - Wisconsin Department of Natural Resources.

Provencher, J.F., Mallory, M.L., Braune, B.M., Forbes, M.R., Gilchrist, H.G., 2014. Mercury and marine birds in Arctic Canada: effects, current trends and why we should be paying closer attention. Environ. Rev. 22, 244–255.

Puls, R., 1994. Mineral levels in animal health. Sherpa International, Clearbrook BC.

Riget, F., Braune, B., Bignert, A., Wilson, S., Aars, J., Born, E., Dam, M., Dietz, R., Evans, M., Evans, T., Gamberg, M., Gantner, N., Green, N., Gunnlaugsdottir, H., Kannan, K., Letcher, R., Muir, D., Roach, P., Sonne, C., Stern, G., Wiig, O., 2011. Temporal trends of Hg in Arctic biota, an update. Sci. Total Environ. 409, 3520–3526. doi:10.1016/j.scitotenv.2011.05.002

Scheuhammer, A.M., Basu, N., Burgess, N.M., Elliott, J.E., Campbell, G.D., Wayland, M., Champoux, L., Rodrigue, J., 2008. Relationships among mercury, selenium, and neurochemical parameters in common loons (Gavia immer) and bald eagles (Haliaeetus leucocephalus). Ecotoxicology 17, 93–101.

Wiener, J., Krabbenhoft, D.P., Heinz, G., Scheuhammer, A.M., 2003. Ecotoxicology of mercury, in: Hoffman, D.J., Rattner, B.A., Burton, G.A.J., Cairns, J.J. (Eds.), Handbook of Ecotoxicology. CRC Press, New York, pp. 409–463.

Glacier and soil/permafrost thaw inputs of mercury, perfluorinated chemicals and organophosphorus flame retardants to a pristine high Arctic watershed in Quttinirpaaq National Park, Northern Ellesmere Island, Nunavut

Apports en mercure, en composés perfluorés et en produits ignifuges organophosphorés dus au dégel des glaciers, des sols et du pergélisol vers un bassin hydrographique vierge dans l'Extrême-Arctique, dans le parc national du Canada Quttinirpaaq, au nord de l'île d'Ellesmere au Nunavut

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Abstract

The high Arctic continues to receive a wide range of contaminants released by human activities in more southerly latitudes and industrialized nations around the world. Thankfully, due to emission regulations and bans in their usage, concentrations of certain legacy contaminants have been declining in the high Arctic. However, a number of contaminants such as mercury (Hg), as well as new, emerging and yet unregulated persistent organic pollutants (POPs), such as certain poly- and perfluorinated alkyl substances (PFASs) and organophosphorus flame retardants (OPFRs), continue to be of priority concerns. Furthermore, it now appears that climate change is also influencing the long-range transport, fate and bioaccumulation of contaminants like Hg and POPs in the Arctic. Recent funding has allowed us to study mercury in the winter atmosphere, springtime runoff of total mercury, and how that runoff changed concentrations of those contaminants in Lake Hazen during the important spring bloom of biological activity under the lake ice. In summer 2015, we began to quantify glacier and soil/permafrost thaw inputs of Hg, PFASs and OPFRs to this watershed. From a socio-economic perspective, understanding present-day contaminant loadings, water quality and climate change impacts is important for predicting how the abundances and quality of certain organisms used as Inuit traditional foods may be altered by future human activities.

Résumé

L'Extrême-Arctique continue de recevoir un vaste éventail de contaminants, lesquels sont libérés par les activités humaines menées à des endroits situés à des latitudes méridionales inférieures et dans différents pays industrialisés dans le monde. Heureusement, la réglementation des émissions atmosphériques et les interdictions touchant leur utilisation ont permis de réduire les concentrations de certains contaminants hérités du passé dans l'ExtrêmeArctique. Toutefois, bon nombre de contaminants comme le mercure (Hg) et les polluants organiques persistants (POP), nouveaux ou émergents et qui ne sont pas encore réglementés, comme les composés perfluoroalkyles et les produits ignifuges à base d'organophosphore, font toujours l'objet de préoccupations majeures. De plus, il semble maintenant que les changements climatiques aient également une incidence sur le transport à grande distance, l'évolution dans l'environnement et la bioaccumulation de contaminants, comme le mercure et les polluants organiques persistants, dans l'Arctique. Un financement récent nous a permis d'étudier le mercure dans l'atmosphère printanière, l'écoulement printanier de mercure total et en quoi cet écoulement a changé les concentrations de ces contaminants dans le lac Hazen pendant l'importante éclosion printanière d'activité biologique sous la glace du lac. À l'été 2015, nous avons commencé à quantifier les apports de mercure, de composés perfluoroalkyles et de produits ignifuges organophosphorés issus du dégel des glaciers et des sols ou du pergélisol à ce bassin hydrographique. D'un point de vue socioéconomique, il est important de comprendre les charges de contaminants, la qualité de l'eau et les incidences des changements climatiques pour être en mesure de prédire comment les activités humaines futures peuvent nuire à l'abondance et à la qualité de certains organismes utilisés comme aliments traditionnels par les Inuits.

Key messages

- Filtered (dissolved) concentrations of both THg and MeHg in glacial river water were much lower than unfiltered concentrations, suggesting that the majority of THg and MeHg in glacial runoff is particle bound or mineral in origin. As such, THg and MeHg concentrations increased with increasing river flow and erosion intensities.
- Unlike Hg, glacial river flow intensity and erosional materials do not appear to influence PFASs loadings into Lake Hazen, and that their source is melt water originating from more recently deposited snow and ice on glaciers.
- We found that small lakes and wetlands were both sites of active microbial Hg methylation. Unlike glacial rivers, a much larger portion of the MeHg was in the dissolved phase and not particle bound, making the MeHg much more readily bioavailable for bioaccumulation in these systems.
- We hypothesize that PFASs in the continuum region of the watershed that we sampled are representative of local sources, due to human activity in the Park.
- MeHg concentrations were extremely low throughout the water column after the height of summer glacial melt and soil/permafrost thaw inputs.

Messages clés

- Les concentrations filtrées (dissoutes) de HgT et de MeHg dans l'eau des rivières glaciaires étaient beaucoup plus faibles que les concentrations non filtrées, ce qui porte à croire que la majorité du HgT et du MeHg contenue dans l'écoulement glaciaire est fixée sur des particules ou d'origine minérale. Ainsi, les concentrations de HgT et de MeHg ont augmenté avec la montée du débit de la rivière et de l'intensité de l'érosion.
- Contrairement au mercure, l'intensité du débit des rivières glaciaires et les matériaux d'érosion ne semblent pas influer sur les charges de composés perfluoroalkyles dans le lac Hazen, et leur source est de l'eau de fusion provenant de neige et de glace s'étant plus récemment déposées sur les glaciers.
- Nous avons constaté que les petits lacs et milieux humides étaient tous deux des sites de méthylation de mercure microbienne active. Contrairement aux rivières glaciaires, une bien plus grande partie du méthylmercure était à la phase dissoute et non fixée sur des particules, ce qui rend le MeHg beaucoup plus facilement biodisponible pour la bioaccumulation dans ces systèmes.
- Nous émettons l'hypothèse selon laquelle les composés perfluoroalkyles dans la région du continuum du bassin hydrographique que nous avons échantillonné représentent les sources locales, en raison de l'activité humaine dans le Parc.
- Les concentrations de MeHg étaient extrêmement faibles partout dans la colonne d'eau après le pic des apports liés à la fonte des glaces estivale et au dégel des sols ou du pergélisol.

Objectives

The objectives of our 2015/16 project were four-fold:

1. Quantify concentrations and loads of THg, MeHg, PFASs and OPFRs in glacial runoff in a pristine high Arctic watershed;
2. Quantify concentrations and loads of THg, MeHg, PFASs and OPFRs in soil/permafrost thaw runoff in a pristine high Arctic watershed;
3. Quantify THg, MeHg, PFASs and OPFRs concentrations in a pristine high Arctic lake during the height of summer glacial melt and soil/permafrost thaw runoff into the lake;
4. Quantify concentrations of THg, MeHg, PFASs and OPFRs into the base of the foodweb (zooplankton) during the height of summer glacial melt and soil/permafrost thaw runoff into the lake, as well as the height of lake productivity.

Previous NCP funding had already allowed us to quantify winter atmospheric loadings and springtime runoff of THg, MeHg, PFASs to a pristine high Arctic watershed, as well as examine how that runoff changed concentrations of those contaminants in a lake during the important spring bloom of biological activity under the lake ice. Our long-term goal is to combine these earlier results to those from this and future projects to construct a current-day annual watershed-scale budget for THg, MeHg, PFASs and OPFRs.

We are using the Lake Hazen watershed, located within Quttinirpaaq National Park, northern Ellesmere Island, Nunavut, as our research system. Studying the Lake Hazen watershed is ideal because:

1. Lake Hazen itself supports one of the largest stocks of landlocked Arctic char in the Canadian Arctic, which was historically harvested by Inuit, Thule and Paleo-Eskimo peoples;
2. As part of the NCP long-term monitoring program, Lake Hazen Arctic char are being analysed yearly for contaminant concentrations including Hg, PFASs, brominated flame retardants and legacy POPs (program led by D. Muir. This project will therefore provide added value to help interpret results from the char monitoring program;
3. We are able to quantify contaminant loadings in total isolation of localized sources of contaminants from communities and northern airports. The Lake Hazen watershed is located in a protected National Park, and thus is a record of changes in contaminant loadings being observed in an otherwise pristine environment.

Introduction

The high Arctic unfortunately continues to receive a wide range of contaminants released by human activities in more southerly latitudes and industrialized nations around the world (Canadian Arctic Contaminants Assessment Report III a and b). The majority of these contaminants are known to bioaccumulate in organisms, and biomagnify as they make their way up the food web to concentrations that may be of concern to human health if upper trophic-level organisms are used as traditional country foods. The atmosphere is a primary source of contaminants to Arctic terrestrial and freshwater ecosystems, and atmospheric deposition is a key mechanism by which contaminants enter these sensitive ecosystems. This is particularly true for POPs, but also for Hg (Canadian Arctic Contaminants Assessment Report III a and b). Because of the Arctic's cold climate, atmospherically deposited contaminants initially accumulate in snowpacks during the long winter before being transferred to downstream water bodies during spring melt. However, snow meltwater and summer deposition (both wet and dry) can also contribute contaminants to soils, where they may be archived for long periods of time if they subsequently become locked in permafrost. In glaciated regions, some of the annual snowpack is converted to ice, and hence contaminants contained within those snowpacks can also be archived for long periods of time. Thankfully, due to emission regulations and bans in their usage, concentrations of certain legacy contaminants have been declining in the high Arctic (Canadian Arctic Contaminants Assessment Report III a and b). However, contaminants such as Hg, as well as new, emerging and yet unregulated PFASs, as well as OPFRs, continue to be of priority concerns.

Furthermore, there is now a growing consensus among environmental scientists that climate warming will also influence the long-range transport, fate and bioaccumulation of contaminants like Hg and POPs in the Arctic (Canadian Arctic Contaminants Assessment Report III a and b). Human-induced climate change is altering polar watersheds at unprecedented rates (ACIA 2004, AMAP 2012). Current climate models predict that in the Canadian high Arctic, autumn and winter temperatures are projected to rise 3-5°C over most Arctic land areas by 2100, but up to 9°C in the very northern Canadian Arctic Archipelago (Climate Change 2007, IPCC 2013). Mean annual precipitation is projected to increase ~12% for the Arctic as a whole over the same period (especially in autumn and winter), but up to 35% in localized regions where the most warming will occur (Climate Change 2007, IPCC 2013). Such warming and wetting, coupled with extended growing seasons (Xu et al. 2013), is anticipated to greatly alter the energy balance of Arctic landscapes (Callaghan et al. 2011), resulting in glacial melt (Lenaerts et al. 2013), soil/permafrost thaw (Froese 2008), altered surface runoff (Peterson et al. 2002), and increased primary production in watersheds (Elmendorf et al. 2012) and freshwaters (Smol et al. 2005). In fact, not only are these changes anticipated, but most are already occurring in the Lake Hazen watershed.

The objectives of our 2015/16 research program were to start examining the complex linkages between the deposition and biogeochemical cycling of contaminants (THg, MeHg, PFASs and OPFRs) and climate change in the high Arctic.

Activities in 2015-2016

Research:

Again, the objectives of our 2015 NCP project were four-fold:

1. Quantify concentrations and loads of THg, MeHg, PFASs and OPFRs in glacial runoff in the pristine Lake Hazen watershed;
2. Quantify concentrations and loads of THg, MeHg, PFASs and OPFRs in soil/permafrost thaw runoff in the pristine Lake Hazen watershed;
3. Quantify THg, MeHg, PFASs and OPFRs concentrations in Lake Hazen itself during the height of summer glacial melt and soil/permafrost thaw runoff;
4. Quantify concentrations of THg, MeHg, PFASs and OPFRs into the base of the Lake Hazen foodweb (zooplankton) during the height of summer glacial melt and soil/permafrost thaw runoff into Lake Hazen, as well as the height of lake productivity.

We are pleased to report that all these objectives were more than successfully met! To meet these and other objectives, we made two trips to Lake Hazen in 2015. The first one occurred from 11-22 May, and the second from 4 July-3 August. During the first spring trip, as an added objective, we collected snow from numerous sites on the surface of Lake Hazen and the surrounding landscape to further enhance our growing dataset on winter atmospheric deposition of Hg in the high Arctic. The four main objectives of our research program were met during the second summer trip. In the results section below, we describe the specifics of the summer sampling program and discuss our initial interpretations of our results. *Please note, however, that OPFRs analyses are still pending.*

Capacity Building:

Northern training and consultation is a large component of all our northern research programs. This has been done through a number of different forums:

- As we have done over the past five years, we continue to collaborate and interact with northern employees of Parks Canada while at the Lake Hazen field site each summer. For example, this past summer (and previously) we directly involved Steven Akeeagok (Seasonal employee, Quttinirpaaq National Park) with our water chemistry and lake sediment sampling/processing activities, thus providing northerners from Parks Canada with a unique opportunity to directly participate in an exciting scientific project, which is taking place in the North. Steven was born in Grise Fiord, but currently lives in Iqaluit.
- In addition, in February 2016 we continued our dialogue with Lilianne Kydd (Contaminants Specialist, INAC, Iqaluit) about the potential for developing our current capacity building and training program to include, for example, the short-term hiring of a recent graduate or aspiring local Resolute Bay student of Arctic College's Environmental Monitor Training Program or the Environmental Technology Program or engaging other interested individuals from the Resolute Bay area to assist with the field portion of our research.
- We have also arranged with Jamal Shirley to help deliver, in early April 2016, a one-day field training session in chemical limnology for 2nd year students in Nunavut Arctic College's Environmental Technology Program in Iqaluit. This training was completed, but will be incorporated into out 2016/17 activities report.

Communications:

- St.Louis, Lehnherr, De Silva, St.Pierre and Wong presented our new results in oral and poster presentations at the 21st Northern Contaminants Program Results Workshop and 11th ArcticNet Annual Scientific Meeting December 2015, Vancouver, BC.
- St.Pierre presented results at the International Conference on Mercury as a Global Pollutant June 2015, Jeju, South Korea.
- Lehnherr presented an overview of the Lake Hazen study in the Environmental Science and Engineering Seminar Lecture Series, Harvard University, November 2015.
- St.Louis gave a presentation at the Sharing Knowledge Symposium (8-9 March 2016, Faculties of Science and Native Studies, University of Alberta) entitled "Water research in the extreme northern reaches of Canada: Engaging communities and mutual education when there are no communities nearby."

Traditional Knowledge Integration:

Parks Canada utilizes the TK of members of the Joint Parks Management Committee to guide their decisions and practices in northern National Parks. Also, with a goal of 80% Inuit employees, Parks Canada hopes that TK is shared amongst staff, and that their actions are reflected in this. Our activities in terms of safe over land and over water travel at Lake Hazen will utilize the knowledge of the Inuit employees of Parks Canada.

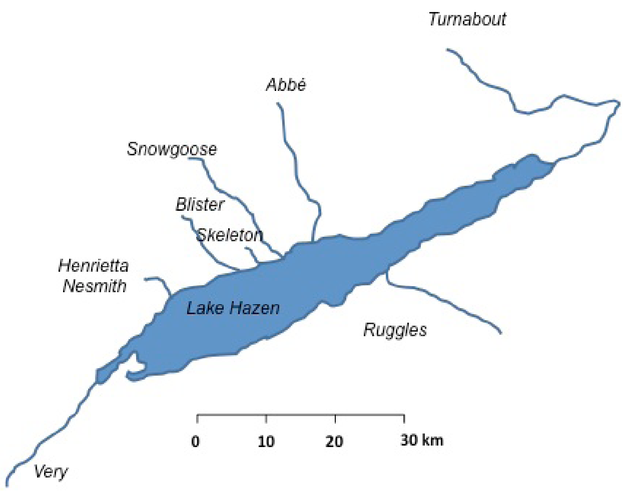
Results

Objective 1. Quantify concentrations and loads of THg, MeHg, PFASs and OPFRs in glacial runoff in the pristine Lake Hazen watershed:

Glacial runoff in the Lake Hazen watershed from late June to August represents the dominant annual hydrological event. Approximately 16 sub-catchments in the watershed drain into Lake Hazen. Once yearly, Parks Canada and

Environment and Climate Change Canada access three of the ungauged glacially-fed inflow rivers (Very, Abbé, Turnabout), as well as the Ruggles River outflow of Lake Hazen, by helicopter to sample for general water chemistry (Figure 1). On July 15th, 2015, we joined Parks Canada staff to sample these rivers, as well as the Henrietta Nesmith River, for contaminants. We also sampled two rivers within walking distance from the Lake Hazen base camp (Blister Creek and the Snowgoose River; Figure 1).

Figure 1: Some of the major glacial melt rivers flowing into Lake Hazen that we sampled. Skelton Creek is a soil/permafrost thaw stream. The Ruggles River is the lake outflow.



We found that average unfiltered MeHg concentrations ranged from 0.007 ng.L-1 in the Abbe River to 0.064 ng.L-1 in Blister Creek (Figure 2). Average unfiltered THg concentrations ranged from 4 ng.L-1 in the Turnabout River to 24 ng.L-1 in the Very River (Figure 3). Filtered (dissolved) MeHg concentrations were much lower and fairly consistent among the different rivers (0.007-0.014 ng.L-1), except in the Turnabout River (0.051 ng.L-1), suggesting that a significant portion of the MeHg in glacial runoff is particle bound (Figure 2). Similarly, filtered THg concentrations were much lower and fairly consistent among the different rivers (~1 ng.L-1), suggesting that the majority of the THg in glacial runoff is mineral in origin (Figure 3). Both unfiltered and filtered concentrations of MeHg and THg in the Ruggles River were lower than any of the inflow concentrations (Figures 2 and 3), suggesting that a combination of sedimentation, dilution and photoreduction is occurring in the lake. PFASs were detected in all of the rivers (Figure 4). For each PFAS congener, concentration in each inflow river was higher than in the outflowing Ruggles River. The highest concentrations of the majority of PFCAs occurred in the Turnabout River, similar to the filtered MeHg spatial trends.

Figure 2: Unfiltered and filtered concentration of MeHg in glacial melt rivers, and the Ruggles River outflow.

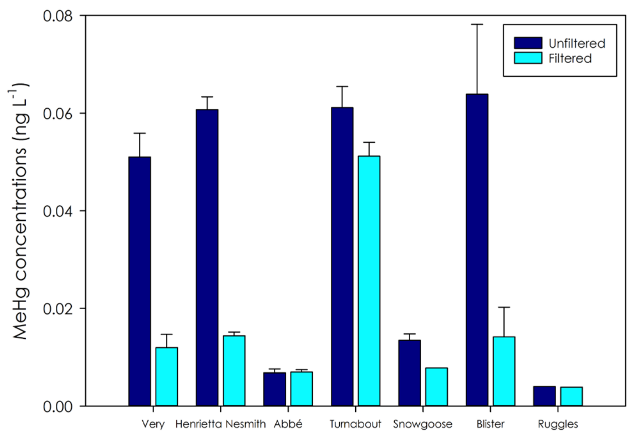


Figure 3: Unfiltered and filtered concentration of THg in glacial melt rivers, and the Ruggles River outflow.

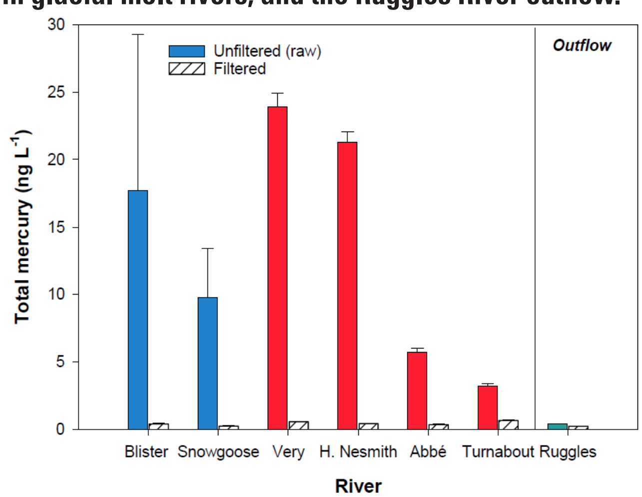
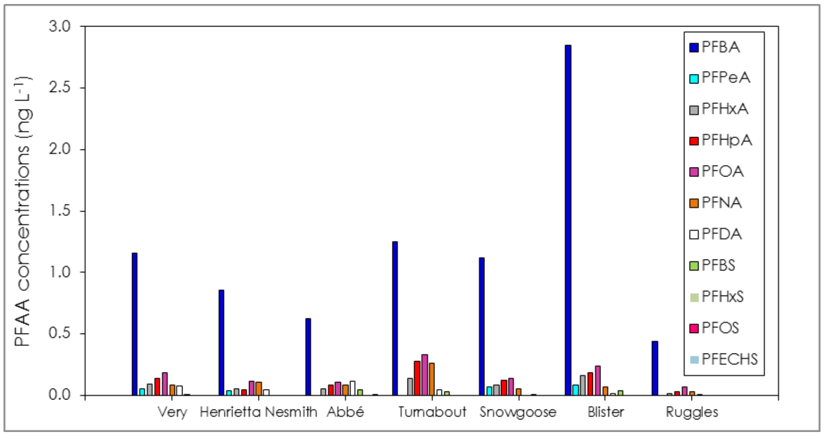
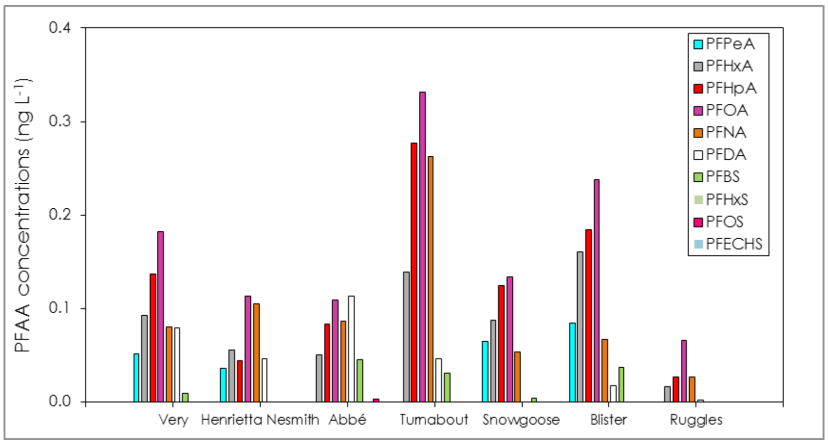


Figure 4: Concentrations of PFASs in unfiltered glacial melt rivers, and the Ruggles River outflow, with PFBA (top graph) and without PFBA (bottom graph).





Because they were within walking distance of the Lake Hazen base camp, we were also able to sample the Snowgoose River and Blister Creek five times during the summer of 2015 to examine changes in contaminant concentrations with changing river flows. These two rivers are representative of larger and smaller glacially-fed inflow rivers, respectively. Unfiltered MeHg concentrations increased from ~0.055 ng.L-1 to ~0.150 ng.L-1 at the height of glacial river runoff, but then declined to concentrations below 0.040 ng.L-1 as air temperatures cooled off and river flow decreased (Figure 5). Filtered MeHg concentrations were consistently low at ~0.010 ng.L-1 in both rivers (Figure 5), suggesting that a large portion of the MeHg in the rivers was particle bound and erosional in origin. Concentrations dropped from the beginning to the end of July by a factor of 1.6-2.0 for PFBA, the predominant PFAS congener, as well as the sum of the other PFASs (C5 to C12, PFBS, PFHxS, PFOS, PFECHS) (Figure 6). This suggests flow intensity and erosional materials do not drive PFAS loadings into Lake Hazen, and that their source is meltwater originating from more recently deposited snow and ice on glaciers.

Figure 5: Unfiltered and filtered MeHg concentrations in the Snowgoose River and Blister Creek throughout summer 2015.

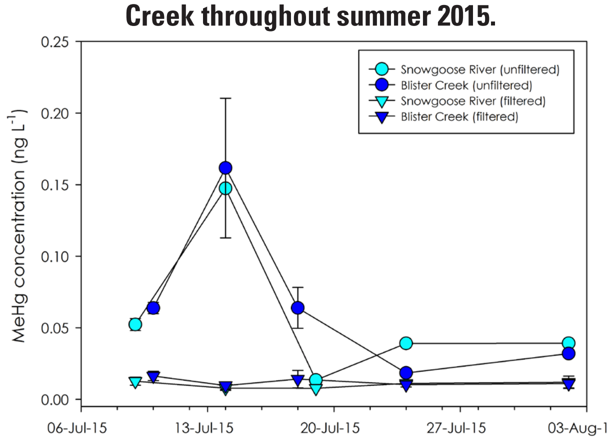
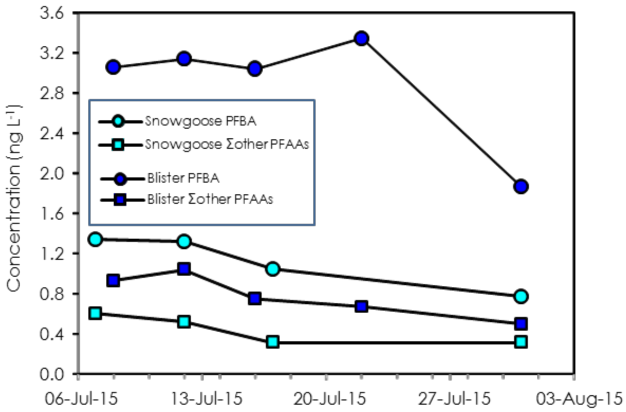


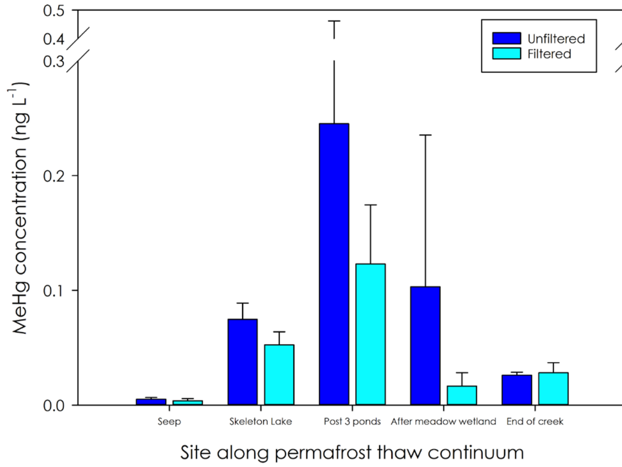
Figure 6: Unfiltered concentrations of PFBA (circles) and SPFAA all other (squares) in the Snowgoose River and Blister Creek throughout summer 2015.



Objective 2. Quantify concentrations and loads of THg, MeHg, PFASs and OPFRs in soil/permafrost thaw runoff in the pristine Lake Hazen watershed:

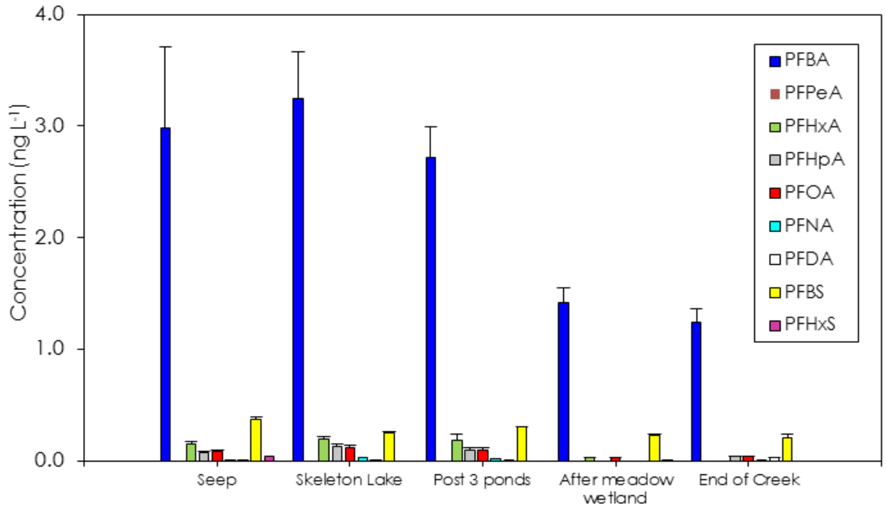
We are extremely fortunate at Lake Hazen because the nearby Skeleton Lake subcatchment allows us to quantify how soil/permafrost thaw water quality changes as it moves along a continuum from: 1) distinct thaw seepage sites; 2) through Skeleton Lake; 3) two smaller ponds; 4) *Carex* grass dominated wetlands; and 5) a tundra creek channel, prior to discharging into Lake Hazen. Both unfiltered and filtered MeHg concentrations were extremely low in water initially seeping from soils/permafrost (~0.005 ng.$L^{-1)}$ (Figure 7). Unfiltered MeHg concentrations increased as water moved through Skeleton Lake (0.075 ng.L^{-1}) and two downstream ponds (0.245 ng.L^{-1}) (Figure 7), indicating that these were both sites of active microbial Hg methylation. Unlike glacial rivers, a much larger portion of the MeHg was in the dissolved phase and not particle bound, making the MeHg much more readily bioavailable for bioaccumulation in these systems. MeHg concentrations declined as water flowed downstream through the *Carex* grass dominated wetlands and the tundra creek channel prior to entering Lake Hazen at a concentration of ~0.028 ng.L^{-1} (Figure 7), suggesting that MeHg was either sequestered or demethylated in these latter sites of the landscape continuum.

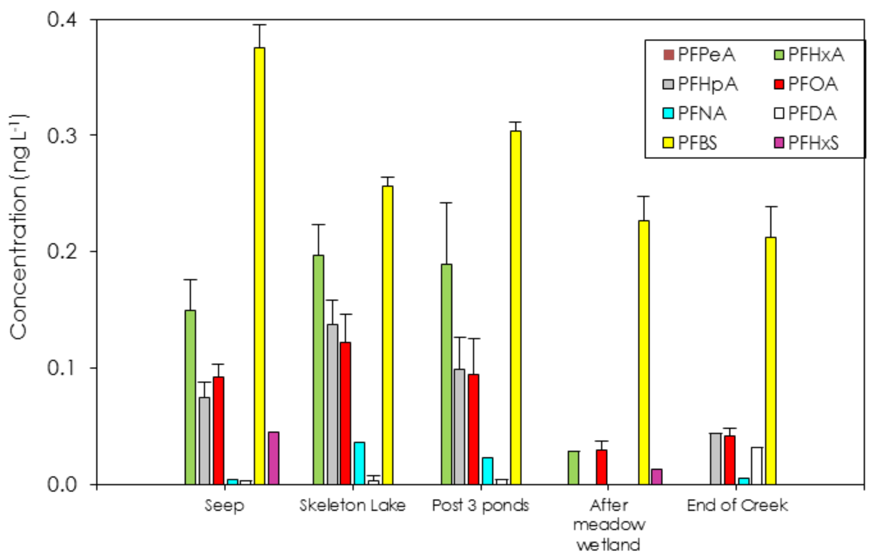
Figure 7: Changes in unfiltered and filtered MeHg concentrations in soil/permafrost thaw water as it moved across a landscape continuum from a seep site to a creek channel just prior to entering Lake Hazen.



The PFAA profile in the Skeleton continuum from the seepage site through to the tundra creek indicated high concentrations of PFBS (the four-carbon perfluorinated sulfonate) and of PFBA (Figure 8). This is a unique result as PFBS was not a predominant contaminant in the glacial rivers, the Ruggles River outflow, or in Lake Hazen itself. This suggests that the seep is a specific source of PFBS into Skeleton Creek. One hypothesis is that the seep is representative of local sources due to human activity in the Park whereas PFAAs in the tributaries and Lake Hazen are more representative of long-range atmospheric transport and deposition. Concentrations of PFAAs declined through the continuum (Figure 8), suggesting PFAA sedimentation in these latter sites.

Figure 8: Changes in PFAS concentrations in soil/permafrost thaw water as it moved across a landscape continuum from a seep site to a creek channel just prior to entering Lake Hazen, with PFBA (top graph) and without PFBA (bottom graph).

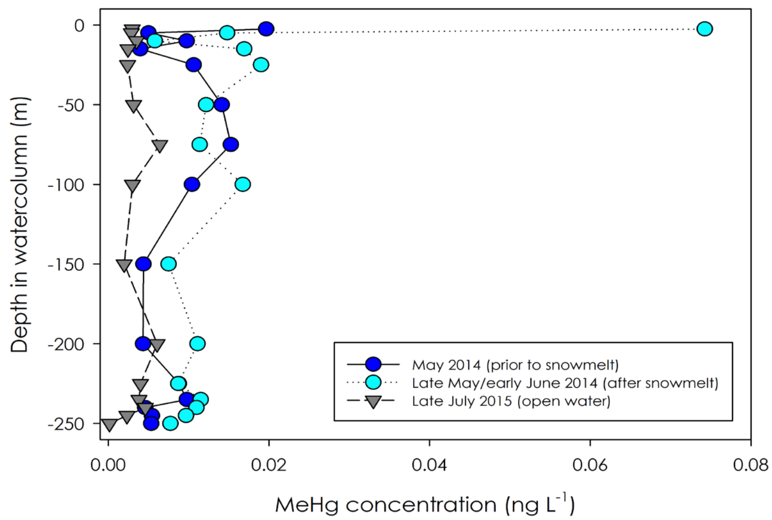




Objective 3. Quantify THg, MeHg, PFASs and OPFRs concentrations in Lake Hazen itself during the height of summer glacial melt and soil/permafrost thaw runoff:

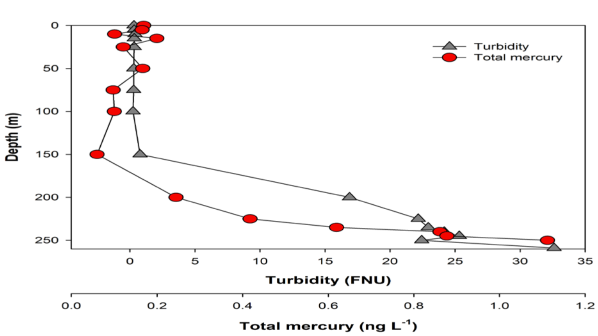
To determine the impact of glacial and soil/permafrost thaw runoff on contaminant loadings to Lake Hazen, we did a detailed sampling of the Lake Hazen water column from 27-29 July 2015 after the height of summer glacial melt and soil/permafrost thaw when the lake was mostly ice-free. Previously we found that snowmelt increased MeHg concentrations from ~0.020 ng.L^{-1} to ~0.075 ng.L^{-1} in surface waters during the important spring bloom of biological activity under the lake ice (Figure 9). Surprisingly, MeHg concentrations were extremely low (<0.006 ng.L-1) throughout the water column after the height of summer glacial melt and soil/permafrost thaw inputs, all of which were higher in MeHg concentration.

Figure 9: Unfiltered concentrations of MeHg throughout the water column of Lake Hazen under the ice before snowmelt (May 2014), under the ice following snowmelt (late May/early June 2014) and during the mostly open water period after the heights of summer glacial melt and soil/permafrost thaw (late July 2015).



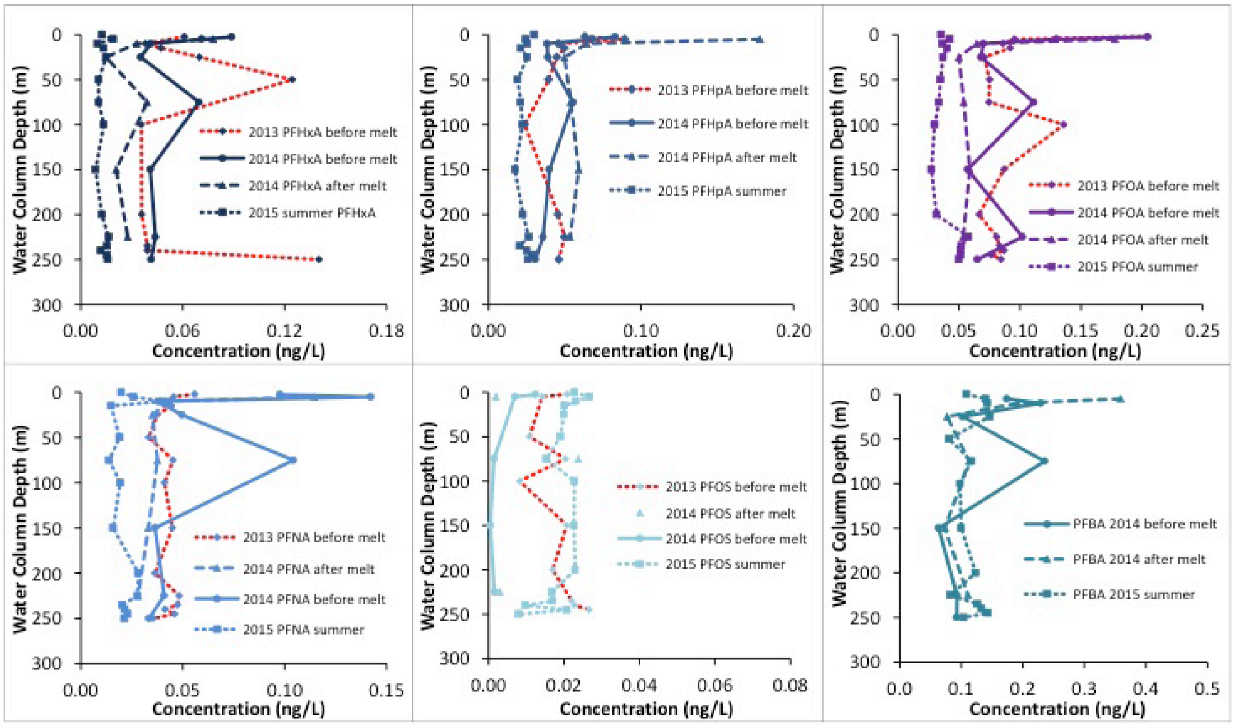
THg concentrations throughout the upper water column after the height of summer glacial melt and soil/permafrost thaw inputs were also very low (<0.3 $ng.L^{-1}$) (Figure 10). However, THg concentrations began to increase below 150 m, reaching concentrations of 1.1 $ng.L^{-1}$ near the bottom (Figure 10). Increases in THg concentrations paralleled increases in turbidity, again strongly suggesting that THg was of mineral origin. Dense and turbid glacial runoff enters the shores of Lake Hazen, and then plummets rapidly to the bottom of the lake.

Figure 10: Unfiltered concentrations of THg and turbidity throughout the watercolumn of Lake Hazen during the mostly open water period after the heights of summer glacial melt and soil/permafrost thaw (late July 2015).



PFAS contaminants throughout the Lake Hazen water column were dominated by the PFCAs, and in particular PFBA (Figure 11). PFHxA, PFHpA, PFOA and PFNA were also detected in the water column, but only at sub ng/L concentrations. The only PFSA consistently detected was PFOS, albeit at very low concentrations relative to PFCAs (Figure 11). As with MeHg, concentrations of PFAAs were elevated in surface waters following the influx of snow melt water in late May/early June. Concentrations of PFHxA, PFHpA, PFOA and PFNA were at their lowest throughout the water column after the height of summer glacial melt and permafrost thaw inputs (Figure 11), which were all higher in PFHxA, PFHpA, PFOA and PFNA concentrations.

Figure 11: Concentrations of different PFASs throughout the water column of Lake Hazen under the ice before snowmelt (May 2013 and 2014), under the ice following snowmelt (late May/early June 2014) and during the mostly open water period after the heights of summer glacial melt and soil/permafrost thaw (late July 2015)

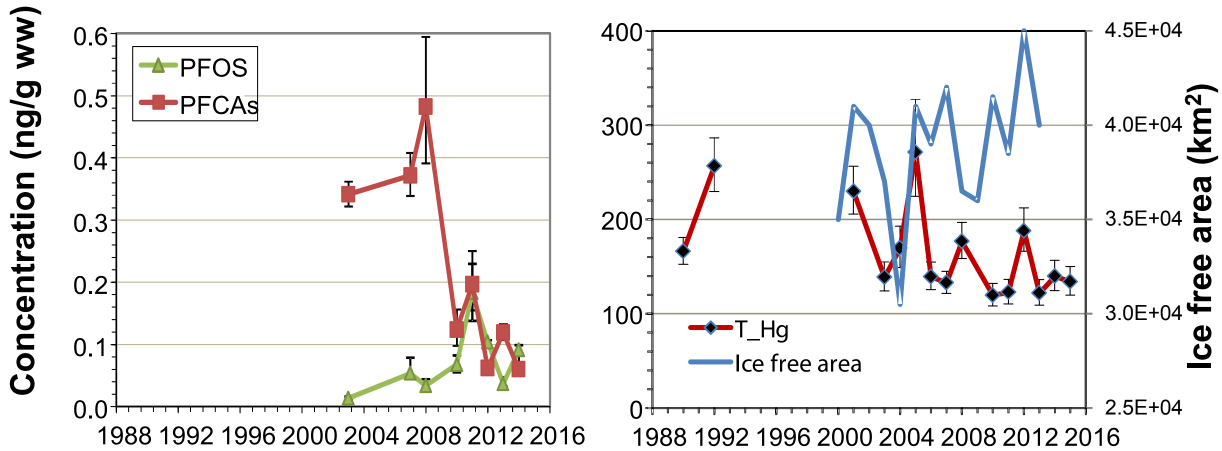


Objective 4. Quantify concentrations of THg, MeHg, PFASs and OPFRs entering into the base of the foodweb (zooplankton) during the height of summer glacial melt and soil/permafrost thaw runoff into Lake Hazen, as well as the height of lake productivity:

Zooplankton samples have not yet been analysed for their contaminant concentrations.

However, THg concentrations in Lake Hazen Arctic char have gone down from highs in the early 1990's and 2004 to lower and steadier concentrations in recent years when the ice-free area of the lake has increased (Figure 12). The decline in char Hg concentrations is much more rapid (11%.yr^{-1} from 2005-2014; Muir et al. 2015) than the decline in atmospheric Hg concentrations at the nearby Alert station on the northern tip of Ellesmere Island (Cole et al. 2013). However the decline in char Hg concentrations parallels a decline in Hg concentrations and fluxes in the most recent horizons (2007-2012) of a sediment core collected in 2013 (Lehnherr et al., unpublished data from another of our recent NCP-funded initiatives). Perfluorocarboxylic acids (PFCAs) and PFOS and have also declined recently after appearing to achieve maximum concentrations in 2008 and 2011, respectively. Declining PFOS has also been observed in the Devon Ice Cap (MacInnis et al. 2015), and reflects the phase-out of PFOS for most uses in North America and Europe. Uses of precursors of the PFCAs increased during the 2000s but are estimated to have levelled off since 2010 due to reduction of residuals in fluoropolymer products (Wang et al. 2014).

Figure 12: Trends in concentrations of PFASs and THg in Lake Hazen Arctic char, and maximum ice-free area of Lake Hazen in years 2000-2012.



Discussion and Conclusions

As described above, 2015 was an incredibly productive year. As such, it will take some time to fully synthesize all our exciting Hg and multi-analyte organic contaminant data. However, numerous questions have already arisen from our 2015 NCP sampling campaign that we will continue to investigate at Lake Hazen in in the future, with the overall goal to construct a present-day mass-balance contaminant budget for Lake Hazen. For example:

1. The summer of 2015 was exceptionally warm at Lake Hazen, resulting in elevated watershed runoff into the lake. For example, for almost 2 weeks in mid-July, the water level of Lake Hazen rose an astounding ~10 cm per day! With a surface area of 540 km^{-2}, that is equivalent to a net input of 54 billion litres of water each day, primarily from glacial runoff, but also permafrost thaw. *What would contaminant concentrations be in glacial melt and soil/permafrost thaw runoff in either a cooler or even warmer summer?* At the moment, due to 2015/2016 being a strong El Nino year resulting in the lowest ever recorded January Arctic sea ice extent (http://nsidc.org/arcticseaicenews/), we are predicting record warm weather and levels of glacial melt in the Lake Hazen watershed in the summer of 2016.

2. As we were leaving Lake Hazen in early August, glacial rivers and soil/permafrost thaw streams were beginning to flow more rapidly again due to a warming trend at that time. *What are contaminant concentrations in late season runoff when older glacial ice and permafrost is being melted/thawed, and possibly releasing archived legacy contaminants previously stored in these cryospheric compartments?* Equally interesting, *what are contaminant concentrations in early season glacial melt and soil/permafrost thaw runoff when recent deposition dominates their melt water source?* In 2015, we arrived at Lake Hazen ~ 2 weeks after the glacial rivers began flowing.

3. *What is the seasonal variation in contaminant concentrations in three of the ungauged glacially-fed inflow rivers (Very, Abbé, Turnabout), as well as the Ruggles River outflow of Lake Hazen, sampled yearly by helicopter by Parks Canada and Environment and Climate Change Canada?* We know that these rivers differ in their contaminant concentrations on a given sampling day, but do they all differ seasonally as we observed in the Snowgoose River and Blister Creek?

4. Most of the contaminants in glacial runoff were particle bound. *What is the concentration of contaminants on the particles themselves, and what is the source of these particles?*

5. Along the soil/permafrost thaw continuum we sampled, MeHg concentrations increased

as water moved through Skeleton Lake and two downstream ponds. *Where in Skeleton Lake and the two downstream ponds is the MeHg being produced, and how does that production change seasonally?*

6. The water column of Lake Hazen was fully mixed and unstratified due to dense sediment-laden and oxygenated glacial river waters sinking rapidly to the bottom of Lake Hazen. *Are the contaminant concentrations throughout the water column at the deepest part of the lake similar at all locations in the lake?* For example, *what are contaminant concentrations throughout the water column near river inflows, or near the outflow of Lake Hazen?*

Expected Project Completion Date

We expect to fully complete this project by March 2018

Project website (if applicable)

We recently purchased the website domain *www.lakehazen.ca*. This interactive website is currently under construction, but will eventually host a short documentary on our field activities, photos, sampling and analytical protocols, historical and current research databases, publications, outreach, etc.

Acknowledgments

We would like to thank the Northern Contaminants Program for financially supporting this research program, with further research funding provided by NSERC and ArcticNet (Network of Centres of Excellence of Canada). We would also like to thank the Polar Continental Shelf Project and ArcticNet for aircraft and field logistical support. We also greatly appreciated the support and field contributions of Parks Canada.

References

AMAP. 2012. Arctic Climate Issues 2011: *Changes in Arctic Snow, Water, Ice and Permafrost*. In: SWIPA 2011 Overview Report. Arctic Monitoring and Assessment Programme (AMAP), Oslo. xi + 97 pp.

ACIA. 2004. *Impacts of a Warming Arctic: Arctic Climate Impact Assessment*. ACIA Overview report. Cambridge University Press, 140 pp.

Callaghan T.V., M. Johansson, J. Key, et al. 2011. Feedbacks and interactions: from the Arctic cryosphere to the climate system. *Ambio*. 40:75-86.

Canadian Arctic Contaminants Assessment Report IIIa: Mercury in Canada's North. Ottawa: Aboriginal Affairs and Northern Development Canada.

Canadian Arctic Contaminants Assessment Report IIIb: Persistent Organic Pollutants – 2013. Ottawa: Aboriginal Affairs and Northern Development Canada.

Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability. *Contribution of Working Group II to the Fourth Assessment Report of the IPCC*. Cambridge: Cambridge University Press.

Cole, A.S., A. Steffen, A., K. A. Pfaffhuber, T. Berg, M. Pilote, L. Poissant, R. Tordon and H. Hung. 2013. Ten-year trends of atmospheric mercury in the high Arctic compared to Canadian sub-Arctic and mid-latitude sites. *Atmos. Chem. and Phys*. 13:1535-1545.

Elmendorf S.C., G.H.R. Henry, R.D. Hollister, et al. 2012. Plot-scale evidence of tundra vegetation change and links to recent summer warming. *Nat. Clim. Change*. 2:453–457.

Froese, D.G., Westgate, J.A., Reyes, A.V., Enkin, R.J., Preece, S.J. 2008. Ancient permafrost and a future, warmer arctic. *Science* 321:1648-1648.

Lenaerts, J.T.M., J.H. van Angelen, M.R. van den Broeke et al. 2013. Irreversible mass loss of Canadian Arctic Archipelago glaciers. *Geophys. Res. Letters*. 40:870-874.

MacInnis, J.J., K. French, D.C.G. Muir, C. Spencer, A.O. De Silva, C.J. Young. 2015. A 12 year depositional ice record of perfluoroalkyl acids in the High Arctic. Manuscript in review.

Muir, D.C.G., G. Köck, and X. Wang. 2015. Temporal trends of Persistent Organic Pollutants and Mercury in Landlocked char in the High Arctic. 2015. In: *Synopsis of research conducted under the 2014-2015, Northern Contaminants Program*. Aboriginal Affairs and Northern Development Canada, Ottawa. pp. 247-256.

Peterson B.J., Holmes R.M., McClelland J.W., et al. 2002. Increasing river discharge to the Arctic Ocean. *Sci.* 298:2171-2173.

Xu L., R.B. Mynemi, F.S. Chapin III, et al. 2013. Temperature and vegetation seasonality diminished over northern lands. *Nat. Clim. Change*. 3:581-586.

Wang, Z., Cousins, I.T., Scheringer, M., Buck, R.C., and Hungerbühler, K. 2014. Global emission inventories for C4-C14 perfluoroalkyl carboxylic acid (PFCA) homologues from 1951 to 2030, Part I: Production and emissions from quantifiable sources. Environment International 70: 62-75.

Temporal trends of emerging pollutant deposition through ice core sampling on the Devon Ice Cap

Tendances temporelles des dépôts de polluants émergents au moyen d'un échantillonnage par carottage de la glace sur la calotte glaciaire de Devon

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Abstract

Pollutants produced in low-latitude regions can travel through the atmosphere and be deposited in high-latitude regions, such as the Arctic, through snow. Remote Arctic ice caps can preserve and record the concentrations of these chemicals and allow us to understand trends in atmospheric transport of pollutants. In this project, ice cores were collected from the summit of a remote ice cap in the Canadian High Arctic and analyzed for perfluoroalkyl substances (PFASs) and organophosphate flame retardants (OPFRs). Changes in concentrations of pollutants with depth in the ice core allow us to determine how pollutants are transported to the High Arctic and any trends over time.

Résumé

Les polluants produits dans les régions situées à des latitudes basses peuvent se déplacer avec la neige dans l'atmosphère et se déposer dans des régions situées à des latitudes élevées, comme l'Arctique. Les calottes glaciaires éloignées de l'Arctique peuvent conserver et enregistrer les concentrations de ces substances chimiques et nous permettre de comprendre les tendances du transport atmosphérique des polluants. Dans le cadre de ce projet, des carottes de glace ont été recueillies au sommet d'une calotte glaciaire éloignée dans l'ExtrêmeArctique canadien et analysées afin de détecter la présence de substances perfluoroalkyliques et de produits ignifuges à base d'organophosphate.

This increases our understanding of sources and pathways that lead to Arctic pollution, which is critical to the management of pollutant exposure for people and wildlife in the North. The PFAS ice core results were consistent with shallow snow-pit sampling in the same location in previous years. Temporal trends dating back over three decades, along with correlations between individual species, suggest a major source to this region is atmospheric oxidation of volatile precursors. The OPFR ice core measurements represent the first of their kind, demonstrating increasing deposition over decades. This information complements current air sampling programs in the Arctic.

Les changements dans les concentrations de polluants en fonction de la profondeur de la carotte de glace nous permettent de déterminer la façon dont les polluants sont transportés vers l'Extrême-Arctique et toute tendance au fil du temps. Voilà qui améliore notre compréhension des sources et des voies qui mènent à la pollution de l'Arctique, ce qui est essentiel à la gestion de l'exposition aux polluants pour les gens et la faune dans le Nord. Les résultats liés aux carottes de glace en matière de substances perfluoroalkyliques correspondaient à l'échantillonnage de neige prise en faible profondeur sur le glacier au même endroit que les années précédentes. Les tendances temporelles remontant à plus de 30 ans, ainsi que les corrélations entre les espèces individuelles, portent à croire qu'une source majeure pour cette région est l'oxydation atmosphérique des précurseurs volatils. Les mesures des produits ignifuges à base d'organophosphate dans les carottes de glace constituent les premières dans leur genre, ce qui démontre un dépôt croissant au fil des décennies. Ces renseignements complètent les résultats des programmes d'échantillonnage atmosphérique en cours dans l'Arctique.

Key messages

- Analysis of ice cores can be used as a way to track deposition of chemicals to remote areas over time.
- Ice cores were collected from the Devon Ice Cap to understand long-range transport of contaminants to the Arctic.
- Ice cores were dated, sectioned, and analyzed for chemicals used in flame retardant and non-stick applications.
- Trends since about 1980 indicate that concentrations of most of the chemicals are increasing with time.
- Patterns and trends help to understand sources of the chemicals to the Arctic, which is essential for regulation and management.

Messages clés

- L'analyse des carottes de glace peut servir afin de suivre le dépôt des produits chimiques dans les régions éloignées avec le temps.
- Les carottes de glace ont été recueillies dans la calotte glaciaire de Devon afin de comprendre le transport à grande distance vers l'Arctique.
- Les carottes de glace ont été datées, sectionnées et analysées afin de détecter la présence de produits chimiques dans les utilisations de produits ignifuges et d'antiadhésifs.
- Les tendances depuis environ 1980 indiquent que les concentrations de la plupart des produits chimiques augmentent au fil du temps.

- Les profils et les tendances aident à comprendre les sources des produits chimiques qui aboutissent dans l'Arctique, ce qui est essentiel à la réglementation et à la gestion.

Objectives

1. Examine temporal trends of atmospheric deposition determined from the ice core analysis and relate to long-range transport, sources, and production trends for PFASs.
2. Examine temporal trends of atmospheric deposition determined from the ice core analysis and relate to long-range transport, sources, and production trends for OPFRs.
3. Provide the new information to local communities and the Nunavut Environmental Contaminants Committee.

Introduction

Remote, high-altitude ice caps receive contamination solely from the atmosphere in the form of wet and dry deposition. Layers of accumulated snow on ice caps are subject to minimal changes and the temporal record can be reasonably well established (Garmash et al. 2013, Peters et al. 1995). Ice caps can provide long-term temporal trends of past atmospheric deposition. This is important for understanding the extent of long-range transport of persistent compounds, as well as their sources and transport mechanisms. A few past studies in the Canadian Arctic have looked at persistent and emerging organic pollutants in ice caps, although these studies have had to rely on snow pits to obtain sample volumes large enough for trace analysis, which has also limited the temporal trends that could be derived from ice cap samples (Zhang et al. 2013, Gregor et al. 1995, Young et al. 2007, Meyer et al. 2012). With the development of new analytical methods and technologies, the sample volumes required to detect many persistent pollutants and emerging contaminants are now much lower, particularly for chemicals that can be analyzed by liquid chromatography-tandem mass spectrometry (LC-MS/MS). As a result, the traditional ice cap sampling technique of ice core collection (Zheng et al. 2007, Zdanowicz et al. 2013) can be applied to selected persistent pollutants and emerging contaminants such as organophosphorus flame retardants (OPFRs) and perfluorinated alkyl substances (PFASs). Collection of ice cores allows sampling of past accumulation over much greater timescales. An ice core of fifteen metres was collected from the Devon Ice Cap in spring of 2015, representing almost 40 years of depositional history, which was to be expected (Colgan and Sharp 2008, Boon et al. 2010). Depositional trends of OPFRs and PFASs going back to the 1970s provides us with a unique opportunity to examine changing Arctic atmospheric deposition with known introduction of these compounds to the market.

PFASs are found ubiquitously in the environment, and have been routinely detected in the remote Arctic, where local sources are not important. Many of these compounds are bioaccumulative and appear to biomagnify, resulting in extremely high concentrations in top predators of the Arctic food chain (Butt et al. 2010). The mechanism by which PFASs are transported to the Arctic remains uncertain. They can be emitted directly from industrial processes into aqueous systems and carried to the Arctic through ocean currents, followed by transport on marine aerosols to inland areas. Alternatively, volatile precursor compounds released from commercial products can be oxidized in the atmosphere to form perfluoroalkyl acids (PFAAs) that are subsequently deposited (Young and Mabury 2010). Samples collected in 2005 and 2006 from snow pits on the Devon Ice Cap were analyzed for PFAAs (Young et al. 2007). The results indicated that atmospheric oxidation of volatile precursors was an important source of PFAAs, but the temporal trends were difficult to interpret because post-depositional transport of water-soluble PFAAs could have impacted the results when considering such a short time series (Young et al. 2007). The results from that study also considered only 5 analytes (C8-C12 perfluorocarboxylic acids (PFCAs) and C8 perfluorooctanesulfonic acid (PFOS)). In 2006, producers of the precursors of the C8-C12 PFCAs (which are mainly fluorotelomer alcohols and related compounds (US EPA 2006) agreed to phase out the C8-containing products in favor of shorter chains (C4-C6 PFCAs) by 2015 (USEPA 2006) and the ban on PFOS has led to its replacement with the C4-compound (perfluorobutylsulfonate; PFBS). Recently PFHxA, PFBS, and several short chain fluorotelomer sulfonates (4:2 FTS, 6:2 FTS) as well as perfluoroethyl cyclohexane sulfonate (PFECHS) were reported in arctic lake waters for the first time (Lescord unpublished data). However little is known about the deposition or temporal trends of these shorter chain products in the Arctic. Therefore, this work looks at a large range of short-to-long chain PFAAs.

OPFRs are emerging contaminants often used as replacements for persistent and bioaccumulative polybrominated diphenyl ethers (PBDEs). As a result, their production and use has been increasing as PBDEs are phased out. Despite their increasing use, data on their levels in the environment, toxicity, and long-range transport remains sparse. The few studies that have examined toxicological effects have found OPFRs and their metabolites can act as mutagens (Gold et al. 1978) and endocrine disruptors (Meeker and Stapleton 2010). Furthermore, they have similar physical properties to some current use pesticides, which have been found to undergo long-range transport to the Devon Ice Cap (Zhang et al. 2013). OPFRs have been detected in a sample of snow in Sweden (Laniewski et al. 1998), in atmospheric particles in Svalbard (Salamova et al. 2014) and in arctic air (Jantunen 2014). To our knowledge there is no information on their time trends in the Arctic as of yet. OPFRs are not particularly bioaccumulative, therefore abiotic samples including ice cores, are ideal for studying temporal trends in deposition as well as long range transport potential.

Activities in 2015-2016

Field and Laboratory Work:

Ice cores were collected in the Canadian High Arctic in May 2015 from the summit (2175.4 m above sea level) of the Devon Ice Cap, Devon Island, Nunavut (Figure 1). Samples were collected using a stainless steel corer (Figure 2) and two separate ice cores were collected. A 15.5 m ice core representing 38 years of deposition (1977-2015) was used to analyze for PFAAs, and a 14.6 m ice core representing 36 years of deposition (1979-2015) was used to analyze for OPFRs. A separate core collected at the same location was dated using major ions. The samples were shipped frozen to the Canadian Center for Inland Waters (CCIW) in Burlington, Ontario, Canada, where they were sectioned in September 2015. The cores were sectioned into specific years for analysis (Figure 3). The sectioning process was performed inside a -10°C freezer and all materials used were cleaned before and after use, with methanol (for PFAAs) and acetonitrile (for OPFRs).

Samples (500 mL) corresponding to each year of deposition were extracted. The PFASs and OPFRs were extracted using solid phase extraction (SPE) and analyzed using UPLC-MS/MS with electrospray ionization in negative mode. Isotopically labeled standards were included for recovery and matrix evaluation, and cartridge blanks and recovery standards were carried through the method to ensure method quality. Matrix effects and extraction efficiency were evaluated and the concentrations of analytes as well as the fluxes per year were determined. The limit of detection (LOD) and limit of quantification (LOD) were also calculated for each analyte.

Capacity Building:

Because of the highly specific sampling process and location, there was no direct involvement of communities or hunting and trapping organizations in this proposed project. We are in the process of making a short video of the ice cap coring and the sample processing steps which will be sent to Grise Fiord, NU and made available on Young's web site (cjygroup.com).

Communications:

In the past, results of long-range transport from the Devon Ice Cap have been communicated to local communities by presentations and posters. We will prepare a poster for circulation in High Arctic communities describing the results of this study. As described above, a short video depicting the ice cap coring and sample processing steps will be posted on Young's web site. The poster and video will also be provided to the NECC. Dissemination to the scientific community will be through conference presentations, reports, and peer-reviewed publications.

Traditional Knowledge Integration:

Traditional knowledge collected in Elder's Conference on Climate Change document was used in conjunction with scientific techniques in the dating of the ice core. We will also use traditional knowledge of wind patterns to help determine the source of air depositing pollutants on the ice cap.

Results

Objective 1. Examine temporal trends of atmospheric deposition determined from the ice core analysis and relate to long-range transport, sources, and production trends for PFASs.

Ice core samples were extracted using SPE and analyzed by UPLC-MS/MS. Concentrations and fluxes of PFAA analytes were then determined. For the PFAAs, the C4-C13 and C18 perfluorocarboxylic acids (PFCAs) were detected with fluxes ranging from 0.162 – 171 ng m^{-2} yr^{-1}. The C6-C10 PFCAs were the only analytes detected in every sample and the longer-chain PFCAs (C12, C13 and C18) were only detected in a few of the samples. PFOA (C8) flux is shown in Figure 4.

The C4 and C6-C8 perfluorosulfonic acids (PFSAs), as well as perfluorooctanesulfonamide (PFOSA), were detected with fluxes ranging from 0.108 – 45.5 ng m-2 yr-1. The PFSAs were only detected in a few of the samples and PFOS (C8) was detected at higher fluxes (>LOQ) between 2011-2015. PFOSA, a neutral volatile precursor to PFOS, was detected in most samples before 2000 but only in 3 samples after 2000. In general, PFAA fluxes were greater from 2000 onwards.

In 2001, 3M, one of the largest global producers of PFASs voluntarily phased out the use and production of PFOSF-based products, including PFOS and its volatile precursor, PFOSA. In 2006, the EPA created the 2010/2015 PFOA Stewardship Program in order to eliminate emissions and product content levels of PFOA and related chemicals. Eight major fluoropolymer and telomer manufacturers volunteered to participate and by 2014, the latest EPA report indicated that all companies had achieved the goals set out by the program and reduced emissions and product content by 90-100% in general (US EPA 2006).

In our results, most of the PFCAs (C4-C13) detected in the ice cores showed either a decrease or non-detect PFCA concentration from 2011 to 2015. PFOA alone decreased from

2011 to 2015 (Figure 4). However, there are still high concentrations of the PFCA compounds being detected. The PFSAs showed a different trend and were for the most part only detected in the ice cores from 2010 onwards. These varying concentrations of PFAAs in the ice cores in more recent years may be attributed to new sources of PFAAs or other precursor compounds.

Objective 2. Examine temporal trends of atmospheric deposition determined from the ice core analysis and relate to long-range transport, sources, and production trends for OPFRs.

For the OPFRs, all of the analytes (TEP, TnBP, TiBP, TCEP, TCPP, TDCPP, TPP, TPPO, TBEP, and iDeDPP) showed a large increase in flux (pg m-2 yr-1) starting in the early 1990s (Figure 5). TCPP had the highest flux of all the OPFRs which was ~12000 pg m-2 yr-1 in 2000. TPP had the second highest flux of ~8000 pg m-2 yr-1 in 2013. TiBP had the lowest fluxes (<35 pg m-2 yr-1) of all the OPFRs present. TCPP tends to dominate the OPFR composition from 1980-2015. There was also a strong correlation between the TCEP and TnBP concentrations.

Objective 3. Provide the new information to local communities and the Nunavut Environmental Contaminants Committee.

Communication to local communities and the NECC will take place upon completion of the data analysis and interpretation. Analysis of major ions and airmass back trajectories is ongoing and is critical to the interpretation of temporal trends. The data will be provided as a poster, along with a video demonstrating the process of collection and analysis of the samples.

Discussion and Conclusions

Ice caps receive their contamination solely from atmospheric deposition and preserve a temporal record of that deposition. By sampling ice caps, we can have a better understanding of the atmospheric trends in long-range transport of persistent pollutants and emerging contaminants. Previous studies of persistent pollutants on Devon Ice Cap have been limited by the analytical methods and technologies available and have only been able to look at very short timescales (Young et al. 2007 and MacInnis et al. unpublished data). With our study, we collected 15.5 m and 14.6 m ice cores that correspond to 38 years and 36 years of deposition, respectively. These ice cores allow us to look at much larger timescales, in order to better understand the temporal trends of these persistent pollutants. As well, with more advanced analytical methodology and technologies, we are able to detect a wide range of PFASs and OPFRs at very low detection limits.

1. Many of the PFCAs were detected in most samples at concentrations above the detection limit. The C6-C9 PFCAs that were detected in all of the samples were all above the limit of quantification. The longer-chain acids (C12, C13 and C18) were the only PFCAs that were only detected in a few of the samples. The concentrations of PFCAs measured in this study were greater than those measured in the 2005 study (Young et al. 2007). The PFSAs showed varying trends among studies.

2. Even-odd pairs of PFCA congeners were observed for the C6-C11 compounds with strong correlations. The correlations between congeners are also similar to those reported previously (Young et al. 2007, Kwok et al. 2013, MacInnis et al. unpublished data). These PFCA congeners are likely from the same volatile precursor sources through gas-phase atmospheric oxidation.

3. The detection of OPFRs in the Devon Ice Cap is significant because previous studies have suggested low long range transport potential of these compounds based on physical properties and reactivity. Particle-bound transport is likely the driving force in OPFRs reaching these distances and also hinder their availability for atmospheric oxidation. The presence of TCEP, TDCPP, and TCPP is noteworthy since these are chlorinated OPFRs and are therefore more persistent and bioaccumulative than the nonhalogenated OPFRs. The time trends show increasing deposition and therefore, further insight into

the spatial pattern of OPFRs in the Arctic as well as their impact on organisms in these unique ecosystems is warranted.

Expected Project Completion Date

We expect to fully complete this project by December 2016.

Acknowledgments

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

Figure 1. Location of ice core collection on Devon Ice Cap.

Figure 2. Ice core drilling and sampling.

Figure 3. Ice core sectioning and images of ice layers.

Figure 4. PFOA flux over time with 3 and 5 year moving averages.

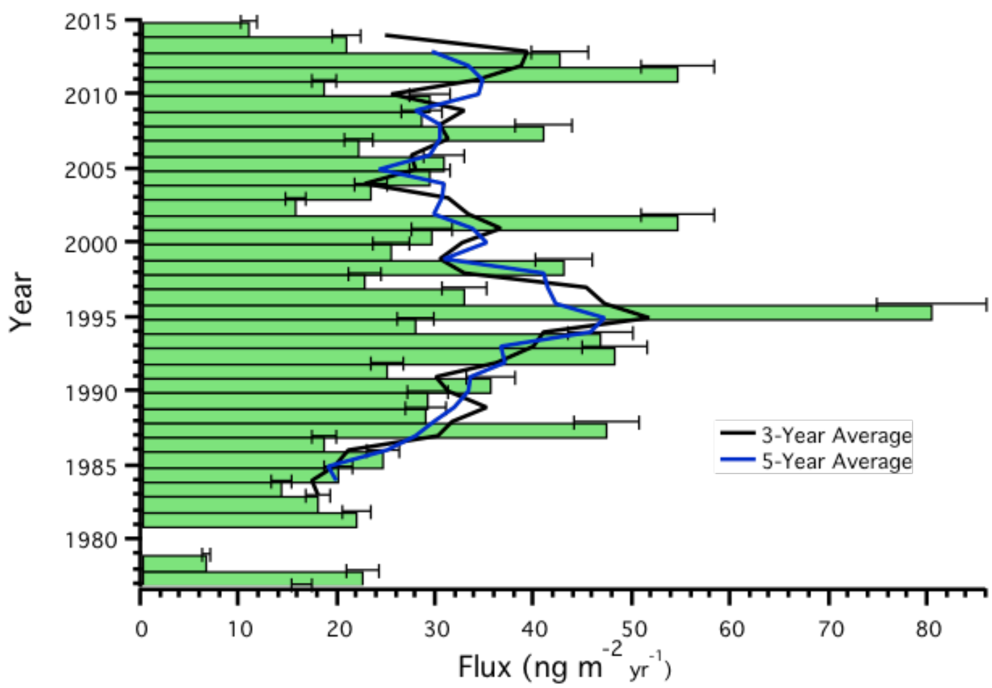

Figure 5. OPFR fluxes over time.

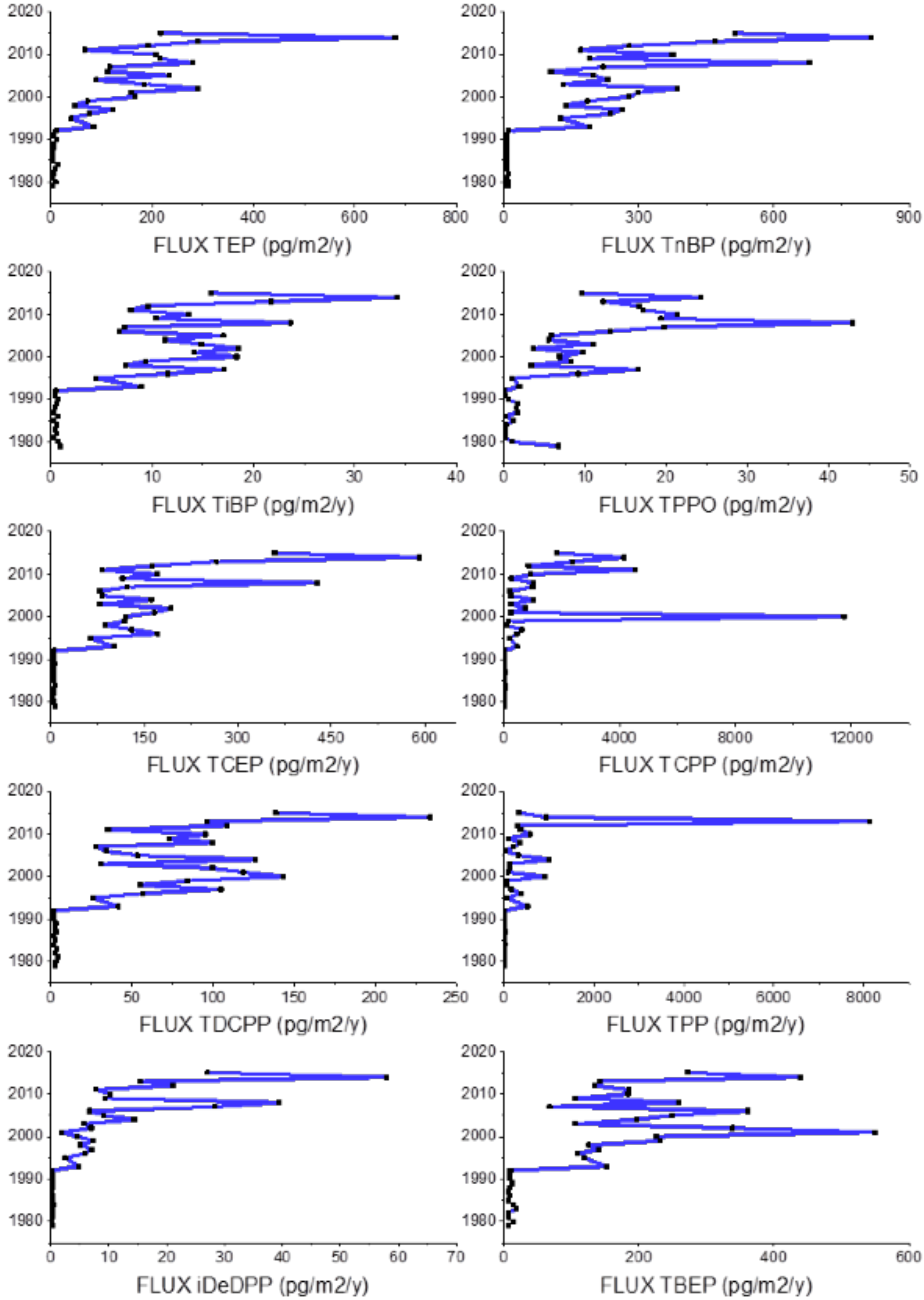

Table.

Name	CAS#	Full name
TEP	78-40-0	triethylphosphate
TBPO	814-29-9	Tributylphosphine oxide
TPrP	513-08-6	Tripropylphosphate
TnBP/TiBP	126-73-8/126-71-6	Tributylphosphate/Tri-isobutylphosphate
TPPO	791-28-6	triphenylphosphineoxide
TCEP	115-96-8	tris(2-chloroethyl)phosphate
TEEDP	995-32-4	Tetraethylenediphosphonate
TCPP	13674-84-5	tris(2-chloroisopropyl)phosphate
TPP	115-86-6	Triphenylphosphate
iDeDPP	29761-21-5	isodecyldiphenylphosphate
TBEP	78-51-3	tris(2-butoxyethyl)phosphate
TDCPP	13674-87-8	tris(1,3-dichloroisopropyl)phosphate
TDBrPP	126-72-7	tris(2,3-dibromopropyl)phosphate

References

Boon, S.; Burgess, D. O.; Koerner, R. M.; Sharp, M. J. 2010. Forty-seven years of research on the Devon Island Ice Cap, Arctic Canada. Arctic. 63: 13-29.

Butt, C. M.; Berger, U.; Bossi, R.; Tomy, G. T. 2010. Levels and trends of poly- and perfluorinated compounds in the arctic environment. Sci Total Environ. 408: 2936-2965.

Colgan, W.; Sharp, M. 2008. Combined oceanic and atmospheric influences on net accumulation on Devon Ice Cap, Nunavut, Canada. J Glaciol. 54: 28-40.

Garmash, O.; Hermanson, M. H.; Isaksson, E.; Schwikowski, M.; Devine, D.; Teixeira, C.; Muir, D. C. G. 2013. Deposition history of polychlorinated biphenyls to the Lomonosovfonna Glacier, Svalbard: A 209-congener analysis. Environ Sci Technol. 47: 12064-12072.

Gold, M. D.; Blum, A.; Ames, B. N. 1978. Another flame retardant, tris(1,3-dichloro-2-propyl) phosphate, and its expected metabolites are mutagenic. Science. 200: 785-787.

Gregor, D.; Peters, A. J.; Teixeira, C.; Jones, N.; Spencer, C. 1995. The historical residue trend of PCBs in the Agassiz Ice Cap, Ellesmere Island, Canada. Sci Total Environ. 161/161: 117-126.

Jantunen, L. 2014. Flame retardants and other persistent organic pollutants in air in the Canadian archipelago. In Synopsis of Research Conducted Under the 2013-2014 Northern Contaminants Program. Ottawa: Aboriginal Affairs and Northern Development Canada. pp. 329-339.

Kwok, K.Y.; Yamazaki, E.; Yamashita, N.; et al. 2013. Transport of Perfluoroalkyl substances (PFAS) from an arctic glacier to downstream locations: Implications for sources. Sci Total Environ. 447: 46-55.

Laniewski, K.; Boren, H.; Grimvall, A. 1998. Identification of volatile and extractable chloroorganics in rain and snow. Environ Sci Technol. 32: 3935-3940.

Lescord, G. L.; Kidd, K. A.; De Silva, A. O.; Spencer, C.; Williamson, M.; Wang, X.; Muir, D. C. G. 2015. Concentrations and biomagnification of polyfluorinated compounds through lake food webs in the Canadian high Arctic. Environ Sci Technol. In Press.

MacInnis, J.J.; French, K.; Muir, D.C.G.; Spencer, C.; De Silva, A.; Young, C.J. 2015. A 12 year depositional ice record of perfluoroalkyl acids in the High Arctic. Environ Sci Technol. Unpublished data.

Meeker, J. D.; Stapleton, H. M. 2010. House dust concentrations of organophosphate flame retardants in relation to hormone levels and semen quality parameters. Environ Health Perspec. 118: 318-323.

Meyer, T.; Muir, D. C. G.; Teixeira, C.; Wang, X.; Young, T.; Wania, F. 2012. Deposition of brominated flame retardants to the Devon Ice Cap, Nunavut, Canada. Environ Sci Technol. 46: 826-833.

Peters, A. J.; Gregor, D. J.; Teixeira, C. F.; Jones, N. P.; Spencer, C. 1995. The recent depositional trend of polycylic aromatic hydrocarbons and elemental carbon to the Agassiz Ice Cap, Ellesmere Island, Canada. Sci Total Environ. 160/161: 167-179.

Salamova, A.; Hermanson, M. H.; Hites, R. A. 2014. Organophosphate and halogenated flame retardants in atmospheric particles from a European Arctic site. Environ Sci Technol. 48: 6133-6140.

US EPA PFOA Stewardship Program; docket ID: EPA-HQ-OPPT-2006-0621; United States Environmental Protection Agency: Washington, DC, 2006.

Wang, X.; Halsall, C.; Codling, G.; Xie, Z.; Xu, B.; Zhao, Z.; Xue, Y.; Ebinghaus, R.; Jones, K. C. 2014. Accumulation of perfluoroalkyl compounds in Tibetan mountain snow: Temporal patterns from 1980 to 2010. Environ Sci Technol. 48: 173–181.

Xie, S.; Wang, T.; Liu, S.; Jones, K. C.; Sweetman, A. J.; Lu, Y. 2013. Industiral source identification and emission estimation of perfluorooctane sulfonate in China. Environ Int. 52: 1–8.

Young, C. J.; Furdui, V. I.; Franklin, J.; Koerner, R. M.; Muir, D. C. G.; Mabury, S. A. 2007. Perfluorinated acids in Arctic snow: New evidence for atmospheric formation. Environ Sci Technol. 41: 3455-3461.

Young, C. J.; Mabury, S. A. 2010. Atmospheric perfluorinated acid precursors: Chemistry, occurrence and impacts. Reviews of Environmental Contamination and Toxicology. 208: 1-110.

Zhang, X.; Meyer, T.; Muir, D. C. G.; Teixeira, C.; Wang, X.; Wania, F. 2013. Atmospheric deposition of current use pesticides in the Arctic: Snow core records from the Devon Island Ice Cap, Nunavut, Canada. Environ Sci Processes Impacts. 15: 2304-2311.

Zheng, J.; Shotyk, W.; Krachler, M.; Fisher, D. A. 2007. A 15,800-year record of atmospheric lead deposition on the Devon Island Ice Cap, Nunavut, Canada: Natural and anthropogenic enrichments, isotopic composition, and predominant sources. Global Biogeochem Cy. 21: GB2027.

Zdanowicz, C.; Krummel, E. M.; Lean, D.; Poulain, A. J.; Yumvihoze, E.; Chen, J.; Hintelmann, H. 2013. Accumulation, storage and release of atmospheric mercury in a glaciated Arctic catchment, Baffin Island, Canada. Geochim Cosmochim Ac. 107: 316-335.

Communications, Capacity, and Outreach

Communication, capacités et la sensibilisation

Nunavut Environmental Contaminants Committee (NECC)

Comité sur les contaminants environnementaux du Nunavut (CCEN)

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Abstract

The Nunavut Environmental Contaminants Committee (NECC) was struck in May 2000 to provide a forum to review and discuss, through a social/cultural lens, Nunavut-based NCP-funded projects and proposals seeking NCP funding. Through its social/cultural review of all Nunavut-based NCP proposals, the committee ensures northern and Inuit interests are being served by scientific research conducted in Nunavut. In addition, the NECC aims to serve as a resource to Nunavummiut for long-range contaminants information in Nunavut. NECC's co-chairs attended the NCP Management Committee meetings in Ottawa in April 2015 and October 2015 and the NCP

Résumé

Le Comité sur les contaminants environnementaux du Nunavut (CCEN) a été mis sur pied en mai 2000 pour fournir une tribune en vue d'examiner, d'un point de vue socioculturel, les projets au Nunavut financés par le Programme de lutte contre les contaminants dans le Nord (PLCN), d'en discuter, et de se pencher sur les propositions demandant des fonds de ce programme. Grâce à son examen socioculturel de toutes les propositions pour le PLCN concernant le Nunavut, le Comité s'assure que les intérêts des résidants du Nord et des Inuits sont pris en compte dans les recherches scientifiques menées dans le territoire. De plus, le Comité

Results Workshop in December 2015. NECC participated in the Wildlife Contaminants Workshop at the Nunavut Arctic College's (NAC) Iqaluit campus in September 2015 by contributing a talk to the seminar portion of the workshop. NECC provided feedback to NCP researchers on summary reports intended for community dissemination, met face-to-face with NCP-funded researchers to discuss their respective proposals/projects, and attended lectures at NAC presented by NCP researchers. NECC also hosted a productive social/cultural review of NCP proposals on Feb 23-24, 2016 in Iqaluit. Sixteen people participated in the face-to-face meeting, including 3 Nunavut community members for which the NECC provided travel support to attend this review meeting in Iqaluit. A total of 29 NU-based proposals were reviewed. Comprehensive feedback was provided by NECC's co-chairs to all project leaders seeking NCP funding for projects taking place in Nunavut.

se veut une ressource pour les Nunavummiuts afin qu'ils puissent obtenir des renseignements sur les contaminants transportés sur de grandes distances présents au Nunavut. Les coprésidents du Comité ont assisté aux réunions du Comité de gestion du PLCN, à Ottawa, en avril et octobre 2015, de même qu'à l'atelier sur les résultats du PLCN, en décembre 2015. Le Comité a participé à l'atelier sur les contaminants des espèces sauvages au Collège de l'Arctique du Nunavut, campus d'Iqaluit, en septembre 2015, et a fait une présentation pendant la portion séminaire de l'atelier. Les représentants du Comité ont fourni des commentaires aux chercheurs du PLCN au sujet des rapports sommaires devant être diffusés dans les collectivités, ont rencontré en personne des chercheurs recevant des fonds du PLCN afin de discuter de leurs propositions ou projets, et ont assisté à des exposés de chercheurs du PLCN au Collège de l'Arctique du Nunavut. Le Comité a également dirigé un examen socioculturel productif des propositions du PLCN, les 23 et 24 février 2016 à Iqaluit. Seize personnes ont participé à la réunion en personne, dont trois membres de la communauté au Nunavut pour qui le Comité a assumé les coûts des déplacements. Au total, 29 propositions concernant le Nunavut ont été examinées. Les coprésidents du Comité ont fourni des commentaires complets aux responsables de projet qui cherchent à obtenir des fonds pour leurs projets au Nunavut dans le cadre du PLCN.

Key Messages

- Through its social/cultural review of all Nunavut-based NCP proposals, the Nunavut Environmental Contaminants Committee (NECC) ensures northern and Inuit interests are being served by scientific research conducted in Nunavut.
- The NECC aims to serve as a resource to Nunavummiut for long-range contaminants information in Nunavut.

Messages clés

- En réalisant un examen socioculturel des propositions associées au PLCN dans le territoire, le Comité sur les contaminants environnementaux du Nunavut veille à ce que les recherches scientifiques menées au Nunavut servent les intérêts des Inuits et du Nord.
- L'objectif du Comité est de fournir aux Nunavummiuts de l'information sur les contaminants transportés sur de longues distances que l'on trouve au Nunavut.

Objectives

1. Through its social/cultural review of all NU-based NCP proposals, the NECC ensures the interests of Nunavummiut are being addressed during research activities, including:

    a. Local or northern training and capacity building opportunities are pursued by Principal Investigators (PI) whenever possible;
    b. Inuit Qaujimajatugangit (IQ) is incorporated into the study design and process;
    c. Research results are appropriately communicated back to participating or nearby communities; and
    d. Meaningful community consultation is achieved.

2. Assist researchers with conversion of NCP-funded contaminant research results into plain language that is understood by Nunavummiut;

3. Assist and advise NCP-funded researchers on the relevant methods and distribution of communication materials to communities;

4. By way of GN-Health representatives on the committee, provide relevant NCP-funded contaminant research results to the Chief Medical Officer of Health (CMOH)

5. Work in partnership with communities, researchers, governments, and Inuit organizations when undertaking community outreach related to communicating NCP research results;

6. When requested by the Government of Nunavut, provide support to the CMOH in GN-Health who will work in collaboration with NTI on the development, implementation and follow up of nutrition recommendations, food policies, and public health messages resulting from NCP funded contaminants research; and

7. Provide advice to communities on securing NCP funding for contaminants research.

Introduction

Multi-stakeholder Regional Contaminants Committees were established to provide a forum to discuss regional contaminant-related issues among interested stakeholders. The committees provide a link to the Northern Contaminants Program (NCP), which funds Northern long-range contaminants research. The NECC fosters partnerships among interested stakeholders when developing and delivering public messages concerning contaminants in relation to human health and the environment. The NECC was struck in May 2000 and since its inception, the annual social/cultural review of NCP proposals has been a primary focus. Through its review of all Nunavut-based proposals, the committee ensures northern and Inuit interests are being served by scientific research conducted in Nunavut.

Activities in 2015-2016

The following activities were undertaken by NECC in 2015-16:

- NCP Management Committee meetings were attended by NTI and INAC co-chairs in April 2015 and in October 2015

- NTI and INAC co-chairs attended NCP Results Workshop in Dec 2015

- Hosted two face-to-face NECC meetings/teleconferences: May 20, 2015 and Sep. 25, 2015 to update committee on NCP funding allocations and complete mid-year review of NCP projects

- Provided feedback on plain language summary reports prepared by PIs for community dissemination

- Participated in Wildlife Contaminants Workshop at NAC on Sep 28-Oct 2, 2015;

NECC co-chair gave presentations on the NCP and NECC

- Meeting with Hayley Hung, Alexander Steffen, Liisa Jantunen, and NECC members on Jan. 27, 2016 in Iqaluit to discuss community outreach plans for their respective proposals (i.e. M-01, M-02, M-03, M-22)
- Hosted face-to-face NECC social-cultural review meeting Feb 23-24, 2016 in Iqaluit; 16 people participated in the review
- 29 NU-based proposals were reviewed and co-chairs provided detailed feedback regarding proposals
- Produced summary report of comments related to NU-based proposals for NCP Secretariat and NCP Management Committee
- Conducted review of mid-year progress reports for NCP-funded projects
- Held sub-committee meeting to pursue work on Nunavut State of Knowledge Report June 15, 2015

Results

- Provided feedback to researchers on plain language summaries
- 2016 NECC Social-Cultural Review Summary Report

Discussion and Conclusions

The work of NECC is on-going and will continue. The NECC had a successful and productive year and plans to build on the contacts it has made with NCP researchers and northern institutions to enhance collaborative efforts that will foster more opportunities for capacity building and training for Nunavummiut and more effective communications between NCP researchers and communities. To that end, NECC is committed to assist PIs with communicating research back to their partnering communities and encourages researchers to contact NECC before they embark on any community consultations or communications.

The committee aims to continue efforts to increase regional representation on our committee by soliciting new members from each of Nunavut's regions: Qikiqtaaluk, Kivalliq and Kitikmeot. NECC will continue with its regular annual activities, including reviewing mid-year reports and requests for additional funding at mid-year, conducting a detailed social-cultural review of 2017-18 NCP proposals, helping coordinate researcher presentations in Nunavut and providing feedback to PIs on presentations and communication products intended for community dissemination. In addition to these activities, NECC is also planning to continue a subcommittee's work to develop a statement of work for a Statement of Knowledge Report on long range contaminants in Nunavut that will provide a synopsis of NCP research conducted in Nunavut over the past 20 years.

Expected Project Completion Date

Work is on-going.

Nunavik Nutrition and Health Committee: Coordinating and learning from contaminants research in Nunavik

Comité de la nutrition et de la santé du Nunavik : Coordination et apprentissage fondés sur la recherche sur les contaminants au Nunavik

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Abstract

The Nunavik Nutrition and Health Committee was established in 1989 to deal with issues related to food, contaminants, nutrition 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

Résumé

Le Comité de la nutrition et de la santé du Nunavik a été mis sur pied en 1989 pour traiter de questions se rapportant aux aliments, aux contaminants, à la nutrition et à la santé au Nunavik. Depuis sa création, le Comité a élargi son champ d'action et a ainsi adopté une approche globale quant aux questions touchant l'environnement et la santé, notamment sur les plans des bienfaits et des risques. Aujourd'hui, le Comité est l'organe autorisé d'examen et de consultation en matière de santé et de nutrition dans la région. Il comprend des représentants de bon nombre d'organismes et d'agences qui s'intéressent à ces questions ainsi que de ceux qui effectuent des recherches à ce sujet. Le Comité donne de l'orientation et assure la liaison pour les chercheurs et les organismes de la région et de l'extérieur, dirige les travaux qui

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.

portent sur les questions importantes, transmet des renseignements au public et éduque celui-ci au sujet de l'environnement et de la santé et des projets de recherche, et représente les intérêts du Nunavik sur les scènes nationale et internationale. Toutes les activités réalisées visent à protéger la santé publique au Nunavik et à en faire la promotion, en favorisant une prise de décisions personnelles éclairée.

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 de la nutrition et de la santé du Nunavik est le principal comité régional chargé des questions liées à la santé et à l'environnement au Nunavik;
- Le Comité fournit des conseils au directeur de la santé publique du Nunavik sur les activités d'information et d'éducation concernant la nutrition et la santé, y compris les bienfaits et les risques associés aux contaminants et aux aliments traditionnels;
- Le Comité continue de participer activement au Programme de lutte contre les contaminants dans le Nord : il étudie et finance la recherche dans la région, assure la liaison avec les chercheurs, et favorise la communication des résultats des recherches d'une manière qui est appropriée et convenable pour les Nunavimmiuts.

Objectives

The general objective of this project is to address regional coordination and communication needs, help researchers connect with Nunavik communities and provide information necessary for the public understanding of data relevant to environmental health and contaminants issues in Nunavik. Specifically, the objectives are:

- To interact with the NCP and other researchers working on health and environment issues and to provide the population and health workers with background information to help them understand and contextualize environmental health, nutrition and contaminants research, objectives and results;
- To compile elements of public concern which 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 or collaborate on summaries on the state of the knowledge on these issues and to assist in communication and intervention activities of local health and environment officials;
- To facilitate the NCP and other research on environmental contaminants, nutrition and health including research on risk communications and risk-perception issues;
- To help researchers translate their data into meaningful information for the public;
- To identify topics related to human health and contaminants to be monitored under the NCP;
- To support partnerships in various research and intervention activities related to country foods, nutrition and health;
- To contribute to the definition of a regional food strategy that will incorporate the issue of contaminants in country food.

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 focussing 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 with 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 2015-2016 year.

Activities in 2015-2016

In 2015-2016, the committee managed to meet three times using the additional funding allocated for two meetings considering that some members were not able to travel for each meeting. The NNHC believes it is very important to continue to meet three times a year in order to ensure regular in-person follow-up on the different files.

The first meeting took place in June 2015 in Kuujjuaq. It was a two-days meeting to discuss regular topics linked to nutrition, contaminants and Nunavimmiut health. The committee started the revision of the the NNHC Terms of References as well as the NNHC Social Cultural Review Form. Final versions of these two documents are to be adopted at the next meeting. Mélanie Lemire joined the committee on the phone to discuss the Lake Trout Project. Michel Lucas presented preliminary results on food security from the Artic Char Distribution Program Data. At this meeting, we also discussed the need of engaging in a lead reduction strategy through communication and concerted regional actions. Furthermore, we had a brief presentation on the development of the Food Security Policy. A meeting on the food security issue, gathering many Nunavik leaders, was organized in December 2014. At that meeting, it was decided that a Food Security Policy working group will be created and its coordination will be ensured by the NRBHSS. Letters to delegate representatives of regional organisations and associations were sent and many answers have been received to this date. The first working group meeting will be held on June 30. Caroline D'Astous, NRBHSS communication officer, also updated the committee about the NRBHSS new website that will be developped in 2015-2016, there will be information about the NNHC on the website.

The second meeting was held in November 2015 in Kuujjuaq and lasted two days. We, once again, addressed and followed up different topics linked to nutrition, contaminants and Nunavimmiut health. At this meeting, we adopted a revised version of the NNHC Terms of Reference (see appendix A) as well as a revised version of the NNHC Social Cultural Review Form (see appendix B). Cédric Juillet came in person to make a presentation entitled ''Harvesting to prevent hunger in Nunavik" about determinants of food security in nothern communities based on Qanuippitaa 2004 data. We also met with Mélanie Lemire on the phone to discuss the Selenium project and their next research team visit in Nunavik planned for March 2016. We also met with Gina Muckle over the phone, she presented the committee with an update on the adolescent cohort of the Nunavik Child Cohort Study. We had a presentation of Nicole Bilodeau on ''Determinant of health and self-related health". Dave Saint-Amour provided the committee with an update of the Nunavik Neurolmaging Project. An article on the ''Assessment and implementation fidelity of the Arctic Char Distribution Program" was commented and discussed at the meeting. Mylène Riva joined the committee on the phone to present the community component of Qanuilirpitaa 2017 Health Survey, the housing intervention synthesis, the socio-economic status and cardio vascular diseases. Nil Basu also gave us an update about his project.

The third meeting was held in February 2016 in Quebec City and lasted three days. It focused mainly on the review of the 2016-2017 NCP proposals for the region. The committee invited the CHUL-Public Health Unit Research team members and other researchers available to meet in person with the committee at that time so that questions raised during the proposal review could be clarified with the researchers themselves. The committee adopted this way of functioning a few years ago and feels that it is very efficient and helpful to meet researchers in person at least once a year. Researchers who were not able to travel were met by telephone conference. At the meeting, the committee also discussed regular topics.

Discussion and Conclusions

We believe it is very much needed to pursue the inter-organisational collaboration and communication through the committee work on the important issues of food, contaminants, nutrition and health.

This year, members of the committee will continue working on various files related to food, contaminants, nutrition and health including the regional lead exposure reduction strategy, the development of a regional food security policy, the planning of the Qanuilirpitaa 2017 Health Survey as well as the biomonitoring of contaminants' exposure amoung pregnant women and the evaluation of the awareness, comprehension and effectiveness of health and dietary recommendations targeted at pregnant women.

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.

Northern Contaminants Researcher: Distributing information within the Nunatsiavut region through different types of media while working with educators to engage youth with traditional and scientific methods of harvesting and sampling traditional foods

Chercheuse sur les contaminants dans le Nord : Diffusion des renseignements dans la région du Nunatsiavut grâce aux différents types de médias, et collaboration avec les éducateurs pour faire découvrir aux jeunes les méthodes traditionnelles et scientifiques de récolte et d'échantillonnage d'aliments traditionnels.

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Abstract

During 2015-2016, the Northern Contaminants Researcher (NCR) job became vacant when the original Principal Investigator Colin Webb took on other employment within the Nunatsiavut Government. Liz Pijogge was hired as the NCR. The NCR is the first point of contact for contaminant related information in the Nunatsiavut region. The NCR worked directly with many contaminant-related research projects as well as other research projects that related to the well-being of Nunatsiavummiut. Communication was achieved

Résumé

En 2015-2016, le poste de chercheur sur les contaminants dans le Nord est devenu vacant lorsque l'ancien chercheur principal, Colin Webb, a accepté un autre emploi au sein du gouvernement du Nunatsiavut. Liz Pijogge a été embauchée pour le remplacer dans ce poste. La chercheuse sur les contaminants est le premier point de contact en ce qui concerne la prestation d'information sur les contaminants dans la région du Nunatsiavut. Elle a contribué directement à plusieurs projets de recherche sur les contaminants ainsi qu'à d'autres projets

through direct trips to the communities of Nunatsiavut, informing Nunatsiavummiut of the contaminant-related research projects taking place, results produced so far and discussed any potential future research projects. This direct interaction allowed local community members to ask questions and get information directly from the NCR. Other forms of communication included social media, in-person interactions and community meetings. The NCR also sits on the Nunatsiavut Research Advisory Committee (NGRAC) and the Northern Contaminants Program (NCP) Management Committee to review research project proposals submitted to Nunatsiavut and NCP.

Key Messages

- The NCR contacted each of the project leaders of NCP projects to introduce herself, gain a better understanding of the specific project, and ensure that the successful NCP programs in Nunatsiavut continue.
- The NCR, along with the Inuit Research Advisor (IRA), visited the Environment Canada facility in Burlington, Ontario to learn how seal and fish samples are processed and analyzed, to meet staff with our partners and to further our research relationship for future projects. This provided excellent training and capacity building for the Nunatsiavut region.
- The NCR communicated information about benefits of traditional food and encouraged Nunatsiavummiut to continue to consume traditional food.
- The NCR, in partnership with the IRA while the position was vacant, worked with a wide variety of contaminant related projects to build capacity in Nunatsiavut, allowing Nunatsiavut to take leadership in these areas. This included capacity building in Nunatsiavut Government employees, harvesters and youth, relating

sur le bien-être des Nunatsiavummiuts. La communication a été assurée dans le cadre de visites dans les collectivités du Nunatsiavut, afin d'informer les Nunatsiavummiuts des projets de recherche sur les contaminants en cours, des résultats obtenus à ce jour et des possibles projets. Ces interactions directes ont permis aux membres des collectivités locales de poser des questions et d'obtenir de l'information directement de la chercheuse. Les autres moyens de communication utilisés comprenaient les médias sociaux, des interactions en personne et des rencontres communautaires. La chercheuse siège par ailleurs au Comité consultatif de la recherche du Nunatsiavut et au Comité de gestion du Programme de lutte contre les contaminants dans le Nord afin d'examiner les propositions de projet de recherche qui leur sont présentés.

Messages clés

- La chercheuse sur les contaminants dans le Nord a communiqué avec chaque responsable des projets liés au Programme de lutte contre les contaminants dans le Nord pour se présenter, bien comprendre les projets précis et assurer le succès continu des projets financés par le PLCN au Nunatsiavut.
- La chercheuse, en compagnie du conseiller en recherche inuite, a visité les installations d'Environnement Canada à Burlington (Ontario) pour apprendre comment les échantillons de phoques et de poissons sont traités et analysés, pour rencontrer les employés de nos partenaires et pour solidifier notre relation de recherche pour les projets à venir. Cette visite a été excellente pour la formation et le renforcement des capacités de la région du Nunatsiavut.
- La chercheuse a communiqué de l'information sur les bénéfices de l'alimentation traditionnelle et a encouragé les Nunatsiavummiuts à continuer de consommer des aliments traditionnels.

to contaminants and associated research processes.

- The NCR continued to work with researchers traveling to Nunatsiavut to ensure they understand the concerns, culture and traditions of the Inuit in Nunatsiavut. Also, the NCR encouraged the researchers to become more involved within the communities, including hiring and training local residents, helping to build capacity within our region.

- The NCR worked in conjunction with the Inuit Research Advisor and the Youth Outreach Worker to host community-wide traditional food events, which include a healthy traditional meal in the Nain Research Centre, while providing an informal environment for residents to access research and contaminate-related information.

- In partnership with the Youth Outreach Program, harvesters and researchers, the NCR collected and processed samples for NCP projects, building capacity and reducing costs for the research projects.

- La chercheuse, en collaboration avec le conseiller en recherche inuite pendant que le poste était vacant, a travaillé à une grande diversité de projets sur les contaminants afin de renforcer les capacités dans le Nunatsiavut, notamment pour permettre au gouvernement du Nunatsiavut de jouer un rôle de premier plan dans ces secteurs. Cela comprend entre autres le renforcement des capacités des employés du gouvernement du Nunatsiavut, des cueilleurs et des jeunes en matière de contaminants, notamment en ce qui concerne les contaminants et les processus de recherche connexes.

- La chercheuse a continué de collaborer avec des collègues venus d'ailleurs pour veiller à ce qu'ils comprennent les préoccupations, la culture et les traditions des Inuits du Nunatsiavut. Elle a incité ses homologues à s'associer plus étroitement aux collectivités, notamment en embauchant des résidants et en les formant, afin de contribuer au renforcement des capacités dans la région.

- La chercheuse a travaillé en collaboration avec le conseiller en recherche inuite et l'agent de sensibilisation des jeunes pour organiser des activités communautaires liées aux aliments traditionnels, notamment un repas traditionnel santé au Centre de recherche de Nain, où les résidants ont pu obtenir de l'information sur la recherche et les contaminants.

- En partenariat avec le programme de sensibilisation des jeunes, des cueilleurs et des chercheurs, la chercheuse sur les contaminants dans le Nord a recueilli et traité des échantillons pour les projets du PLCN, ce qui a permis de renforcer les capacités et de réduire les coûts associés aux projets de recherche.

Objectives

- Be the first point of contact for contaminants and contaminant related information for the Nunatsiavut region;
- Continue to inform Nunatsiavummiut about contaminants in the region as a large percentage of residents rely on traditional foods and need to be informed on what may be in their food and to allow for more informed decision making in the future;
- Serve as liaison between Inuit and regional/national organizations dealing with contaminants, environment and human health research in Nunatsiavut;
- Identify contaminants, environment and health-related research needs in the region, and work towards ensuring that these needs are met through connections with NCP and the greater community and facilitation of researcher-community relationships;
- Provide guidance/advice to the Nunatsiavut Government Department of Lands and Natural Resources and Department of Health and Social Development with regards to contaminant and health issues;
- Work with the Nunatsiavut Inuit Research Advisor and the Nunatsiavut Government Research Advisory Committee to further develop a research support system and infrastructure in Nunatsiavut;
- Participate on the Nunatsiavut Governments Research Advisory Committee, which reviews research proposals for the Nunatsiavut Region;
- Participate as a member of the NCP's Management Committee
- Assist researchers that are coming to Nunatsiavut to conduct research and to directly advise and assist in any planning so that any work being done is culturally relevant to the Nunatsiavut Region;
- Continue to promote alternative country food to caribou, including char and ringed seal;
- Work directly with educators and schools within Nunatsiavut to educate and directly engage youth in contaminants related research;
- Expand and manage the contaminants section of the Nain Research Centre website.

Introduction

Research in Nunatsiavut has shown that contaminants are present in traditional foods as well as water sources. It has also shown that there are drastic changes in climate, which affects the everyday life of Nunatsiavummiut. Presently, contaminant levels in country food have not been of major concern, but this needs to be continually monitored as the level of industrial development and climate change increases, causing concern in Nunatsiavut.

Climate change is changing the way that Nunatsiavummiut use the land, with reduced snow cover, thinner and less predictable sea ice and seasonally warmer temperatures. These changes have prevented Inuit in Nunatsiavut from using the traditional routes to access hunting areas and as a result, have affected the diet of Nunatsiavummiut. Furthermore, as a result in reduction of the George River Caribou Herd and the Provincially imposed 5-year hunting ban, there has been a shift in diet from caribou to seal and char in Nunatsiavut.

Contaminants are making their way into the Nunatsiavut ecosystems via long-range transport, primarily from Industrial Development. Also, local source contamination such as hydroelectric development, mining and old military sites have resulted in metals, oils and PCBs being released into the environment. Being able to discern between these local source and long-range contaminants is essential for research and management of these contaminants.

The Nunatsiavut Government Research Advisory Committee has played a large role in providing information to its beneficiaries about the benefits and risks of country food, and ongoing research in Nunatsiavut. The Northern Contaminants Researcher works closely with outside researchers, Inuit Tapiriit Kanatami, NCP, Universities and the five Inuit communities to ensure that scientific research is communicated to the people in a proper and culturally relevant way. The NCR, as a member of the committee, keeps members informed about ongoing issues that effect the Inuit in their daily lives so that informed decisions are made by all parties involved.

Activities in 2015-2016

Participation in Committees

The NCR sits on the Nunatsiavut Research Advisory Committee (NGRAC) and the Northern Contaminants Program (NCP) Management Committee to review research project proposals submitted to Nunatsiavut. During the hiring process, the NG's Research Manager represented the NCR, and the IRA filled in when necessary. The NCR is the chair of the NCP Regional Contaminants Committee. Furthermore, the NCR participated in the Nunatsiavut Government Land and Resource departmental meetings to identify and overcome challenges relating to contaminants and related information.

Communications

The NCR will use a variety of media to inform Nunatsiavummiut about contaminants, allowing residents to make more informed decisions as it relates to traditional ways of life. Primarily, in-person and phone conversations proved most effective in reaching local Nunatsiavut beneficiaries. The Nain Research Center Website was not updated during the past year, but updates are currently in progress and should be completed by summer 2016.

Collaboration and Participation in Research.

The NCR has established working relationships between Nunatsiavut and researchers of other regions that deal with contaminant-related research. The NCR has and will continue to collaborate with researchers coming to Nunatsiavut, holding open houses, and displaying research to the communities while handing out information to residents. The NCR has and will continue to work with the Going Off, Growing Strong Youth Outreach Program, taking samples and processing them for multiple contaminant-related projects including the NCP Blueprint sampling programs for ringed seal and arctic char. Additionally, the NCR and IRA travelled to Burlington, Ontario to help process seal and fish samples, learn about the analysis process and meet members of the research team. This provided essential training opportunities for NG employees, and continued to help build capacity in the region.

Nunatsiavut Government Research Advisory Committee

The NCR continues to participate on the Nunatsiavut Government Research Advisory Committee (NGRAC) to review research proposals that are relevant to the Nunatsiavut Region. This is a chance to voice concerns as a committee to ensure that all proposals are culturally appropriate, valuable and that other researchers are not already completing similar research projects. This committee provides an opportunity to represent Nunatsiavut priorities in research.

Additionally, the NGRAC serves as the Regional Contaminants Committee, reviewing all Nunatsiavut-based NCP proposals through a social-cultural lens appropriate for the Nunatsiavut region.

Website

www.nainresearchcentre.com

Twitter

@NG_research

Coordination, participation and communication: evolving Inuit Research Advisor responsibilities in Nunatsiavut for the benefit of Inuit and their communities

Coordination, participation et communication : évolution des responsabilités du conseiller en recherche inuite du Nunatsiavut, au bénéfice des Inuits et de leurs collectivités

- **Project Leader:**
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- **Project Team Members and their Affiliations:**
  Tom Sheldon, Rodd Laing, Elizabeth Pijogge, Nunatsiavut Government

Abstract

The Inuit Research Advisor for Nunatsiavut continues to serve as the first step in a coordinated approach to community involvement of Arctic science, representing a new way of knowledge sharing and engagement of Inuit in Arctic science. The Nunatsiavut Government (NG) encourages researchers to consult with Inuit Community Governments in the 5 Nunatsiavut communities, Rigolet, Makkovik, Postville, Hopedale and Nain, as well as NG departments in developing more community based research proposals. Comprehensive reviews of proposals are initiated involving appropriate NG departments, 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

Résumé

La conseillère en recherche inuite (CRI) du Nunatsiavut demeure la première personne-ressource lorsqu'il s'agit de coordonner la participation de la collectivité et les travaux scientifiques liés à l'Arctique, elle représente une nouvelle façon de mettre en commun les connaissances et de faire participer les Inuits à la science de l'Arctique. Le gouvernement du Nunatsiavut incite les chercheurs à consulter les gouvernements des cinq collectivités inuites du Nunatsiavut (Rigolet, Makkovik, Postville, Hopedale et Nain) ainsi que ses ministères pour l'élaboration de propositions de recherche communautaire. L'examen complet des propositions est effectué par les ministères concernés, les administrations des collectivités inuites et les sociétés communautaires inuites. De concert avec les CRI des autres régions inuites du Canada, la conseillère en recherche inuite du Nunatsiavut s'efforce de promouvoir

program is co-funded by ArcticNet and the Nunatsiavut Government.

Key messages

- The IRA co-coordinates 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 34 researchers from 1st April 2015 to 31st March 2016. This year the IRA has chaired 12 NGRAC meetings one of which was a face to face meeting in Nain
- 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.
- 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, researchers, students, and other organizations.

une nouvelle façon de diffuser les connaissances et de mobiliser les Inuits en ce qui concerne les sciences de l'Arctique dans la région. Le financement des activités est conjointement assuré par le Programme de lutte contre les contaminants dans le Nord (PLCN), ArcticNet et le gouvernement du Nunatsiavut.

Messages clés

- La CRI coordonne le bureau de la recherche du gouvernement du Nunatsiavut, faisant office de premier point de contact pour tous les chercheurs qui mènent des travaux au Nunatsiavut et qui doivent communiquer avec le gouvernement du Nunatsiavut ou obtenir son aide.
- La CRI est la présidente et l'administratrice du Comité consultatif de la recherche du Nunatsiavut. Le CRI a communiqué avec plus de 34 chercheurs du 1er avril 2015 au 31 mars 2016 et, cette année, elle a présidé 12 réunions du comité consultatif de la recherche au Nunatsiavut, dont une réunion en personne tenue à Nain.
- La CRI a joué le rôle d'agente de liaison, de contact et d'assistance pour ce qui est des projets de recherche menés au Nunatsiavut. Entre autres, elle a mis les chercheurs en rapport avec les personnes ou organisations pertinentes, par exemple les ministères du gouvernement du Nunatsiavut et les administrations des collectivités inuites du Nunatsiavut, et elle a fait des suggestions quant aux propositions et aux plans de recherche.
- La CRI a également assuré la liaison avec des partenaires comme l'Inuit Tapirit Kanatami, le Conseil circumpolaire inuit (Canada), les administrations des collectivités inuites et les sociétés communautaires inuites du *Nunatsiavut*, des chercheurs, des étudiants et divers organismes.

Objectives

- *Improving the coordination and operation of the Nain Research Center*
- Continued development and management of the Nunatsiavut Government research consultation process.
- Direct engagement (through implementation) in several specific regionally-led research programs, rather than solely focusing on overall research coordination and facilitation. This includes evaluation of the community freezer program in Nain.
- Improve the delivery of health messaging in the region by working directly with the Northern Contaminants Researcher, the Nunatsiavut Department of Health and Social Development and Labrador Grenfell Health to ensure appropriate health messaging related to the environment, especially messages related to valued country foods.
- Together with the IRA coordinators, and ITK and ICC Canada, ensure that projects funded by the Northern Contaminants Program (NCP) and ArcticNet have addressed local realities and concerns, integrated Inuit knowledge and undergone sufficient and meaningful consultation with Inuit.

Introduction

The Inuit Research Advisor provides guidance and recommendations related to Inuit needs, priorities, policy development, and research to NCP and ArcticNet. The Nain Research Centre is a hub for community and regionally-owned research in Nunatsiavut, including contaminants related research, and requires operational coordination. Efficient coordination will result in enhanced benefits for community members with respect to research. The Inuit Research Advisor will also focus on internal capacity building by participating more directly and actively in regionally-led research initiatives. Finally, as research in the region increases, including research related to contaminants, publication of the first annual 'Nunatsiavut research compendium' will result in greater awareness of research and a better understanding of research results generally, and contaminants related issues, specifically.

Activities in 2015-2016

- *Managed the Nain Research Center and served as chair of the Nunatsiavut Government Research Advisory Committee, making contact with all researchers, students and organizations visiting or wanting to conduct research in the Labrador Inuit Land Claim Area.*
- *Along with the IRA's in the other regions participated in numerous teleconferences and attended training/workshop in Ottawa.*
- *Attended Arcticnet's Inuit Advisory Committee teleconferences.*
- *Attended one IAC meeting in Quebec City as well as the mid-term review for ArcticNet.*
- *Participated in numerous teleconferences as a member of the Inuit* Qaujisarvingat National Committee.
- *Reviewed NCP proposals along with members of NGRAC for Nunatsiavut.*
- Actively participated in several specific regionally-led research programs, including evaluation of a community freezer program in Nain with associated contaminants research.
- Attended NCP's results workshop in Vancouver and presented a poster.
- Attended ArcticNet's, annual scientific meeting in Vancouver.
- Numerous local presentations to a variety of audiences including community public

meetings, meetings with organizations such as Inuit Community Governments and Food Security Network NL.

- Assisted researchers with hiring of local research assistants, school visits and holding open houses

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 communications, capacity and outreach products for policy makers and Inuvialuit communities in the ISR

Produits de communications, de renforcement des capacités et de sensibilisation du PLCN à l'intention des décideurs et des collectivités de la région désignée des Inuvialuit

- **Project Leader:**
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- **Project Team Members and their Affiliations:**
  Evelyn Storr (Executive Director Community Development Division), Bob Simpson (Director of Intergovernmental Relations & Corporate Operating Officer), Inuvialuit Regional Corporation, Inuvik, NT

Abstract

In 2015-2016, the Inuit Research Advisor (IRA) completed all project deliverables of this proposal including, attending two NWT Regional Contaminants Committee meetings held in Yellowknife, NT in October 2015 and February 2016, attending the NCP Annual Results Workshop in Vancouver, BC from December 7-8, 2015, and from February 23-25, 2016 helped coordinate, participated and contributed funding to the NCP funded Beluga Summit that was hosted by researcher, Dr. Lisa Loseto and her team.

Résumé

En 2015-2016, la conseillère en recherche inuite a réalisés tous les produits à livrer de cette proposition. Elle a notamment assisté à deux réunions du Comité régional des contaminants des T.N.-O. tenues à Yellowknife en octobre 2015 et février 2016, a participé à l'atelier annuel sur les résultats du Programme de lutte contre les contaminants dans le Nord (PLCN) tenu à Vancouver (C.-B.) les 7 et 8 décembre 2015, et a aidé à coordonner le sommet sur les bélugas du 23 au 25 février 2016, financé par le PLCN, y a participé et a versé une contribution financière. Cet événement était organisé par la chercheuse Lisa Loseto et son équipe.

Key messages

- Participated in the planning and execution of a Beluga Summit (Feb. 23-25, 2016, Inuvik)
- Participated in the social-cultural review of NCP proposals as part of the Northwest Territories Regional Contaminants Committee
- IRA was elected co-chair of the Northwest Territories Regional Contaminants Committee. Term ends February 2017
- IRA is engaging with the Joint Secretariat or Inuvialuit Game Council to discuss ways to enhance the review of NCP proposals in the Inuvialuit Settlement Region
- NCP Results Workshop (Dec 7-8, 2016, Vancouver) was a good opportunity to hear from many northerners about their roles in NCP projects

Messages clés

- La conseillère a participé à la planification et à la tenue du sommet sur les bélugas (23 au 25 février 2016, à Inuvik).
- Elle a participé à l'examen socioculturel des propositions du PLCN dans le cadre du Comité régional des contaminants des Territoires du Nord-Ouest.
- Elle a été élue coprésidente du Comité régional des contaminants des Territoires du Nord-Ouest. Son mandat prend fin en février 2017.
- Elle a mobilisé le secrétariat mixte du Conseil de gestion du gibier pour discuter des façons d'améliorer l'examen des propositions du PLCN dans la région désignée des Inuvialuit.
- L'atelier sur les résultats du PLCN (7 et 8 décembre 2016, à Vancouver) a été une bonne occasion d'entendre le point de vue de nombreux résidants du Nord sur le rôle qu'ils jouent dans les projets du PLCN.

Objectives

This project contained 3 main objectives including,

- Travel and participate in NWT Regional Contaminants Committee teleconferences and in person meetings.
- Participate and present a poster at the NCP Annual Results Workshop.
- Contribute to planning and funding of the NCP funded Beluga Summit.

Introduction

The Inuit Research Advisor (IRA) Program has been funded by NCP since 2006. Since then there has been an IRA in the Inuvialuit Settlement Region (ISR) advising researchers, reviewing proposals and communicating with students and researchers about Inuit involvement and benefits in research on behalf of NCP and ArcticNet. Since the inception of the IRA Program, the IRA has also communicated about NCP to ISR residents through the Inuvialuit Research Newsletter and IRA Community Tours. The IRA has also promoted other government programs that benefit northerners and researchers such as the Aboriginal Affairs and Northern Development Canada's (AANDC's) Climate Change Adaptation Program and Health

Canada's (HC's) Climate Change and Health Adaptation Program for First Nations and Inuit Communities.

The general context of the work done by the IRA is to help to improve the communication of research information and consultation undertaken by researchers in Inuit regions. As well, the position has made it possible to ensure research projects provide benefits of research to both researchers and communities in regards to capacity building, training, education and employment.

The IRA position has provided the opportunity for northern research programs like NCP and ArcticNet to meaningfully involve Inuit in their work and priorities. There has been a noticeable shift in NCP and other partner organizations on how Inuit are involved in academic and community based research, where we've seen an increase in Inuit participation, acknowledgement, capacity and interest. These changes have in turn improved researcher-community relationships thus paving the way to increased partnerships that benefit both sides, specifically around the use of traditional knowledge and Inuit experts.

IRC believes that the IRA position has and will continue to benefit Inuit regions and scientific partners across Canada and beyond for the following ways:

- Continued coordination and advice given to NCP researchers
- Increased opportunities for Inuit capacity building and training
- Increased northern engagement at NCP related events and initiatives
- Inuit involvement in proposal review process and projects

Activities in 2015-2016

In this fiscal year, the IRA completed all duties and related activities with NCP and ArcticNet as required. As well as, was able to lead two other projects on behalf of IRC on topics of climate change and food security.

In October 2015, the IRA was nominated along-side Scott Tomlinson of NCP to co-chair a new Health Subcommittee, set up to review communication materials and health messaging of current contaminants results for the Beluga Summit.

In February 2016, the IRA attended the NWT Regional Contaminants Committee (NWT RCC) social-cultural review of proposals and reviewed all ISR based proposals. Ms. O'Hara was nominated and accepted the role of co-chair the NWT RCC until February 2017.

During the NCP Results Workshop (Dec 7-8, 2015, Vancouver), the IRA presented a poster. The poster focused on the timeline of the consultation process between NCP researchers and northern communities in the ISR. The IRA also participated and attended other sessions that were relevant to the ISR during the workshop.

Leading up to the Beluga Summit in Inuvik, the IRA coordinated a regional meeting with Inuvialuit organizations, including the Inuvialuit Game Council and Joint Secretariat, as well as DFO. The IRA also took part in planning meetings via several teleconferences and phone conversations. It was determined that through the IRA, IRC would support the event by coordinating a traditional feast, supporting local caterers to do this work.

The Beluga Summit was very successful and appreciated by everyone in attendance. The IRA participated in breakout sessions and community and academic presentations, and it was clear that the mix of experts sharing results together was the key to its success. Both northerners and scientists took a lot of knowledge away from the meeting and it was good to see Inuvialuit who were part of the research do their presentations and be highly engaged in their questions for researchers, and vice-versa. You can tell that the community members in attendance gained a lot of insight and clarification on what NCP does and how the result of the work impacts them for the better. Traditional knowledge sharing was a highlight of the meeting as different communities were able to learn more about each other's techniques for hunting and monitoring beluga whales.

Capacity Building

Inuit Advisory Committee meeting, Quebec City, September 29-October 1, 2015

The Inuit Advisory Committee (IAC) met prior to the ArcticNet Mid-term Review meeting in Quebec City in September 2015. At this meeting, the IAC met to strategize how the Committee would handle the priority of ensuring an Inuit Legacy in Arctic research and how to handle the concept within ArcticNet of Highly Qualified Inuit Personnel (HQIP). At the meeting the IAC drafted up a statement for ArcticNet addressing Inuit interest of planning to address Inuit legacy into the future, specifically when ArcticNet sunsets in 2018.

Inuit Legacy breakout session at ArcticNet Annual Scientific Meeting

As a result of the IAC meeting in Quebec City, it was determined that in order to address the idea of HQIP and Inuit Legacy in research, we needed more input and feedback from other Inuit and other northern organizations that might have role in this work. Therefore, the IAC submitted an abstract to ArcticNet to hold a one hour break out session at ArcticNet Annual Scientific Meeting to bring together scientists, northern organizations, Inuit and other northerners to have an initial conversation about the concept. The audio recording of this session will be professionally analyzed in 2016. The next step of the IAC is to undertake a professional evaluation of Inuit involvement in research through the ArcticNet program, and come up with a way to measure the success of Inuit capacity building and training in this program. This evaluation will allow the IAC to draft up a best practices and successes document that will outline where gaps may exist for Inuit participation and involvement in research and where Inuit have been successful in leading or engaging in research.

Youth Climate Change Coordinators

One of the projects led by the IRA in 2015-2016 was called Inuvialuit Youth: On the Frontline of Climate Change, funded by INAC. This grassroots project empowers youth to lead climate change adaptation workshops in each Inuvialuit community through support of full-time positions. IRC set up 6 offices in ISR organizations that allowed youth to lead these workshops and engage with their community. Youth Coordinators also put up climate change story boards and interviewed Elders and community members on what they knew about climate change, adaptation and how to plan for these changes. This work will be converted into 6 community climate change adaptation plans, a regional adaptation strategy and website to house all this material.

Reindeer Harvesting Training Program

Another project led by the IRA was called Sustaining Inuvialuit Households: Increasing Food Security and Decreasing Poverty in the Inuvialuit Settlement Region. This is a grassroots level program funded by the NWT Anti-Poverty Fund, running over two years (2014-2016). The basic goal of this work was to encourage youth and adults in the region to learn new skills and techniques in the occupation of reindeer husbandry and harvesting. Also part of this training was an introduction to food insecurity and mental health issues that may be caused by having not enough food to eat. Professional councillors and staff from IRC's Resolution Health Support Program were on hand throughout the life of the project to give our youth participants information on what programs are available to them. Meat from the program was distributed in each Inuvialuit community first to single parent families, Elders and those with disabilities or in need. Once that need was met, meat was then donated to community organizations in Inuvik such as the Arctic Food Bank, Inuvik, Food Bank, Inuvik Homeless Shelter, Inuvik Warming Shelter, Ingamo Hall, Inuvik Youth Center and Inuvik Regional.

Communications

Poster at NCP Annual Results Workshop

The IRA communicated to NCP researchers and students at the NCP Annual Results Workshop by presenting a poster outlining the timeline of consultation that should be followed to improve relationships, partnerships and community involvement and interest in research. This timeline was very clear and the poster provided lot of tips on how to better communicate research information and results back to the region.

Traditional Knowledge Integration

Beluga Summit 2016

The Beluga Summit was a perfect opportunity for the IRA to become engaged in contaminants issues and learn more about traditional knowledge of beluga whales. There were many informative discussions and presentations during the meeting that helped to shape how Traditional Knowledge (TK) will be viewed and respected in future NCP work.

Discussion and Conclusions

The main focus this year was the NWT Regional Contaminants Committee, researcher consultation and communications. The IRA attended two NWT RCC meetings and the Annual Results Workshop. It is the hope of IRC that NCP will once again give the IRA funding to conduct regional projects that help to communicate NCP research and initiatives in a more direct way (e.g., community visits). In addition, the IRA would still like to pursue completing an evaluation of the Newsletter and will focus this coming year on that task.

Expected Project Completion Date:

March 31, 2016

Project website

http://www.arcticnet.ulaval.ca/research/advisors.php

http://www.nasivvik.ca/our-team/inuit-research-advisors

Acknowledgments

Thank you to Dr. Loseto for nominating the IRA to co-chair the Beluga Summit Health sub-committee.

Thank you to staff at DFO, Joint Secretariat and Inuvialuit Game Council for their support and effort to plan and deliver a successful first Beluga Summit in the ISR.

Thank you to NCP researchers and students who took the time to contact and consult with IRC prior to their research taking place.

Nunavik Inuit Research Advisor

Conseiller en recherche inuite au Nunavik

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Abstract

The Nunavik Inuit Research Advisor (IRA) is part of the Renewable Resources, Environment, Lands and Parks Department of the Kativik Regional Government. The IRA works in close cooperation with the Nunavik Board of Health and Social Services (NRBHSS) and the Makivik Research Centre, and is co-funded by the NCP and ArcticNet. The aim of the IRA is to facilitate research at the regional level and assure the effective liaison between northern communities and researchers.

In order to achieve the objectives, the advisor reviews research proposals and provides relevant comments and suggestions. Attending meetings, like the Northern Contaminants Program (NCP) Results Workshop, Nunavik Nutrition and Health Committee meetings (NNHC), and international scientific conferences such as the ArcticNet Annual Scientific Meeting (ASM), is part of the IRA mandate. The IRA also organizes and gives training sessions in collaboration with the three other regional IRAs, in the Inuvialuit Settlement Region, Nunavut, and Nunatsiavut.

Résumé

Le conseiller en recherche inuite (CRI) au Nunavik fait partie du Service des ressources renouvelables, de l'environnement, du territoire et des parcs de l'Administration régionale Kativik. Le CRI travaille en étroite collaboration avec la Régie régionale de la santé et des services sociaux du Nunavik (RRSSSN) et le Centre de recherche de Makivik, et il son poste est cofinancé par le Programme de lutte contre les contaminants dans le Nord (PLCN) et ArcticNet. L'objectif du CRI est de faciliter la recherche à l'échelle régionale et d'assurer une liaison efficace entre les collectivités du Nord et les chercheurs.

Afin de réaliser les objectifs, le conseiller examine les propositions de recherche et fournit des commentaires et des suggestions pertinents. Assister à des réunions, comme l'atelier sur les résultats du PLCN, les réunions du Comité de la nutrition et de la santé du Nunavik, et à des conférences scientifiques internationales, comme la réunion scientifique annuelle d'ArcticNet, fait partie du mandat du CRI. Le CRI organise des séances de formation en collaboration avec les trois autres CRI régionaux, dans la Région désignée des Inuvialuit, au Nunavut et au Nunatsiavut.

Key messages

- Research occurring in the North is beneficial and should be done in concert with local communities to better answer their needs, values, priorities and/or concerns
- In order to achieve that goal, communication between northern and scientific communities must be possible
- The role of the IRA is to promote this communication and facilitate the establishment of a relationship and collaboration between northerners and the research community
- The IRA guides and advises research projects or regional authorities in regards of Inuit needs, and communicates back to the communities the project results

Messages clés

- La recherche effectuée dans le Nord est bénéfique, et elle devrait être effectuée de concert avec les collectivités locales pour bien tenir compte de leurs besoins, de leurs valeurs, de leurs priorités et de leurs préoccupations.
- Pour atteindre cet objectif, il faut que les communications entre les collectivités nordiques et scientifiques soient possibles.
- Le rôle du CRI est de favoriser cette communication et de faciliter l'établissement d'une relation et d'une collaboration entre les résidants du Nord et le milieu de la recherche.
- Le CRI guide et conseille les responsables de projets de recherche et les autorités régionales en ce qui concerne les besoins des Inuits, et il diffuse auprès des collectivités les résultats des recherches.

Objectives

The main objectives in relation to the Northern Contaminants Program are to guide and assist researchers with their project and involve Inuit, Northern communities and local organization within those research programs.

- Be an active member of the NNHC;
- Liaise with national and international organizations and other Inuit regional organizations in matters related to Arctic science and research;
- Act as a liaison between researchers and communities to facilitate research and the development of effective partnerships;
- Collaborate with Nunavik Research Center in developing and implementing a research licensing tool for the Nunavik region; ensuring that the researchers communicate with the appropriate community representatives (and vice-versa);
- Develop a research mentorship program for KRG and Nunavik;
- Identify concerns and priorities of northerners, communities, and regional organizations in order to promote these to the NCP and other researchers;
- Identify potential community or regional partnerships to be made with existing and future projects;
- Identify opportunities for youth to become engaged in research and science;
- Identify northern students and youth interested in participating in research activities and connecting them with

appropriate research projects and training initiatives;

- Identify Inuit-led project proposals that could apply for funding;
- Provide information on other research activities occurring in the region;
- Provide support and advice to communities on research from the Northern Contaminants Program;
- Offer guidance in the production of promotion and communication materials and the distribution of these materials in each region for the research programs and individual projects;
- Offer guidance and, where appropriate, assist with communicating research results of individual projects to relevant communities and regional organizations;
- Gather and locate accurate and relevant contaminant materials to distribute;
- Provide support and direction for researchers coming to work in Nunavik and help with communicating the results back (e.g. to communities, policy makers, local decision makers) in a responsible and collective manner;
- Provide information regarding research in Nunavik and opportunities for local involvement
- Inform and communicate with the Nunavik population about contaminants research and the results of research studies. (NNHC communication protocol differs from other regions; therefore the IRA alone may not freely communicate the research results without discussing the accuracy and terminology of research with the NNHC. If the media is used as a source of communication, the communication department of KRG must give a consent form before the results are published or announced for the region by the IRA);

Introduction

The past decade has seen a reinvestment in Arctic Science in Canada and an increased level of research activity in the Arctic. Currently a series of multidisciplinary science programs, are looking to work closer with Nunavik communities in order to better integrate Inuit concerns and needs into science and policy and to improve cooperation at community, regional and international levels.

In 2003, The Nasivvik Centre for Inuit Health and Changing Environments identified the need for coordination of research being undertaken in the North, Utilizing NCP's successful partnership model Nasivvik, in collaboration with ITK and ICC- Canada, developed the regional Inuit Research Advisor (IRA) positions. These positions were established to better coordinate research, build capacity, and encourage greater Inuit engagement in research and foster researcher and community interactions. The Nasivvik Centre is no longer able to fund the IRA positions.

The ArcticNet Network of Centers of Excellence and the Northern Contaminants Program now provide funding for an Inuit Research Advisor (IRA) in each of the four Inuit land claim regions of the Canadian Arctic. To guide Arctic research and to engage Inuit in undertaking research activities of importance to their communities. Inuit participation at the regional level is mandatory to ensure appropriate community consultation and liaison and effective communication between researchers, regions, coordinators, and liaison officers. The IRAs receive support and training to assist university and government researchers in making the appropriate connections with communities and regional organizations, to develop Inuit-led research projects, and to facilitate research in Inuit regions on contaminants, climate change and environmental health. The IRA position is a step towards a more coordinated approach to community involvement and coordination of Arctic science and represents a new way of knowledge sharing and engagement of Inuit in Arctic science.

These regionally based IRA positions receive support and coordination both nationally and internationally from Kendra Togoona and Eric Loring from ITK from Dr Scot Nickels and from Pitsey Moss-Davies, the ICC ArcticNet Coordinator. Additional support in Nunavik, for the IRA position, will come with mentorship from Michael Barrett as well as other members in the environmental and renewable resources fields of the Kativik Regional Government and the from the NCP funded Nunavik Nutrition and Health Committee.

Activities in 2015-2016

During 2015-16 the Nunavik Inuit Research Advisor, Betsy Palliser, kept in contact with the Communities, Regional Entities, Researchers and Research Institutions through telephone and internet from her office in Puvirnituq. She also worked in collaboration with the other Inuit Research Advisors including participating on monthly conference calls organized by the ITK. During the year of 2015-16, Research advisor for Nunavik became an active member of the scientific committee for Qanuilirpitaa 2017 for Inuit health survey that is planned to be held during summer of 2017. She also became a member of Tukisik Observatoires hommes-milieux international (OHMi).

Travels and meetings attended include the following:

Inuit Research Advisors meeting and training Ottawa in May 23-28, the training was about Translating Research into a policy and practice offered by University of Ottawa.

Open dialogue seminars Laboratório de Excelência (Labex) DRIIHM in Aix en Provence, France from June 5-13, 2015.

Consulting population of Salluit and Kangiqsujuaq regarding ice monitoring project near Raglan, June 15-19, 2015 with 2 researchers from University Laval.

Attending Qanuilirpitaa 2017 (Inuit Heath Survey) Scientific Committee meeting for the first time in June 29 in Quebec City and attending the visio-conference the same committee on August 28, 2015

On August 19-27 Inuit research Advisors(IRA) we invited to National Inuit Youth Council in Iqaluit to give a presentation about their role as Inuit Reseach Advisor to You from all over Canada

Centre Etudes Nordiques (CEN) is planning to build a research centre in Kangiqsualujjuaq, on September 23 IRA consulted the population of Kangiqsualujjuaq about the future centre, with two directors of CEN.

Inuit Advisory committee had a face to face meeting in Quebec City followed by ArcticNet Mid-year meeting on September 27-29, 2015

Resources and Sustainable Development in the Arctic (ReSDA) invited the Nunavik IRA to be in meeting that was held in Kuujjuaq on October 21-23

Nunavik Nutrition and Health Committee meeting in Kuujjuaq November 17-19, 2015

IRA is involved in working group for Qanuilirpitaa 2017; she was in meeting with Qanuilirpitaa 2017 December 01, 2015. The following day they consulted all the mayors of Nunavik communities in Montreal to inform them about upcoming Inuit Health Survey.

NCP result workshop in Vancouver December 02-09, 2015

ArcticNet ASM in Vancouver December 07-11, 2015

IRAs has regular conference call about once a month and some with Tukisik team (Observatoires hommes-milieux international) (OHMi).

Results

The Nunavik IRA, Betsy Palliser, was again very active this year in attending many regional and international meetings. She was able to develop collaborations with researchers and helped in the development of their project. She helped in defining main concerns of those projects in relation to the Nunavimmiut priorities in terms of research. She also was able to reorient some aspects of scientific projects to better tally Northern Communities' needs. The IRA therefore initiated and simplified interactions between scientists and Northerners. One good example for this is the role that she played in the implementation and development of the OHMI project. The aim of this project is to investigate concerns within Northern communities. Those concerns are numerous and include among other things ice safety, climate change, tourism and development, mining impacts. The investigation of those concerns is done through the gathering of community members, academic researchers and cross cultural exchange with other arctic communities. Betsy was therefore an important pawn in first helping out to highlight main priorities in Northern communities, and secondly, to facilitate contacts between community members and researchers.

Each year, the IRA is active in advising regional authorities on various subjects like food and health issues. As a member of the Nunavik Nutrition and Health Committee, Betsy Palliser attended meetings and reviewed proposals, results, updates and recommendations. In regards of what Betsy could observe in communities and from what Inuit were telling her, she was able again to lead the NNHC's work in the direction fitting communities' priorities and needs in terms of public's education on food and health problems. As part of the Northern Contaminants Program, the IRA was again this year really essential in advising them on policy issues, determining in what direction research should go and again making recommendations.

IRA is also contributing in various ways, during the year of 2015-16, Betsy Palliser became an active member of the scientific committee for Inuit Nunavik Health Survey, Qanuilirpitaa 2017, that is planned to be held during Summer of 2017.The Scientific Committee is divided in three sections, *Adult health component*, *Youth health component* and the new component is Community *health component*. The committee had one face to face, but the rest of the conferences are being held by visio-conference.

She also became a member of Tukisik-Observatoires hommes-milieux international (OHMi-Nunavik) Betsy Palliser travelled to Aix-en- Provence to attend an open dialogue Seminars. In Nunavik, there are five University students who have travelled to conduct research in field. They are funded by OHMi- Nunavik and they are working closely with Kativik Regional Government and Nunavik Research Centre.

The IRA was also a key link between the scientific and Northern communities. It is important that Inuit be aware of research occurring near them, the results that are coming out of them and that they are able to give feedbacks. The IRA played also a major role in decimating results for example from ArcticNet network studies. Betsy also heard communities' opinions and knowledge and tried to make recommendations on how this can be incorporated in research.

Discussion and Conclusions

With the expansion of population in the North and with the new reality of climate changes, more and more research projects are occurring in Northern communities. They are necessary to better understand what is happening in communities and their surroundings, to better understand the impacts of changing environments, resources exploitation and/or new ways of living. Therefore, those research projects are important to better manage natural, economical and human resources. However, what is important or what is interesting in terms of research projects to scientists who are strangers to the North, is not often a priority for people living in Northern communities. There is also a big gap in terms of communication between communities and researchers that is hard to fill.

The IRA therefore has a key role in Northern research projects and for Inuit's interest that should be kept. It is essential to try to gather the Northern and scientific communities. To achieve that goal, communication between the two parties must be possible. Northern communities should have the chance to express their needs, concerns and priorities in terms of research. They should be aware of past, ongoing and future research projects and associated results. They should also be able to integrate traditional knowledge within those projects. Researchers should be able to hear them, and integrate, modify, and/or adapt their studies to better answer their needs and concerns.

The IRA serves well this mission. She is there to work with communities and transfer back the information to them. She can advise, orient, and produce tools in regards to a research project to better answer communities' needs and understanding. She facilitates the development of links between scientists, local people and traditional knowledge holders that are not so evident to create. However, those links are essential to do "good research" in accordance to Inuit's priorities: this collaboration is beneficial to both parties.

In the long term and in some cases, the establishment and maintenance of relationships between scientist and community is possible without any intervention. However, it is not the majority and therefore, the IRA still serves an important role. She can help in creating the link between them by assuring communication and/or she can help in putting a scientific project in a broader context of Inuit's needs and concerns.

The IRA will therefore continue to attend various meetings and conferences in order to stay up-to-date on researches occurring in the North and their results/recommendations. She will continue to attend NCP result workshop, and NNHC meetings. She will also be participating at various conferences like the National Inuit Climate Change Committee, the ArcticNet Inuit Advisory Committee, the ArcticNet Students Association meetings, etc. Consequently, she will be able to continue advising and guiding scientists throughout their research project, and she will be able to communicate the information back to Northern communities. In sum, the IRA is essential in creating and preserving the relationship and collaboration between Northern communities and scientists to have research projects adapted and meaningful to Nunavimmiut.

Expected Project Completion Date

This project is a long-term one: the IRA in Nunavik has an important role and should not be abandoned. Therefore, it is impossible to tell a completion date; at the moment, the longer the IRA is in position, the better it is for research in collaboration with Northern communities.

Wildlife Contaminants Workshop – linking wildlife and human health through a hands-on workshop

Atelier sur les contaminants des espèces sauvages : Associer les espèces sauvages et la santé humaine dans le cadre d'un atelier pratique

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Abstract

We delivered an environmental contaminants training workshop for students in Nunavut Arctic College's Environmental Technology Program in Iqaluit, September 26 to October 5, 2015. The workshop employed classroom lectures, field trips, group discussions, and interactive laboratory activities, to teach students core concepts, issues, and methodology related to study and assessment of chemical contaminants in the Arctic environment from both scientific and Inuit perspectives. Students learned directly from Northern Contaminants Program research scientists how contaminant trend monitoring programs are designed and

Résumé

Nous avons offert un atelier de formation sur les contaminants environnementaux aux étudiants du Programme de technologie environnementale du Collège de l'Arctique du Nunavut, à Iqaluit, du 26 septembre au 5 octobre 2015. L'atelier comprenait des cours magistraux, des visites sur le terrain, des discussions de groupe et des activités interactives en laboratoire pour enseigner aux étudiants les concepts de base, les problèmes et les méthodes liés à l'étude et à l'évaluation des contaminants chimiques présents dans l'environnement arctique, du point de vue tant des chercheurs que des Inuits. Les étudiants ont

conducted. Students also received hands-on training in specific methods for marine bird and seal tissue sampling, and they participated in a field activity to learn techniques for measuring chemical dispersion in aquatic environments. Students also learned traditional Inuit techniques for harvesting, flensing and butchering ringed seals from a local wildlife expert, and they took part in a unique dialogue with an experienced elder/hunter about traditional methods to assess animal health and to determine the safety and quality of country foods. Throughout the workshop students learned methods for assessing health risks posed by contaminants in country foods, and participated in developing strategies to communicate contaminants research and health information to specific target audiences in Nunavut. A formal assessment of the workshop's impact found that student self-assessed knowledge of and ability to communicate about contaminant issues increased between the start and end of workshop, and that students' awareness and understanding, and ability to apply knowledge related to contaminant exposure and health risks increased through their participation in the workshop.

appris directement auprès des scientifiques du Programme de lutte contre les contaminants dans le Nord comment les programmes de surveillance des tendances des contaminants sont conçus et exécutés. Ils ont aussi reçu une formation pratique sur les méthodes précises pour l'échantillonnage de tissus des oiseaux marins et des phoques, et ont participé à des activités sur le terrain pour apprendre les techniques de mesure de la dispersion chimique dans les environnements aquatiques. Un expert local de la faune a enseigné aux étudiants les techniques traditionnelles inuites pour chasser et dépecer le phoque annelé. Les étudiants ont aussi eu l'occasion de discuter avec un aîné chasseur d'expérience au sujet des méthodes traditionnelles pour évaluer la santé de l'animal, et déterminer l'innocuité et la qualité des aliments traditionnels. Pendant l'atelier, on a enseigné aux étudiants des méthodes pour évaluer les risques pour la santé posés par les contaminants dans les aliments traditionnels, et ils ont participé à l'élaboration de stratégies pour communiquer les résultats des recherches sur les contaminants et les renseignements sur la santé à des auditoires cibles au Nunavut. Une évaluation officielle des répercussions de l'atelier a permis d'établir que les étudiants estimaient que leurs propres connaissances et leurs capacités de communiquer des renseignements sur les problèmes des contaminants avaient augmenté grâce à l'atelier. De plus, les étudiants étaient davantage sensibilisés à la question des contaminants et la comprenaient mieux. Ils avaient une capacité accrue d'appliquer leurs connaissances sur l'exposition aux contaminants et les risques pour la santé.

Key messages

- The Wildlife Contaminants Workshop was held at the Nunavut Arctic College as part of the Environmental Technology Program in September 2015.
- Students, Elders, community members and researchers were involved in the workshop with the purpose of increasing the group's knowledge and understanding of contaminants in northern wildlife.

Messages clés

- Un atelier sur les contaminants environnementaux a été organisé au Collège de l'Arctique du Nunavut dans le cadre du Programme de technologie environnementale, en septembre 2015.
- Des étudiants, des aînés, des membres de la collectivité et des chercheurs ont participé à l'atelier, qui avait pour but d'augmenter les connaissances des participants sur les

- The 2015 workshop also included an evaluation component that aimed to assess the workshops ability to increase student understanding and communication skills of northern contaminants studies.
- Student self-assessed knowledge, ability to apply knowledge, and communication skills were all found to increase throughout the workshop.

contaminants présents dans la faune du Nord, et d'améliorer leur compréhension du sujet.

- Dans le cadre de l'atelier de 2015, une évaluation était aussi incluse pour évaluer si l'atelier améliorait la compréhension des étudiants et leurs capacités de communication des études sur les contaminants dans le Nord.
- Les étudiants ont évalué leurs connaissances et leur capacité de les appliquer, ainsi que leurs compétences en matière de communication, qui ont toutes augmenté grâce à l'atelier.

Objectives

The intent of the workshop was to provide ETP students with foundational knowledge, skills, and experience they will need to engage meaningfully in contaminants research and communication activities upon entering Nunavut's workforce as frontline environmental practitioners.

Overall project objectives included the following:

1. To provide students a background of contaminant research in the Arctic, resulting in an increased capacity to understand the Northern Contaminants Program (NCP) and contextualize into the broader health and environment, information on contaminants and individual project results.
2. To provide training with two applied science projects, demonstrating how research projects in the North are used to study wildlife health and the safety of country foods, allowing an increased capacity to engage in contaminants research in the future.

Specifically, the workshop aimed to:

1. To enhance student knowledge an understanding of contaminant sources and pathways.
2. To increase student awareness of contaminants research being done in northern Canada, and its role in informing guidelines and policies.
3. To enhance student understanding on how health risks related to contaminants in country foods are assessed.
4. To engage students in developing an evaluating materials/strategies to communicate contaminants information to target audiences in their home communities.
5. To increase student awareness of how community collaboration is an active and important component in contaminants research.
6. To foster student skills in dissection and contaminant tissue collection in two wildlife examples: marine birds and seal.
7. To provide students an opportunity to interact with contaminant researchers and

ask questions about contaminants research in the North.

8. To increase student awareness of the value of bringing together local ecological knowledge with science for contaminants research and understanding.

9. Carry out a formal assessment of the workshop's impact on student knowledge.

Introduction

"Frontline workers" such as wildlife and fisheries officers, HTA managers, community health workers and nurses, and other local experts, play crucial roles in NCP research, communication, and outreach efforts throughout the North. These local experts are frequently involved in reviewing research proposals and permit applications, and they are often called upon to support operational aspects of research, such as coordinating specimen collection, administering health and dietary surveys, providing interpretation, and other forms of logistic support. Frontline workers are also often asked to help translate, disseminate, and explain contaminants research results and related health advice to other community members. They are typically the individuals who other community members turn to for information about environmental contaminants.

In the early phases of the NCP, a focused effort was made to build northern frontline workers' capacity to engage with contaminants research and communication efforts through delivery of targeted training. Frontline worker training courses were delivered throughout the North, including in Iqaluit in 1998 and in Rankin Inlet in 2000 (DIAND 2003). These training efforts may have been very successful, but they were not well documented and were never thoroughly evaluated to determine their efficacy.

Previous frontline worker training targeted community professionals, elders, and youth, and did not typically include students from Nunavut Arctic College's Environmental Technology Program (ETP) who are preparing to enter Nunavut's workforce as frontline workers.

ETP has now been running for 26 years. The approximately 100 graduates of the program have worked in broad range of occupations including conservation officers, water and fisheries technicians, environmental policy analysts, environmental assessment practitioners, and environmental educators. ETP graduates have also worked as Inuit research advisors, and have served on the Nunavut territorial contaminants committee.

The *wildlife contaminants workshop* is an adaptable, integrative and iterative training program tailored for the specific needs and interests of ETP students. The workshop is delivered as a core part of the ETP curriculum and builds on a long established outreach partnership between Nunavut Arctic College and Environment and Climate Change Canada, initiated during the International Polar Year (2007 – 08). Through applied training in the fields of biology, wildlife management, communication, and the health sciences, the workshop provides our students with core skills and experience to engage competently in contaminants research and communication activities when they enter the workforce.

From 2007 to 2013 the workshop focused on providing students hands-on experience dissecting marine birds as part of a long term research study to assess contaminant and parasite burdens in birds, and to document the spread of disease within bird populations. The curriculum covered basic science related to the sources, pathways, fate, and effects of contaminants in the marine environment. Short-term employment opportunities have been provided for students that show proficient dissection skills. In 2011, the Arctic College Fur Production and Design class (hereafter, the design class) also joined the workshop to learn about marine bird research in Nunavut and to teach and learn about how eider skins are used in traditional design.

Since the inception of the workshop, its scope has expanded beyond pure science to include the participation of regional health authorities, and members of the Nunavut Environmental Contaminants Committee, to foster broader discussions related to human health risk assessment, country food and nutrition, and community research relationships. In 2013, the program also included a presentation on contaminants in caribou and a science communication workshop. Since this time the workshop has also included the involvement of elders/hunters to share their experiences through an interactive discussion with the students and researchers. In 2015, the workshop expanded to extend additional opportunities for other NCP researchers and local experts to participate and share diverse knowledge and experience related to contaminants, wildlife health, and contaminants communication.

The 2015/16 ETP class represents the ninth class of the program to participate in the workshop. With the aim to learn from past experiences, and evaluate how the workshop is meeting its current objectives, the workshop instructional team partnered with researchers from Trent University to carry out a formal assessment of the workshop. The evaluation focused on 6 learning domains fields (depth and breadth of knowledge, knowledge of methodologies, application of knowledge, communication skills, limits of knowledge and understanding, and professional capacity and aptitude), with the goal to improve curriculum content and delivery of future workshops.

Activities in 2015-2016

This year again we held a weeklong workshop that covered several wildlife groups, and how we study contaminants in each. Due to other activities occurring at the college during the week, this year the workshop only involved in the first year students for most of the program.

Monday Sept 28th – The students were given a 'pre-module' survey, to be analysed in comparison with a 'post-module' survey (for each section of the workshop) as part of the workshop program evaluation that we conducted this year. The start of the wildlife contaminants workshop then started with an

in-depth presentation on contaminants in the Arctic including the following:

- Definition of contaminants
- Where contaminants come from and how they travel to the Arctic
- Concepts of biomagnification and bioaccumulation
- Classes of contaminants, with a focus on mercury
- Mercury in seals
- Health assessments

In the afternoon, the students participated in a hands-on exercise measuring river flow with Murray Richardson. The purpose of this activity was to investigate how contaminants can move through freshwater systems.

Environmental Technology Students at the Nunavut Arctic College in Iqaluit learn how to process samples for contaminant knowledge at the Wildlife Contaminants Workshop

Tuesday September 29th – The presentation on contaminants in the Arctic continued with the following:

- Persistent organic pollutants: legacy and current use
- Focus on POPs in seals
- POPs in other Arctic wildlife studied under NCP
- Contaminants in caribou and polar bears (Rob Letcher)

In the afternoon Murray Richardson did a follow up calculation with the class for the river flow exercise. This was followed by a presentation on climate change and the potential effect of climate change on contaminants in the environment. After this presentation, the students broke into groups to discuss ways in which we can reduce contaminants in the environment. Each group made a formal presentation of their ideas to the class.

Wednesday September 30th – The students were given a 'pre-module' survey, to be analysed in comparison with a 'post-module' survey (for each section of the workshop) as part of the workshop program evaluation that we conducted this year. Students were split into two groups. One group learned about marine bird research in northern Canada, and learned how to dissect and take samples from marine birds with Jennifer Provencher and Guy Savard. The other group of students learned about seal hunting and dissection through a demonstration by Glenn Williams (Nunavut Tunngavik Inc.). This group also learned how to take samples for contaminant analysis and to weigh samples for mercury analysis. These samples were then taken back to Derek Muir's lab in Burlington, analysed for mercury and the results sent back to the students.

Thursday October 1st – The groups were switched from Wednesday so that all students experienced the marine birds and seal dissections.

In the evening Derek Muir and Robert Letcher from ECCC gave a joint community lecture at the Nunavut Research Institute. Translation was made available to all who attended. The title of the talk was "An overview of how we sample Arctic Char, ringed seals and polar bears for research and monitoring of chemical contaminants".

Friday October 3rd – The students were given a 'pre-module' survey, to be analysed in comparison with a 'post-module' survey (for each section of the workshop) as part of the workshop program evaluation that we conducted this year. Guest speakers were invited to talk to the students about various contaminants research in the north. Speakers included:

- Sharon Edmunds-Potvin (Nunavut Tunggavik Inc.)
- Rob Letcher (Environment and Climate Change Canada)

- Lilianne Kydd (Indigenous and Northern Affairs; Northern Contaminants Committee)

During the second half of the morning Joshua Kanga from the Amarok Hunter and Trapper Association (Iqaluit) came to talk with the students. Joshua, an experienced hunter, answered questions from both the students and the researchers related to wildlife and contaminants.

For the program evaluation we developed an evaluative framework to guide assessment of workshop activities and experiences in association with specified workshop objectives and recognized learning outcomes. Outcomes were established through assessing the goals of the workshop, and by interviewing the instructors to gain an understanding of what they were aiming to communicate to the students. As identified above, pre-and post-module surveys were completed by students during the workshop. A random selection of students were also invited to participate in a more detailed semi-directed interview discussing their perspectives on the workshop and its various components. Semi-directed interviews were also conducted following the workshop with the organizers, and guest instructors. Pre- and post-module survey data was entered into a spreadsheet program for analysis. Interview recordings were transcribed and entered into NVivo for qualitative analysis. A review of workshop materials (hand-outs, instruction slide content etc.) was reviewed for the evaluation in addition to participant observation notes taken by an observer from the evaluation team during the week in Iqaluit.

The goal of the evaluation was to both assess student knowledge gained during the workshop, and to evaluate how different components of the workshop could be improved on in the future to better prepare students to discuss issues related to northern contaminants research.

Environmental Technology Students at the Nunavut Arctic College in Iqaluit learn how to flense and butcher ringed seals as part of the Wildlife Contaminants Workshop

Results

In 2015 a total of 16 first year students from the ETP at Nunavut Arctic College in Iqaluit participated in the program assessment. Preliminary results give insight to the impact of the workshop module delivery on student knowledge and understanding of contaminant sources and pathways. Results related to Workshop Objective 1 are provided here.

In relation to workshop Objective #1 'To enhance student knowledge and understanding of contaminant sources and pathways' the evaluation indicated the following:

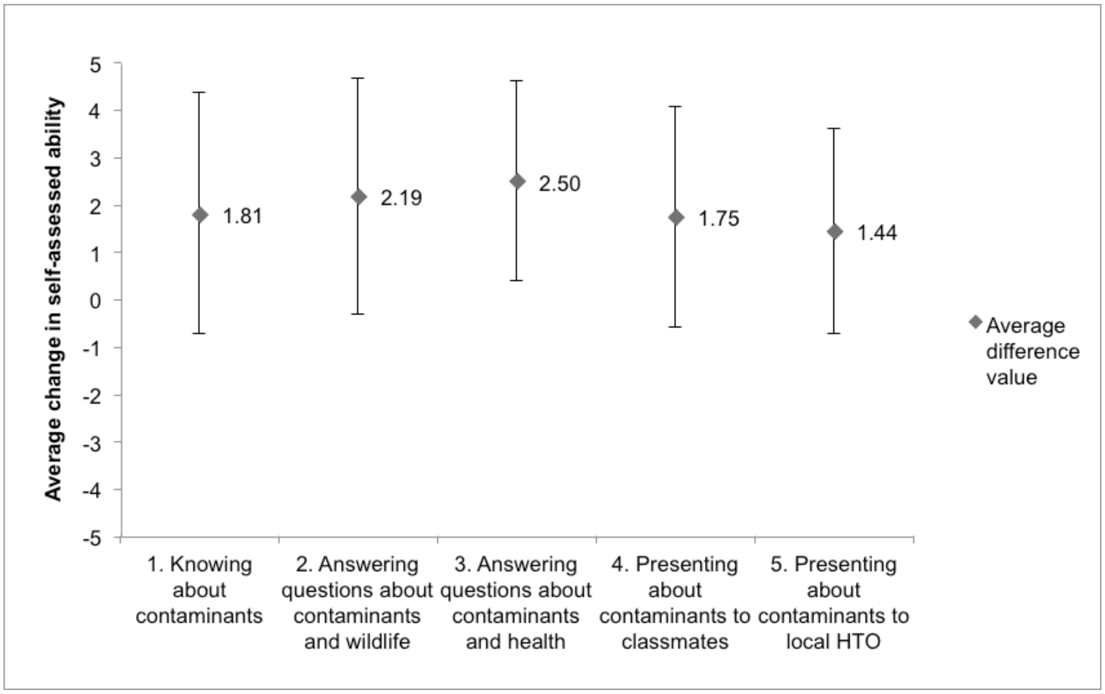
- Student self-assessed knowledge of and ability to communicate about contaminant issues increased between the start and end of workshop module 1 (Wildlife and Contaminants, Fig 1).
- The evaluation survey indicated that students' awareness and understanding, and ability to apply knowledge related to contaminant exposure and health risks increased through their participation in workshop module #1 (Fig 2).
- Further, workshop module 1 increased students' understanding of what contaminants the NCP program works with and refers to when using the term "contaminant" as well (Fig 3).

Results of semi-directed interviews with 8 workshop participants indicated that 100% of students provided responses indicating that Objective #1 was met. Students highlighted having learned about the distance and complexity of contaminant pathways, the lifetime of contaminants in the environment, processes through which they are transferred in Arctic food chains, and concentration levels in Arctic wildlife species. The exposure to this information was seen as being very valuable by students, as one reported "…*it's really valuable learning about the contaminants, and how they get here, and how they are literature stuck here. That was important.*" (Workshop Participant).

Interviews with core and guest instructors indicated that they all felt that the workshop achieved objective 1 very well. As stated by one, *"I think that we do depth and breadth of knowledge in a fairly good way. We try to give them a background of contaminants research, we try to give them background in, you know, what is a contaminant? How does a contaminant get to the north? Why is it important to study?"* (Core Instructor). A review of curriculum materials for the module showed that key concepts about contaminants, sources and pathways was delivered and space was made for classroom discussion and complementary activities to support learning of concepts. Classroom observations indicated that the amount and nature of student questions about contaminants greatly improved throughout the module and week. Students scored 100% on a pop quiz about contaminants at the end of module 1.

Workshop objective 1 was associated to the learning outcome of "Depth and Breadth of Knowledge" in the evaluation framework. Data gathered from the various sources (semi-directed interviews, pre-and post-module surveys, participant observation and review of curriculum materials) all supported an assessment that the workshop process and content achieved objective 1, and that the students acquired a depth and breadth of knowledge on contaminant sources and pathways. Analysis of the evaluation data for the workshop is ongoing and planned to be completed during the summer 2016.

Figure 1. Average change (+/-S.D.) in self-assessed ability among students on various topics pertaining to contaminant knowledge and communication capacity in pre- & post-module 1 surveys (skills were assessed on scale from 1-10).



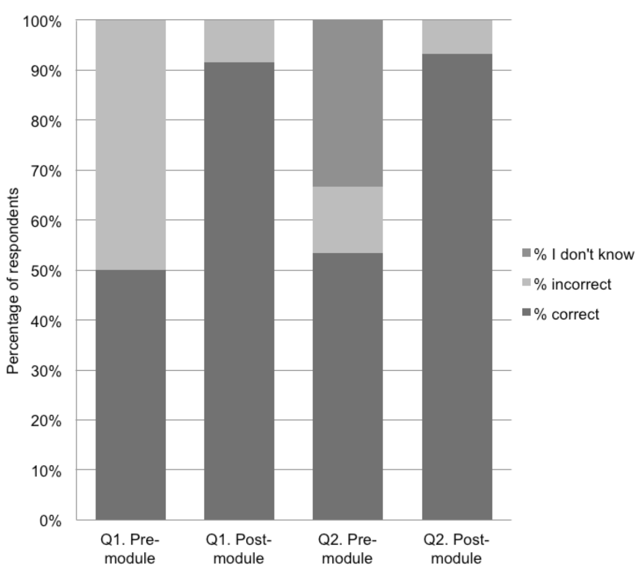


Figure 2. Change in responses to questions assessing knowledge and understanding on contaminants issues in the Arctic among workshop participants pre- and post-module 1; [Q1 What is the main (most important) way that people in Nunavut are exposed to contaminants like mercury and PCBs? (n=12); Q2 Considering contaminant levels in country food, which is the better food meal choice for a young woman of child-bearing age? (n=15)].

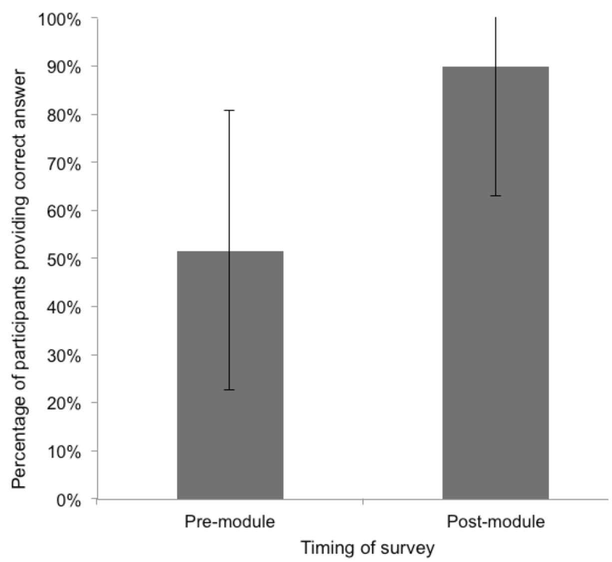


Figure 3. Percentage of students answering multiple choice question "Which of the following things do you consider to be contaminants found in country foods? (Check all that apply)" correctly before and after participating in workshop module 1 (n=15). Bars represent the standard deviation.

Discussion and Conclusions

The main purpose of the workshop is to build core understanding of contaminants research among Nunavut's future environmental managers and decision makers, and increase their capacity to effectively interpret, evaluate, and convey contaminants information to other community members. Thus, while increasing knowledge about contaminants research in the north among the ETP students is an essential part of this objective, it is also critical that students are given the opportunity to discuss and apply these ideas for them to be able to answer community questions and participate in discussions about northern contaminants. While the workshop has traditionally focusing on discussing how researchers communicate their findings using different media, and how these are effective for difference audiences in Nunavut, the program evaluation program has also highlighted that students need more opportunities within the workshop to promote the application and synthesis of the concepts being taught.

While we present our initial findings here, the overall analysis of the results is still underway. Data analysis will be completed by May 2016, with final writing of the evaluation report for peer-review will wrap up in August 2016. Once the analysis is complete, we will also share our findings with our project partners. These findings will also be instrumental in planning the workshop for 2016/17 (contingent on funding).

Expected Project Completion Date

The workshop component of this project finished in October 2015. The program evaluation component is ongoing, with early results presented here. We anticipate the program evaluation to be completed and submitted for peer-review in August 2016.

Acknowledgments

We thank all those project partners who have worked and supported this workshop since it first started in 2007 under the International Polar Year. We are particularly thankful to the Northern Contaminants Program for recognizing the importance of this program, and their support to continue this work at the Nunavut Arctic College. We are especially thankful to the community of Coral Harbour, Cape Dorset, and Resolute Bay, Nunavut who have supported this workshop through the scientific collections of marine birds in the region. We would also like to extend our appreciation to the Amarok Hunter and Trapper Association and to Joshua Kanga in particular, who each year provides a valuable discussion where both researchers and students can learn about Inuit traditional knowledge. Also, special thanks to Lilianne Kydd, Sharon Edmunds-Potvin and Glenn Williams for sharing their knowledge with the students; to Joe Nowdlak for supplying the seals used in workshop activities. We also want to extend our immense appreciation to Romani Makkik for her continued support of the workshop over several years, and for this year helping to coordinate NTI's critical involvement in the project.

The collection of marine birds used for this project was supported by Environment and Climate Change Canada, the Northern Scientific Training Program (Polar Knowledge Canada), and the Arctic Institute of North America (via Grant in aid program). JFP is supported by Ducks Unlimited (Bonnycastle Fellowship), the Garfield Weston Foundation (via the Association of Canadian Universities for Northern Studies (ACUNS)), Polar Knowledge Canada (annual scholarship), the Arctic Institute of North America (Jennifer Robinson and Lorraine Allison awards), Natural Sciences and Engineering Research Council of Canada (NSERC), and the Ontario Graduate Scholarship program. The evaluation component of this project was supported through funding from the NCP, the Nasivvik Centre and in-kind contribution from Trent University. The analytical components of this project were supported by the Northern Contaminants Program (Indigenous and Northern Development Canada), and the University of Windsor, NSERC, and the Canada Research Chairs Program.

Community gathering in the ISR: Sharing knowledge about beluga whales

Rencontre communautaire dans la RDI : Diffuser les connaissances sur les bélugas

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Abstract

A Beluga Communications Summit was held in Inuvik, Northwest Territories, February 23-25 2016. The meeting was jointly organized by Fisheries and Oceans Canada (DFO), the Fisheries Joint Management Committee (FJMC) and the Inuvialuit Game Council (IGC). The Summit brought together approximately 80 participants that included researchers from government (DFO, Health Canada and Indigenous and Northern Affairs Canada), academia and interest groups, local Inuvialuit (including harvesters, elders and youth) from the six Inuvialuit Settlement Region (ISR) communities along with regional DFO resource managers and Inuit Tapiriit Kanatami to share their knowledge on the Beluga population in the ISR and discuss future priorities. The concept of holding this type of

Résumé

Un Sommet de communication sur les bélugas a été organisé à Inuvik, dans les Territoires du Nord-Ouest, du 23 au 25 février 2016. La réunion était organisée conjointement par le ministère des Pêches et des Océans (MPO), le Comité mixte de gestion de la pêche (CMGP) et le Conseil inuvialuit de gestion du gibier (CIGG). Le Sommet a réuni environ 80 participants, dont des chercheurs du gouvernement (MPO, Santé Canada et Affaires autochtones et du Nord Canada), des universitaires et des groupes d'intérêt, de même que des Inuvialuits (notamment des chasseurs/trappeurs, des aînés et des jeunes) de six collectivités de la Région désignée des Inuvialuit (RDI) et des gestionnaires régionaux des ressources du MPO et d'Inuit Tapiriit Kanatami. L'objectif était de mettre en commun les connaissances sur les populations

meeting stemmed from Inuvialuit beneficiaries who wanted a more structured and holistic presentation of the current state of knowledge on beluga based on the numerous, ongoing Beluga research and monitoring activities in the region. In recent years, both research and monitoring of Beluga whales in the ISR has grown in both the diversity of topics (e.g., habitat use, vocalization, health, integration of traditional knowledge), and local community participation in research and monitoring (e.g., project design, implementation, data collection). The first day of the summit gave community members the opportunity to present their community concerns and issues for discussion. The second day focused on presentations of research and monitoring results. The final day was dedicated to discussions on co-management. During the Summit, common concerns and knowledge gaps were documented. These discussions will help to direct future research and monitoring of the Beluga population in the ISR. The level of engagement and participation was high among all participants. Overall the session was very well received and participants recommended that it be repeated on a regular basis (every few years). The Fisheries Joint Management Committee has agreed to set aside funds in support of the Summit, as well as adopt the outputs into their Beaufort Sea Beluga Management Plan.

de bélugas dans la RDI et de discuter des priorités pour l'avenir. Les bénéficiaires inuvialuits avaient demandé la tenue d'une rencontre de ce type pour avoir une idée structurée et globale de l'état actuel des connaissances sur les bélugas, en raison des nombreuses activités de recherche et de surveillance en cours dans la région. Au cours des dernières années, la recherche sur les bélugas et la surveillance dans la RDI ont vu une diversification des sujets (p. ex. utilisation de l'habitat, vocalisation, santé, intégration des connaissances traditionnelles) et la participation des collectivités locales à ces activités a augmenté (p. ex. conception du projet, mise en œuvre, collecte des données). La première journée du Sommet, les membres de la collectivité ont eu l'occasion de faire part de leurs préoccupations et des points à discuter. La deuxième journée était axée sur la présentation des résultats des activités de recherche et de surveillance. La dernière journée a été consacrée à des discussions sur la cogestion. Pendant le Sommet, on a pris note des préoccupations courantes et des lacunes dans les connaissances. Ces discussions contribueront à orienter le futur des recherches et de la surveillance de la population de bélugas dans la RDI. Le niveau d'attention et de participation était élevé chez les participants. En général, le Sommet a été bien accueilli et les participants ont recommandé qu'on organise des sommets similaires de façon régulière (à quelques années d'intervalle). Le Comité mixte de gestion de la pêche a accepté de réserver des fonds en vue de l'organisation du Sommet, en plus d'adopter les résultats de la réunion dans son Plan de gestion du béluga de la mer de Beaufort.

Key messages

- The Summit brought together approximately 80 participants that included researchers, Inuvialuit from all six Inuvialuit communities and resource managers to share knowledge on the status of the Canadian Beaufort Sea Beluga population in the Inuvialuit Settlement Region (ISR)
- The Summit was very well received and participants recommended that it be repeated on a regular basis. The FJMC has agreed to set aside funds in support of this meeting as well as adopt meeting

Messages clés

- Le Sommet a réuni environ 80 participants, dont des chercheurs, des Inuvialuits de six collectivités et des gestionnaires des ressources qui ont fait part de leurs connaissances sur l'état de la population de bélugas dans la mer de Beaufort au Canada, dans la Région désignée des Inuvialuit (RDI).
- Le Sommet a été bien accueilli et les participants ont recommandé qu'on organise des sommets similaires de façon régulière. Le CMGP a accepté de réserver des fonds en vue de l'organisation du

- outputs into their Beaufort Sea Beluga Management Plan
- Future meetings with Indigenous and co-management partners, on beluga and other key northern issues, will continue this collaborative approach to build trusting relationships and facilitate the inclusion of Traditional Knowledge

Sommet, en plus d'adopter les résultats de la réunion dans son Plan de gestion du béluga de la mer de Beaufort.

- Pour les prochaines réunions avec les partenaires autochtones et les partenaires de cogestion, au sujet des bélugas et d'autres questions clés pour le Nord, on continuera d'adopter cette approche de collaboration pour bâtir des relations de confiance et faciliter l'inclusion des connaissances traditionnelles.

Objectives

- Share Knowledge on beluga whales, to include both western science and traditional/local knowledge held by the Inuvialuit
- Knowledge to be shared over a regional multi-day meeting in Inuvik that fosters the co-production of knowledge about beluga whales in the Western Arctic.
- Summarize our current state of knowledge and identify gaps and needs
- Develop a plan for research and management of beluga whales for the next 5 and 10 years
- A holistic and long-term communication strategy that integrates community needs, and knowledge across human health, beluga health and ecosystem health.

Introduction

Scientists have studied trends in contaminants within the context with climate change in the eastern Beaufort Sea beluga population for the past two decades (e.g. NCP funded beluga monitoring), while the 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 and monitoring programs. This communication event builds on past communication efforts in the ISR and the expansion of the beluga sampling and research program to include the collection of local and traditional ecological knowledge. We feel the need for such an event is timely given a) the increased diversity of beluga research, b) increased community leadership on beluga programs extending beyond Tuktoyaktuk, and c) the recent unusual observations of belugas in 2014 (stranded whales in Inuvik and increased hunts Ulukhaktok). The beluga program has grown to include collaborations with the Paulatuk, Inuvik and Olokhaktomiut HTCs in addition to the Tuktoyaktuk HTC, and has provided opportunities for the inclusion of local knowledge, and increased participation of community members in various aspects of the beluga health program. Several communities in the ISR have requested a Beluga Communications Event that would provide research and monitoring updates to all in the community. In recent years research and monitoring of beluga whales has grown both in diversity of research topics (i.e. spanning from beluga habitat use, vocalization, health and traditional knowledge of beluga whales) as well as diversity of community participation in the research and monitoring programs (i.e. project design, implementation, data collection) that has built capacity in communities and in the beluga monitoring program across the ISR.

The last beluga communications event took place in February 2012 over 3 days in the community of Tuktoyaktuk. Outcomes from the event resulted in new research direction and projects that addressed both community and science needs. More significantly the outputs of the large inclusive communication event led to stronger partnerships with the community and boards that strengthened DFO/FJMC/HTC research and monitoring of beluga whales.

Since the last communication event and given the recent expansion in both the geography of the programs and the research topics we have been asked to hold a communication event that brings together all key players. Communities and Boards have asked to hear from the individual researchers (rather than have one researcher present on behalf of others) and have asked for information to be shared with all (not just boards) in a meaningful way to address questions and allow for communities to be more engaged in the research and monitoring programs.

Activities in 2015-2016

Steering Committee and Planning

After meetings with both the Inuvialuit Game Council (IGC) and Fisheries Joint Management Committee (FJMC) it was decided that DFO, IGC and FJMC would chair the meeting to represent the interests of community members (IGC), co-management (FJMC, DFO) and science (DFO and other science partners). Following this a steering committee was struck to include representation of the boards, federal departments and relevant partners to ensure inclusiveness and effectiveness of the meeting. The committee had representation from IGC, FJMC, DFO, INAC-NCP, and the IRC. Additionally we worked closely with GNWT PHA and ITK with regards to human health and public messaging. Overarching guidance from the boards was to ensure proper representation of communities and science and ensure effective communication on the benefits and risks of consuming beluga whales.

The steering committee held monthly meetings to develop a plan and secure additional funds to support the communication event. It was decided that HTC's would select three delegates to represent a youth, elder and hunter. Additionally HTC's were consulted on for meeting design (using a survey), to provide guidance on a) what type of information about beluga was most relevant to be shared (priority ranking), b) how should the information be shared (format) and c) how would communities like to share their knowledge to scientists. Results from the survey were used to inform and set up the meeting.

Capacity Building and Communications

We used this as an opportunity to build capacity in knowledge of communication among the scientists, community members and managers. While the event was a 3 to 4 day event there was time spent preparing both scientists and community members on communication approaches. Specifically scientists were tasked to develop one page fact sheets about their research and a poster for display. Fact sheets and posters went through a review process to ensure appropriate messaging for the audience. Those scientists giving power point presentations were assisted by relevant experts on how to best convey and communicate their messages and findings. We worked closely with the community representatives (i.e. youth, elder, hunter) from each community to first work on what information/knowledge would be shared and then develop a communication approach to share the knowledge and key messages.

The steering committee worked with the Inuvialuit Communications Society (ICS) to develop a plan for a video and a means to capture all of the material as a means to capture traditional Knowledge. Additionally we worked with the DFO media team to provide any training for anyone requiring assistance with speaking with the media present at the meeting.

Traditional Knowledge Integration

The Beluga Communication Summit was designed to share both western science and traditional knowledge for application to future decision making. Careful consideration and consultation was taken into the set-up of the meeting. We held a one day meeting in advance of the official start of the meeting to bring together all community representatives to allow one another to meet as well as discuss what some key questions would be for western science. This time was also used to finalize the community presentations. The first meeting day was 'Community Day' and began with opening words and introductions. This was followed by presentations by each of the six communities who spoke on their knowledge and perspectives on beluga whales. It also included a presentation by the Alaskan Beluga Whale Committee Chair to provide the Inupiat beluga perspective and knowledge. This was followed by a cultural evening to enable the continued sharing with videos, demonstrations and photos. The second day was 'Research Day' and the morning began with an acknowledgement that beluga health is same synonymous with Inuvialuit health. Talks to follow focused on knowledge around food safety that included contaminants, how food preparation impacted nutritional value and contaminants, reviewed outcomes of the Inuit Health Survey and discussed diseases. Presentations by community members were made on proper food storage and handling. To cover the ecological research on beluga whales we held breakout groups for six topics. Science experts and Inuvialuit experts divided themselves into their expert topics to discuss: habitat, populations, contaminants, diseases, diet and future impacts. The breakout group enabled sharing of both western science and traditional knowledge.

Results

Community Day: All communities were represented by a youth, harvester and elder as well as additional reps supported by boards (e.g. beluga monitors and board representatives). Each community provided a presentation on belugas reflecting their community's perspective, knowledge and concerns. While information/presentations shared were diverse many had common threads throughout, in particular changes in the ecosystem, affecting beluga and beluga harvesting. The importance of beluga to their culture, health and well-being was highlighted. Communities not only shared significant amounts of knowledge with scientists they also learned a lot from one another. The Inupiat Alaskan representative shared similar challenges from their region with pressures of climate change and development. All communities expressed interest in wanting to work more closely together to continue to learn from one another.

Research Day: Over twenty posters were made to share the wide range of beluga research occurring. Presentations focused on health related topics in the morning followed by breakout groups in the afternoon that covered: Population/genetics, Diseases and Condition, Contaminants, Diet and Condition, Habitat and Habitat use and Future Impacts.

From the beluga/human health experts we learned that parts of the beluga whale like muktuk/blubber are important sources of nutrients such as essential fatty acids (Omega 3 and 6), vitamins and minerals such as selenium. Other beluga parts like the muscle that are a good source of protein are also high in mercury, and as such should be limited. Health officials, beluga researchers and regional Inuvialuit Beluga experts are reviewing the latest contaminant information and data and will be developing an easy to read fact sheet on the latest contaminant and health information to be released in the coming year.

Toxoplasma (cat parasite) is not new in the Arctic and is typically found in undercooked or raw meat and organs from a wide range of animals, as well as other contaminated food (wildlife and store bought); therefore, pregnant women or people with compromised immune systems are advised against eating raw animal foods and unwashed produce. Average Inuvialuit had lower mercury and low Toxoplasma exposure (8% of people) when compared to other Arctic regions, based on findings from the 2008 Inuit Health Survey.

During the breakout groups some key future research needs highlighted included the need to study climate change impacts to belugas, their habitat, their food and their condition.

Using new technologies alongside TEK should be explored to gain better understandings of changes and impacts to belugas health and populations. It is important to train beluga monitors to be resources for their communities regarding beluga health and research in the ISR. There is continued need for ecosystem research paired with beluga and human activity impacts research to build our understanding of cumulative impacts. Lastly it was agreed that there is need for research to better understand the impacts of contaminants on Inuvialuit health and the health of beluga.

Co-Management Day: Presentations throughout all three days highlighted the strength in the co-management framework and Inuvialuit Final Agreement. Presentations highlighted the strength of knowledge and research in the region and how it has enabled better informed decision making. The beluga harvest monitoring program highlighted how well the FJMC, DFO scientists and the communities have worked together as a team to develop the world's longest beluga monitoring program. A Husky Lakes Entrapment Session was held for community delegates and Boards to review the action plan for beluga entrapments in the Husky Lakes.

Outcomes and recommendations from the Beluga Summit will be included the FJMC Beluga Management Plan, and the FJMC supported that the Beluga Summit occur again on a regular basis.

Discussion and Conclusions

The Beluga Summit was a success!

The success of this meeting was due to the collaborative approach taken with our co-management partners (FJMC, six Hunters and Trappers Committees, IGC). This collaborative effort allowed us to incorporate a variety of perspectives and hold a meeting where all participants were fully engaged. The format of the Summit resulted in common agreement and acceptance of the conclusions and outcomes of the discussions. New ideas, questions and synergies were identified and will formulate the direction of new research and monitoring programs.

Overall the Beluga Summit was successful in building positive relationships and producing direction for future research and monitoring in the Inuvialuit Settlement Region. This collaborative approach should be repeated in the future for key topics and issues of concern under the Northern Contaminants Program. Future meetings with Indigenous and co-management partners, on beluga and other key northern issues will continue this collaborative approach to build trusting relationships and facilitate the inclusion of Traditional Knowledge.

Expected Project Completion Date

The event was successfully completed, however products following the event continue. Communication products include:

- Beluga Summit program (with fact sheets on each beluga project) – completed
- Beluga Summit summary video – completed (https://www.youtube.com/watch?v=j9EvM4Fz7Qo)
- Beluga Bulletin – completed
- Technical report that will summarize information shared and outcomes, in preparation for completion in Sept 2016
- Visual Report- issue of the Tusaayaksat magazine to focus on the Beluga summit (pending on funds available in the new fiscal year)
- Special Issue Publication: currently a consideration with the journal Arctic for completion in 2017/18.

Program Coordination and Aboriginal Partnerships

Coordination du programme et partenariats autochtones

National Coordination and Administration of the Northern Contaminants Program, and Facilitation of International Action related to the Long-range Transport of Contaminants into the Arctic

Coordination et administration nationales du Programme de lutte contre les contaminants dans le Nord et facilitation de l'action internationale relative au transport à grande distance de contaminants dans l'Arctique

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Abstract

The Northern Contaminants Program (NCP) engages Northerners and scientists in researching and monitoring of long-range contaminants in the Canadian Arctic, and in making use of the data generated to: 1) assess ecosystem and human health in order to address the safety and security of traditional country foods that are important to the health and traditional lifestyles of northern communities; and 2) inform policy, resulting in action to eliminate contaminants from long-range sources. The NCP Secretariat, within Indigenous and Northern Affairs Canada, provides the administrative, financial, and logistical support and coordination required to deliver the NCP within Canada, and facilitates Canada's action internationally with respect to initiatives and regulations related to the long-range transport of contaminants into the Arctic. Highlights for 2015-2016 included: 1) funding decisions from the April 2015 Management Committee meeting resulted in funding for 56 projects under a total of 27 Contribution agreements (including amendments), 5 Interdepartmental Letters of Agreement, and transfers to 5 regions; 2) the 21st NCP Results Workshop took place at the Westin Bayshore hotel in Vancouver, BC on December 7&8, 2015 in advance of the ArcticNet Annual Science meeting; 3) the Canadian Arctic Contaminants Assessment Report III – Contaminants in Canada's North: Summary for Policy Makers, was distributed early in 2015-2016, beginning with distribution to NCPMC members at the April meeting, and is also available online through the NCP website and NCP Publications Database; 4) the POP Review Committee recommended that Deca-BDE be added to Annex A of the Stockholm Convention, and advanced the evaluation of SCCPs and PFOA; and 5) information on NCP mercury monitoring and research was contributed to the Canadian National inventory that was submitted to UNEP Minamata Convention for presentation at the seventh Intergovernmental Negotiating Committee meeting that was held March 10-15 in Jordan.

Résumé

Le Programme de lutte contre les contaminants dans le Nord (PLCN) fait participer les habitants du Nord et les scientifiques à la recherche et à la surveillance axées sur les contaminants transportés sur de longues distances, et à l'utilisation des données obtenues aux fins suivantes : 1) évaluer les écosystèmes et la santé humaine en vue d'assurer la salubrité et la sécurité des aliments régionaux et traditionnels qui sont importants pour la santé et le mode de vie traditionnel des collectivités du Nord, et 2) éclairer les politiques qui donnent lieu à des mesures visant à éliminer les contaminants de sources lointaines. Le Secrétariat du PLCN, au sein d'Affaires autochtones et du Nord Canada, assure la coordination et le soutien administratifs, financiers et logistiques nécessaires pour réaliser le PLCN au pays, et il facilite la participation du Canada, sur la scène internationale, aux initiatives et à la réglementation concernant le transport à grande distance de contaminants dans l'Arctique. Points saillants pour 2015-2016, notamment : 1) les décisions concernant le financement de la réunion du Comité de gestion d'avril 2015 ont entraîné le financement de 56 projets dans le cadre d'un total de 27 accords de contribution (y compris les modifications), cinq lettres d'entente interministérielles, ainsi que des transferts à cinq régions; 2) le 21e Atelier sur les résultats du PLCN a eu lieu à l'hôtel Westin Bayshore de Vancouver (Colombie-Britannique) les 7 et 8 décembre 2015 avant la tenue de la Conférence scientifique annuelle ArcticNet; 3) le troisième Rapport de l'évaluation des contaminants dans l'arctique canadien, intitulé « Les contaminants dans le nord du Canada : Sommaire à l'intention des décideurs » a été distribué au début de 2015-2016, en commençant par les membres du Comité de gestion du PLCN à la réunion d'avril, et est également disponible en ligne sur le site Web du PLCN et dans la base de données des publications du PLCN; 4) le Comité d'examen des polluants organiques persistants a recommandé que le décaBDE soit ajouté à l'annexe A de la Convention de Stockholm et a fait progresser l'évaluation des paraffines chlorées à courte chaîne (PCCC) et de l'acide perfluorooctanoïque (APFO);

et 5) les renseignements sur les activités de surveillance et de recherche sur le mercure du PLCN ont été ajoutés à l'inventaire national canadien, qui a été soumis à la Convention de Minamata du Programme des Nations Unies pour l'environnement aux fins de présentation à la septième réunion du Comité intergouvernemental de négociation qui a eu lieu en Jordanie du 10 au 15 mars.

Key messages

- The NCP Secretariat provides the administrative, financial, and logistical support and coordination required to deliver the NCP.
- The NCP facilitates international cooperation to identify the significance of long-range contaminant sources and their transport pathways and potential impacts on the environment and human health, and assists with the implementation and development of appropriate international controls on emissions and discharges of contaminants of significance to Canadian northern populations.
- The Minamata Convention on Mercury, a legally-binding agreement to cut emissions and releases of mercury to the environment, was signed by Canada in October 2013 and as of July 2016, includes 128 signatory nations and 28 ratifications. Through use of its data, information and expertise, the NCP made important contributions towards this historic signing. The Convention will enter into force 90 days after 50 countries have ratified the treaty. Canada is presently working to be in a position to ratify and implement the treaty.
- The 7th Conference of the Party (COP) of the Stockholm Convention on Persistent Organic Pollutants (POPs) took place 4 – 8 May, 2015. Three more chemicals were agreed to be added to the Annex A of elimination at the meeting: pentachlorophenol (PCP) and its salts and esters, polychlorinated naphthalenes (PCNs: di, tri, tetra, penta, hexa, hepta, octa), and hexachlorobutadiene (HCBD).

Messages clés

- Le secrétariat du PLCN assure la coordination et le soutien administratifs, financiers et logistiques nécessaires pour réaliser le programme.
- Le PLCN facilite la collaboration internationale afin de déterminer l'importance des sources de contaminants venus de loin, de leurs voies de transport et des répercussions possibles sur l'environnement et la santé humaine, et il aide à établir et à mettre en œuvre les mesures internationales de limitation des émissions et des rejets des contaminants qui importent pour les populations du Nord canadien.
- La Convention de Minamata sur le mercure, un accord international juridiquement contraignant pour réduire les émissions et les rejets de mercure dans l'environnement, a été signée par le Canada en octobre 2013, et, depuis juillet 2016, compte 128 pays signataires et 28 ratifications. Les données, les renseignements et l'expertise issus du PLCN ont grandement contribué à la signature de cet accord historique. La Convention entrera en vigueur 90 jours après que 50 pays auront ratifié le traité. Le Canada travaille actuellement pour être en mesure de ratifier et de mettre en œuvre le traité.
- La septième Conférence des Parties de la Convention de Stockholm sur les polluants organiques persistants (POP) a eu lieu du 4 au 8 mai 2015. On a convenu à la réunion d'ajouter trois substances chimiques supplémentaires à l'annexe A

- NCP continues as Canada's main contributor on contaminant issues to the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP). In February 2016, AMAP released its 2015 Assessment on Human Health in the Arctic, which is available for download from the AMAP website (www.AMAP.no). The Human Health assessment was co-led by Shawn Donaldson of Health Canada, and was supported by NCP-funded scientists and Indigenous partners who functioned as chapter leads and contributing authors.

(pour élimination) : le pentachlorophénol (PCP) ainsi que ses sels et ses esters, les polychloronaphthalènes (PCN : di, tri, tétra, penta, hexa, hepta, octa) et l'hexachlorobutadiène (HCBD).

- Le PLCN demeure le principal intervenant canadien s'intéressant aux problèmes liés aux contaminants dans le cadre du Programme de surveillance et d'évaluation de l'Arctique (PSEA) du Conseil de l'Arctique. En février 2016, le PSEA a publié son évaluation de 2015 sur la santé humaine dans l'Arctique, qui peut être téléchargée à partir du site Web du PSEA (www.AMAP.no). L'évaluation de la santé humaine a été codirigée par Shawn Donaldson, de Santé Canada, et a été appuyée par des partenaires autochtones et des scientifiques financés par le PLCN qui agissaient comme responsables de chapitres et auteurs collaborateurs.

Introduction

The 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 Northern Contaminants Program (NCP) engages Northerners and scientists in researching and monitoring of long-range contaminants in the Canadian Arctic, that is, contaminants that are transported to the Arctic through atmospheric and oceanic processes from other parts of the world and which remain in the Arctic environment and build up in the food chain. The data generated by the NCP is used to assess ecosystem and human health, and the findings of these assessments are used to address the safety and security of traditional country foods that are important to the health and traditional lifestyles of Northerners and northern communities. The findings also inform policy, resulting in action to eliminate contaminants from long-range sources. The NCP contributes scientific data and expertise to contaminants-related international initiatives such as the Arctic Monitoring and Assessment Programme (AMAP), and to international agreements such as the UNEP Minamata Convention on Mercury, the Stockholm Convention on Persistent Organic Pollutants, and two protocols under the United Nation Economic Commission for Europe Convention on Long-range Transboundary Air Pollution, working globally to improve the health of Arctic people and wildlife over the long term. Reduction and elimination of contaminant input to the Arctic from distant sources outside of Canada requires comprehensive international cooperation.

Since 1991, Indigenous and Northern Affairs Canada has provided the NCP with financial administration and management services to support approximately 1322 scientific and other northern-related projects. The department has also maintained the Chair and secretariat support of the NCP Management Committee, and the secretariat support (including some chairs) of the NCP Review Teams and other committees (e.g. Human Health, Environmental Monitoring and Research, and Regional Contaminants Committees). This management structure ensures that the program remains scientifically and socio-culturally defensible, while at the same time, achieves real progress in terms of its broad policy objectives.

National Activities and Results in 2015-2016:

i. Implementing decisions from the 2015 Spring NCP Management Committee meeting:

The 2015 Spring NCP Management Committee meeting was held April 14-16, 2015 in Ottawa, with member attendance of 94%. Draft minutes and action items were circulated within 1 month of the meeting. Reports on the progress of implementing decisions and action items from that meeting were presented to the Management Committee at its Fall meeting.

ii. Letters to funding applicants:

The majority of all formal letters went out to all funding applicants between Mid-May and mid-June.

iii. Funding to project leaders:

To flow funding to some 56 NCP projects, a total of 27 Contribution agreements (including amendments), 5 Interdepartmental Letters of Agreement, and transfers to 5 regions (NWT: 8 recipients; Yukon: 8 recipients; Nunavut: 8 recipients; Quebec: 1 recipient; Atlantic: 4 recipients) were implemented between mid-June 2015 and late-March 2016.

The budget templates, first introduced in 2014-2015, were further modified for 2015-2016, and continue to prove to be beneficial for ensuring accuracy and improving efficiency in administering project funds.

iv. NCP 21st Results Workshop, December 7-8, 2015, Vancouver:

The 21st NCP Results Workshop was co-located with the ArcticNet Annual Science meeting this year, at the Westin Bayshore hotel in Vancouver, BC on December 7&8, 2015. More than 105 people registered in advance for the Results Workshop, and there was also a significant number of additional participants who walked in and attended during the two days.

The agenda included sessions on mercury, a focus on beluga, a human health session, and a communications session. These latter two each incorporated panels of experts in the field, allowing for broader discussions and interaction with the audience. The workshop wrapped up on December 8th with a joint NCP/ArcticNet session on contaminants. Over the two days, there was a total of 23 presentations on contaminants research and related activities.

Additionally, 36 posters were presented during the poster-viewing session at the end of December 7th. Posters were judged by the NCP Aboriginal Partners against criteria focused around community need, communications, northern partnership, capacity building, and co-production of traditional knowledge. The Northern Involvement Poster Award for 2016 was given to Heidi Swanson, University of Waterloo for her poster on “Bioaccumulation and biomagnification of mercury in food fishes from the Dehcho region, NT (George Low, PI).” Runners up were: John Chételat (Environment and Climate Change Canada) for his poster on “East Hudson Bay Network research initiative on regional metal accumulation in the marine food web”; and Mylene Ratelle (University of Waterloo), for her poster on “Networking for Research: A human biomonitoring project in Dehcho and Sahtu regions of the NWT".

A new element introduced at this year's workshop included a Living Library of 6 NCP-affiliated experts that could be "signed out" for 10-minute discussions during the poster-viewing session. This inaugural year's Living Library collection included Mr. Joey Angnatok, Dr. Birgit Braune, Dr. Laurie Chan, Dr. Derek Muir, Ms. Norma Kassi, and Mr. Russel Shearer.

Also new this year was the Recognition of Northern Community Contributions to the NCP. In the weeks leading up to the workshop, NCP PIs were asked to nominate northerners who had made significant contributions to NCP work over the years. In total 23 northerners were nominated and recognized in a presentation during the workshop.

ITK, on behalf of all of the NCP Aboriginal Partners, administered $30,000 in travel funding that allowed 11 northerners to attend the Results Workshop who would not have otherwise participated.

The NCP had a booth that was well attended during the ArcticNet conference. The display table was filled with NCP and AMAP publications for distribution. Additionally, the NCP Synopsis of Research 2014-2015 publication was available for download.

v. Revisions to NCP blueprints

Revisions to all NCP Blueprints were made in accordance with recommendations by review teams, NCP Secretariat and NCP Management Committee in advance of issuing the 2016-2017 Call for Proposals. The most substantive changes included: modifications to the listing of NCP Contaminants of Concern to remove any confusion in regard to which contaminants are eligible for annual sampling (Schedule B) and those to be analyzed every two years (Schedule B); changes to the Communications, Capacity and Outreach blueprint, and the addition of new criteria for use in the social/cultural review by Regional Contaminants Committees. These and other changes are outlined in section 1.4 of the Call for Proposals.

vi. Fall NCP Management Committee meeting

The Fall NCP MC meeting was held in Ottawa, October 6-7, with member attendance of 78%. The meeting was scheduled to take place in Iqaluit; however, due to the large number of Committee members who were unable to travel to Iqaluit, for a variety of reasons, the meeting location was changed less than 1 month prior to the meeting. Draft meeting minutes and summary and status of the action items were posted on SharePoint, prior to the April Management Committee meeting.

vii. 2016-2017 Call for Proposals and review process

The 2016-2017 Call for Proposals was launched by email on November 18, 2015 and posted online on the NCP website on science.gc.ca/ncp on December 8, 2015. The online posting was timed with the official announcement of the Call for Proposals by INAC's Minister, Carolyn Bennett, and also timed with the second day of the NCP Results Workshop. A total of 67 proposals were submitted by the deadline of January 12, 2016 with a total funding request of approximately $5.38M (not including N-1 and N-2 proposals). All reviews (peer reviews, social/cultural review by RCCs, technical reviews by review teams) went ahead successfully as planned. The regional contaminants committees each reviewed the following number of proposals: Yukon, 7; NWT, 24; Nunavut, 28; Nunavik, 9; and Nunatsiavut, 11. Each technical review team reviewed the following number of proposals: HH, 9; EMR, 32; CBMR, 10; CCO, 12.

viii. Website updates

Updates to the content of the NCP website on science.gc.ca were made throughout 2015-2016, with the exception of during the writ period (August to October), during which no updates were permitted. Efforts continue to making it a more colourful, interactive and useful resource for the NCP community and the broader public. In addition to updates to the project pages for each NCP-funded project, a new interactive map tool, the *Northern Contaminants Program Project Discovery Portal*, has been developed. The "portal" will be presented to the NCP Management Committee at its April 2016 meeting and will be posted online shortly thereafter.

ix. Publications: CACAR III, Synopsis of Research, CACAR IV

The *Synopsis of Research conducted under the 2014-2015 Northern Contaminants Program* was developed during June-August 2015, as scheduled. Due to delays in obtaining an ISBN number, as of March 15, 2016 the report has not yet been officially released nor distributed by email to the NCP community. Efforts are being made to ensure the ISBN issue is resolved before fiscal year-end (March 31, 2016), at which time the full document will be shared. A draft version has been available online through the NCP publications database, and abstracts & key messages have been prepared for posting on the NCP website, which is expected to occur by March 31, 2016. Previous editions of the Synopsis reports [all since 2010-2011] are now available electronically through the NCP publications database.

The *Canadian Arctic Contaminants Assessment Report III – Contaminants in Canada's North: Summary for Policy Makers*, was distributed early in 2015-2016, beginning with distribution to NCPMC members at the April meeting, and is also available online through the NCP website and NCP Publications Database. This 16-page document provides a succinct and high-level overview of the issue of contaminants in the North, 10 key findings, future directions and recommendations.

Work on the production of the more detailed *CACAR III Highlights Report*, which has a greater emphasis on region-specific results, progressed throughout 2015-2016. It was unfortunately not ready for its planned release to coincide with the NCP Results Workshop in 2015. It is currently in a complete draft form, undergoing internal review.

x. Data Management - **Polar Data Catalogue – NCP Metadata/database**

The Polar Data Catalogue (PDC) continues to act as the metadata repository for NCP funded projects. The PDC Data Manager has spent considerable time working with NCP researchers to complete the metadata collection: In 2015-2016, 18 new metadata records were submitted, and 60 of the 144 current NCP metadata were updated with new information. Of the 80 NCP projects active between 2011 and 2016, 67 have complete metadata, 6 have partial metadata, and 7 have no metadata. This is a substantial increase in completeness over 2014-2015 when only 33 projects had complete metadata and 22 had no metadata records at all. Of the projects with no metadata, five of the seven were funded in 2015-2016. PDC staff are working with NCP personnel to address this issue.

The Yukon Contaminants Database has been fully cleaned in preparation for public release via the PDC, but approval has been delayed due to negotiations with two researchers who seek additional time to publish their results. A new database, the Yukon Waste Site Database, has recently been provided to the PDC and is in the queue for review and conversion to a more accessible format. Additional activities this year have involved development of a draft Data Policy for NCP (currently under review) as well as PDC co-hosting two significant Canadian and international polar data conferences, the Canadian Polar Data Workshop and the Polar Data Forum II. To increase the visibility of the NCP data and other resources in the PDC and enhance awareness and collaboration of Arctic and Canadian polar data management activities, the PDC has hired a full-time Project and Outreach Coordinator.

xi. QA/QC

In 2015-2016 the NCP QAQC program successfully carried out the Phase 9 Interlaboratory study involving 49 analytical labs, including 30 Canadian and 19 international labs. The Phase 9 report was finalized in February 2016 and distributed to participating lab managers and NCP project leaders. . In addition to the Phase 9 final report, the QAQC team has prepared a confidential report that includes results for labs that produce analytical results for the NCP. This confidential report, which reveals the lab ID codes for “NCP labs”, is intended exclusively for the Management Committee and should not be circulated. The report reveals that most NCP labs are performing satisfactorily; however, some labs are not performing adequately on certain substances. According the direction provided by the Management Committee, the QAQC team is now preparing letters to the underperforming labs requesting that they complete corrective action reports related to their poor performances in the study. The corrective action report is a standard means of investigating poor analytical performance, and a process that is required by any ISO certified lab in response poor performance. The QAQC team will work with the participating labs to help identify process improvements so that lab performance is improved. The QAQC team also recently issued a survey to program participants to solicit feedback on how the program is run. The team will use this feedback to improve operations for the coming year. Invitations for the Phase 10 interlab study have been issued and the QAQC team will be working with the NCP Secretariat over the coming weeks to ensure that all NCP labs participate as required.

xii. NCP Publications Database

In 2015-16, ASTIS indexed a total of 201 items for the NCP Publications Database, for a total of 3,457 items in the database. A detailed breakdown of the numbers is included in the final report available from the NCP Secretariat. ASTIS assisted 24 of 60 NCP project leaders to obtain ORCID identifiers. ASTIS has also received ORCID information from 100 additional NCP project researchers (not project leaders) for a total of 124 NCP researchers with ORCID identifiers in ASTIS. As researchers must obtain the ORCID personal digital identifier themselves, this process has been challenging and has taken more time than anticipated. ASTIS will continue to work on this process in 2016-17.

ASTIS has also completed the storing of NCP documents (Synopses of Research from 2005-2006 to present and CACAR I, II, and II) on the server with persistent URLs. Links to these documents have been sent to the NCP for addition to the NCP website. They are also available via links from their records in ASTIS and in the NCP Publications Database.

International Activities and Results in 2015-2016

1. FACILITATE IMPLEMENTATION OF THE STOCKHOLM CONVENTION ON POPS AND ASSOCIATED GLOBAL ACTIONS ON POPS

Progress to Date:

The UNEP Stockholm Convention on POPs entered into force in May 2004. The last Conference of the Parties (COP-7) was held in May 2015. At COP-7, three new chemicals were listed under Annex A (for elimination): hexachlorobutadiene (HCBD), pentachlorophenol (PCP) and polychlorinated naphthalenes (PCNs). The next COP (8) will take place April - May 2017.

Throughout the development and implementation of the Stockholm Convention, the NCP has played an important role in providing data on POPs in the Arctic. Data from the Arctic and other remote regions of Earth is recognized as particularly valuable in the assessment of POPs as global pollutants. The current focus of NCP's efforts to support the Stockholm Convention is through contributions to the Global Monitoring Plan (GMP). NCP scientists contribute important monitoring data to the GMP and are leading on several aspects of reporting for the GMP. The second GMP regional reports were presented at COP-7 with a focus on establishing baseline trends of POPs and identifying data gaps. These reports are being compiled into a global report to be presented at COP-8. The global report is the primary source of monitoring data that is informing the work of the newly established Effectiveness Evaluation Committee (EEC) in preparing the first full Effectiveness Evaluation report of Stockholm Convention, to be presented at COP-8. Tom Harner is Canada's representative on the global coordinating group for the GMP and also serves as the group's representative on the EEC. Tom also leads the Global Atmospheric Passive Sampling (GAPS) network that is a primary source of atmospheric POPs data to the GMP. Derek Muir and Hayley Hung also have leadership roles in the preparation of chapters for both the regional and global reports.

The NCP additionally plays a significant role in producing data that is used to evaluate candidate POPs. NCP data is important for the evaluations and submissions on POP candidates of the **Persistent Organic Pollutants Review Committee** (POPRC), and is used both by the Canadian Government, as well as the Inuit Circumpolar Council, who participate in the POPRC process. The POPRC is the Stockholm Convention's technical body and meets annually to review data on chemicals that have been nominated as substances to be added to the Convention. POPRC 12 will take place in September 2016.

Deca-BDE

POPRC 11 decided to recommend the listing of Deca-BDE in Annex A of the convention. During the intersessional period until POPRC 12, further information will be collected on needed exemptions for spare parts of the automotive and aerospace industries, as well as consideration for needs of the textile industry.

Dicofol

Dicofol was proposed as a POP candidate by the EU in 2013, however due to opposition by one POPRC member, its progress was stalled at POPRC 9 (October 2013). At POPRC 10 it was decided to move dicofol to Annex E, and a risk profile was prepared. At POPRC 11 (October 2015), one POPRC member stalled the adoption of the risk profile, and the decision was deferred to POPRC 12. Data on dicofol in the Arctic is scarce and is needed to inform the risk profile development.

Short-chained chlorinated paraffins (SCCPs):

POPRC 11 adopted the risk profile and a risk management evaluation is being compiled, which will be discussed at POPRC 12. In particular information about POP-like characteristics of possible SCCP alternatives, including MCCPs and LCCPs, would be helpful.

PFOA:

The EU nominated PFOA at COP-7, and POPRC 11 decided that the screening criteria are fulfilled. During the intersessional period until POPRC 12, a risk profile is being prepared. Information on long-range transport, bioaccumulation, persistence and toxicity of PFOA, and also possible PFOA alternatives, will be helpful to inform the review process.

2. CONTRIBUTING TO UNEP GLOBAL ACTIONS ON MERCURY – THE MINAMATA CONVENTION

Progress to Date:

In January 2013, the UNEP Intergovernmental Negotiating Committee reached an agreement to reduce global mercury contamination. This agreement known as the Minamata Convention, represents a major achievement for the NCP and

AMAP, which contributed much of the scientific justification for global action. As of March 27, 2016, 128 countries have signed the Convention, including Canada, and 25 countries have ratified, including the United States. Canada is currently implementing the necessary regulatory instruments required to be compliant with the Convention, and is working towards being in a position to ratify in 2017.

Work is ongoing to prepare for when the Convention enters into force. This includes preparatory work for the implementation of Article 22 on effectiveness evaluation. NCP has contributed to this work with the submission of a detailed inventory of related monitoring and research activities. The NCP information makes up a substantial portion of the Canadian National inventory that was submitted to UNEP for presentation at the seventh Intergovernmental Negotiating Committee meeting that was held March 10-15, 2016 in Jordan.

3. ARCTIC MONITORING AND ASSESSMENT PROGRAMME (AMAP)

Progress to Date:

The goal of AMAP is to monitor the levels of, and assess the effects of, anthropogenic pollutants and climate change on all components of the circumpolar Arctic environment including human health.

Current, ongoing and recent AMAP Assessment activities include those related to:

- human health *(STATUS: Assessment released February 2016)*
- emerging POPs *(STATUS: near-complete draft assessment, on track for completion late-2016)*
- biological effects of POPs and mercury on wildlife *(STATUS: writing in progress, expected completion late-2016/early-2017)*
- short-lived climate pollutants (black carbon/ tropospheric ozone, and methane) *(STATUS: 2 Assessments released Oct&Nov 2015)*
- Adaptation Actions for a Changing Arctic (AACA), which assesses drivers of Arctic change – 3 regional reports (including Baffin Bay/ Davis Strait and the Bering, Chukchi & Beaufort Sea), and a Pan-Arctic report *(STATUS: regional reports currently under peer review, on track for completion late-2016/ early-2017; Pan-Arctic report delayed)*
- Update of Snow, Water, Ice, Permafrost in the Arctic (SWIPA) assessment *(STATUS: under peer review, on track for completion late-2016/early-2017)*
- Arctic Ocean Acidification assessment follow-up *(STATUS: progressing on schedule)*
- Sustaining Arctic Observing Networks (SAON)
- Arctic Freshwater Synthesis *(STATUS: report released March 2016; also, freshwater chapter in SWIPA assessment)*
- Use of unmanned aircraft systems (UAS) for scientific purposes in the Arctic *(STATUS: report and white paper released Fall 2015).*

Nearly all assessments are currently on track to meet their planned timelines and deliverables between 2015 and 2017. The NCP is contributing significantly to these assessments, particularly for human health, emerging POPs and effects in wildlife (POPs and mercury), for which Canada co-leads.

Of particular note, in February 2016 AMAP released its 2015 Assessment on Human Health in the Arctic, which is available for download from the AMAP website (www.AMAP.no). The Human Health assessment was co-led by Shawn Donaldson of Health Canada, and was supported by NCP-funded scientists and Indigenous partners who functioned as chapter leads and contributing authors. Assessments on chemicals of emerging concern and biological effects of contaminants are currently underway. Both of these assessments are being co-led by NCP scientists Derek Muir and Rob Letcher, and will contain substantial amounts of NCP data. The reports should be completed later in 2016 (emerging chemicals), and early 2017 (biological effects).

The current major assessment activity being undertaken by AMAP is Adaptation Actions for a Changing Arctic (AACA) to be completed by 2017. AMAP, in cooperation with other Arctic Council working groups, is leading on the current phase of the AACA (AACA-C), which focuses on environmental modeling and prediction and presenting information for use in adaptation strategies at the regional level. AACA-C is being organized around three regional assessments that include the Barents Sea, Baffin Bay/Davis Strait, and the Bering/Chukchi/Beaufort Seas. Each of these regional assessments are being coordinated by regional implementation teams. ArcticNet and NCP scientists are contributing directly to regional assessments for the Baffin Bay/Davis Strait, and Bering/Beaufort/Chukchi regions. A Pan-Arctic report, which will synthesize information across the regions, is getting under way.

Expected Project Completion Date

This is an ongoing core component of the NCP.

Project website (if applicable)

www.science.gc.ca/ncp

Council of Yukon First Nations – Northern Contaminants Program

Conseil des Premières Nations du Yukon - Programme de lutte contre les contaminants dans le Nord

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- **Project Team Members and their Affiliations:**
  Yukon First Nations, Yukon Contaminants Committee

Abstract

Over the past year the Council of Yukon First Nations (CYFN) has continued to be active as a member of the NCP management committee as well as responding to requests for information, participating in regional contaminants committee activity, informing Yukon First Nations about the annual call for proposals, maintaining and updating the Yukon NCP website and working with NCP researchers active in the Yukon.

Résumé

Au cours de l'année, le Conseil des Premières Nations du Yukon a poursuivi sa fonction de membre du Comité de gestion du Programme de lutte contre les contaminants dans le Nord (PLCN) et a répondu aux demandes de renseignements, participé aux activités du comité régional des contaminants, informé les Premières Nations du Yukon au sujet de l'appel annuel de propositions, tenu à jour le site Web du PLCN au Yukon et collaboré avec les chercheurs du PLCN qui travaillent au Yukon.

Key messages

- Levels of contaminants are generally low in the Yukon.
- We need to continue monitoring as new contaminants are being released into the atmosphere and water which may cause problems in the future.
- The effects of climate change on contaminant mobility and loading needs to be tracked.
- The work of the Northern Contaminants Program continues to be relevant at the local, regional, national and international level.

Messages clés

- Les concentrations de contaminants sont en général faibles au Yukon.
- Il faut continuer la surveillance, car de nouveaux contaminants susceptibles de poser des problèmes sont rejetés dans l'atmosphère et dans l'eau.
- Les effets des changements climatiques sur la mobilité des contaminants et les besoins en matière de charge en contaminants doivent faire l'objet d'un suivi.
- Les travaux liés au Programme de lutte contre les contaminants dans le Nord sont toujours pertinents aux niveaux local, régional, national et international.

Objectives

- To enhance the confidence of Yukon First Nations in making informed decisions about traditional food consumption and other health related factors.
- Ensure that Yukon First Nations are aware of the latest research regarding the transportation of long range contaminants to the Yukon and their effects on the environment and human health.
- Ensure that the programs offered by and the research done for the Northern Contaminants Program meets the needs of Yukon First Nations.
- Ensure that Yukon First Nations are aware of the funding envelopes and calls for proposals available under the Northern Contaminants Program and that these envelopes are relevant for and accessible to Yukon First Nations.

Introduction

The Council of Yukon First Nations has been a member of the Yukon Contaminants Committee and participated in the Northern Contaminants Program as a member of the Management Committee since the program became active in the Yukon. The current Northern Contaminants Program focus is addressing northern community concerns as people are being exposed to higher levels of long-range contaminants than the rest of Canada. The Yukon is not a high priority area, but still it is important that Yukon First Nations have the information necessary to make informed decisions on the risks and benefits of consuming traditionally harvested foods.

Activities in 2015-2016

Over the past year the Council of Yukon First Nations participated in Northern Contaminants Program management committee activities. A CYFN representative attended the Management Committee meetings held in Ottawa in April to review proposals and funding recommendations made for the various envelopes and advise the

Program on the Committee's recommendations. We also attended the fall Management Committee meeting held in Ottawa in October and participated in the Results Workshop in Vancouver in December.

Information on the Northern Contaminants Program was shared at the Council of Yukon First Nations General Assembly held at Minto Landing in June. The Circumpolar Relations Department had a display set up, talked to individuals regarding contaminants concerns and made information packages and literature available to the delegates attending the assembly. We also attend First Nations General Assemblies if invited and provide information and answer questions about contaminants issues. When the annual call for proposals was issued, we provide First Nations with information regarding the call and work with any First Nation interested in submitting a proposal.

CYFN also participates in the work of the Yukon Contaminants Committee, meeting with researchers, discussing communications on contaminants issues and doing a review of proposals submitted to NCP to conduct research in the Yukon. We also work with researchers to disseminate information on their research and ensure they engage with communities in all aspects of their work.

CYFN maintains and updates the website www.northerncontaminants.ca. The site documents activity carried out by researchers active on contaminants issues in the Yukon and provides information on contaminants of concern. Over the course of the year the site was refreshed with a new look.

We participated in the deliberations and activities of both the traditional knowledge and risk communication subcommittees.

CYFN took over the financial administration of operating aspects of the Little Fox Lake air quality monitoring site on April 1st, 2015. To celebrate the event and raise the profile of the monitoring program an event was held at the site on June 3rd, 2015. The Yukon Contaminants Committee, working with Environment Canada researchers Hayley Hung and Alexandra Steffen and the Ta'an Kwäch'än Council, on whose traditional territory the site is located, arranged a visit to the site. A number of Ta'an Kwäch'än citizens visited the site and an elder related stories of living, travelling and trapping in the area. The Yukon Contaminants Committee continued to work with Hayley and Sandy to find a student to attend their lab in Downsview to learn about contaminants monitoring and sample analysis. The visit was successful and we are exploring opportunities to follow up with communications efforts in the Yukon.

Continuing discussions were held with Health Canada regarding the expansion of health monitoring into the Yukon, perhaps based on the work of the Inuit Health survey. Efforts continue to have Shawn Donaldson (Health Canada) and Scott Tomlinson (NCP) visit the Yukon and meet with the First Nations Health and Social Services Commission.,

In February, Bob Van Dijken travelled to the Arctic Science Summit Week and Arctic Observing Summit in Fairbanks, attending resiliency and health, tradional knowledge and other sessions, as well as AMAP side meetings.

Results

- Attended management committee meeting to recommend funding for research envelopes
- Attended the Northern Contaminants Program Results Workshop
- Communicated information on contaminants and the NCP to Yukon First Nations at the CYFN General Assembly
- Attended Yukon Contaminants Committee meetings and reviewed projects proposing to do work in the Yukon
- Attended NCP midyear management meeting
- Updated and revised the northerncontaminants.ca website

- Administered the Yukon costs of the Little Fox Lake mercury and POPs air monitoring site
- Engaged in dialogue with NCP and Health Canada regarding possible bio-monitoring programs in the Yukon
- Meet with Environment Canada researchers Hayley Hung and Sandy Steffen about the Little Fox Lake site
- Organized a public education and Ta'an Kwäch'än Council engagement session at the Little Fox Lake air quality monitoring site.

Discussion and Conclusions

The NCP plays a vital role in monitoring the health of Yukon ecosystems and assuring Yukon residents that traditionally harvested foods are safe to eat. In general, levels of contaminants transported to the Yukon through the atmosphere and aquatic sources remains low, however levels of mercury may be a concern for older, larger fish in some areas. We continue to generate new chemicals on a continuous basis, some of these are now showing up in the Arctic and accumulating in animals and fish as well as in water and on the land. Long term data sets are critical to understand background levels, track changes and understand their relationship with climate change, industrial activity and other factors.

Expected Completion Date

Ongoing.

Project Website

www.northerncontaminants.ca

Dene Nation participation in the national NCP Management Committee and Northwest Territories Regional Contaminants Committee (NWTRCC)

Participation de la Nation dénée au Comité de gestion national du PLCN et au Comité régional des contaminants des Territoires du Nord-Ouest (CRCTNO)

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Abstract

In the 2015-2016 Fiscal Year the Dene Nation received funding from the Northern Contaminants Program to support its participation in the NCP Management Committee and on the NWT Regional Contaminants Committee (NWTRCC). As a national organization representing First Nations Peoples, the Dene Nation assists Canada in reviewing proposals for research under the Northern Contaminants Program, participating in the social-cultural review that assesses the extent to which research projects are relevant to Indigenous communities and are executed in a respectful and culturally appropriate manner. During the review process Dene Nation makes recommendations to help ensure that research projects are addressing the major concerns of

Résumé

Au cours de l'exercice 2015-2016, la Nation dénée a reçu des fonds dans le cadre du Programme de lutte contre les contaminants dans le Nord (PLCN) pour appuyer sa participation au Comité de gestion du PLCN et au Comité régional des contaminants des T.N.-O. (CRCTNO). En sa qualité d'organisation nationale représentant des membres des Premières Nations, la Nation dénée aide le Canada à examiner les propositions de recherche présentées dans le cadre du Programme de lutte contre les contaminants dans le Nord, à participer à l'examen socioculturel qui évalue la mesure dans laquelle les projets de recherche sont pertinents pour les collectivités autochtones et à faire en sorte que les recherches sont

Dene communities, that researchers include traditional knowledge where appropriate and that results are shared with communities. The Dene Nation has been an active Aboriginal Partner in the Northern Contaminants Program, participating in the national and regional coordination of the NCP since its inception. The Dene Nation hosts one Dene National Assembly and two leadership meetings a year, where reports on NCP activity are provided presented to the membership and included in the Dene Nation Annual Report.

effectuées de manière respectueuse et adaptée à leur réalité culturelle. Pendant le processus d'examen, la Nation dénée formule des recommandations pour s'assurer que les projets de recherche traitent des préoccupations importantes des collectivités dénées, que les chercheurs incluent le savoir traditionnel, s'il y a lieu, et que les résultats sont communiqués aux collectivités. La Nation dénée, depuis sa création, est un partenaire autochtone qui participe activement au Programme de lutte contre les contaminants dans le Nord, notamment pour ce qui est de la coordination nationale et régionale du PLCN. La Nation dénée est l'hôte d'une assemblée nationale de la Nation dénée et de deux réunions des dirigeants par année, à l'occasion desquelles des rapports d'activité du PLCN sont présentés aux membres de la Nation dénée et compris dans le rapport annuel de la Nation dénée.

Key Messages:

- Participation on NCP Management Committee
- Participation on NWT Regional Contaminants Committee
- Provide advice to NCP on contaminant issues in the communities
- Liaison on NCP activities within the Dene Nation Membership

Messages clés

- Participation aux travaux du Comité de gestion du PLCN
- Participation au Comité régional des contaminants des Territoires du Nord-Ouest
- Conseille le PLCN au sujet des contaminants dans les collectivités
- Informe les membres de la Nation dénée au sujet des activités du PLCN

Objectives

The Program's key objective is to work towards reducing, and where possible, eliminating contaminants in traditional/country foods, while providing information that assists individuals and communities in making informed decisions about their food use.

Summary

The Northern Contaminants Program (NCP) was established in 1991 in response to concerns about human exposure to elevated levels of contaminants in 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 (POPs), heavy metals, and radionuclide's - many of which had no Arctic or Canadian sources, but which were, nevertheless, reaching unexpectedly high levels in the Arctic Ecosystem.

The funds provided to the Dene Nation under the Northern Contaminants Program (NCP)

in 2015-16 allowed it to work with the NCP Secretariat and other Aboriginal Partners in addressing contaminant issues in research and monitoring projects, the social/cultural review of proposals and in updating the Blueprint for Communications, Capacity and Outreach. Funding enabled Dene Nation to also consider capacity and coordination issues for the Dene Nation and NWTRCC, developing a regional workshop proposal for discussion.

Results

The Dene Nation's Lands and Environment Director participated in conference calls and meetings between April 1, 2015 and March 31, 2016, including these meetings:

- NCP NWTRCC Communications Meeting, August 13-15, 2015, Yellowknife
- NC NWTRCC Mid-year Review Meeting, September 24, 2015, Yellowknife
- NCPMC Meeting – October 6-7, 2015 Ottawa (moved from Iqaluit)
- NCP NWTRCC Communications Blueprint Meeting, November 25-26, 2015, Yellowknife
- NCP Results Workshop - December 8-9, 2015, Vancouver
- NCP NWTRCC Proposal Social-Cultural Review, February 16-18, 2016, Yellowknife

Discussion / Conclusions

The funding supported the Dene Nation Lands and Environment Director's participation in NCP activities including preparations and follow up for teleconferences and face to face meetings, email and phone communications related to aboriginal partnership discussions, review of NCP funded projects and national/regional coordination meetings. The budget covered salaries to continue NCP work throughout the year and provide of NCP information at Dene National General Assembly and Dene Leadership Meetings.

The Dene Nation is also seeking to promote capacity building and improve the coordination of contaminants research and monitoring among Dene communities to the extent possible within the funding limitations of the program. More recently, the Dene Nation has also been seeking to encourage more consideration of the possible impacts climate change may have on the presence of contaminants in the country foods the Dene depend on. There is a growing concern about the rapid expansion of permafrost thaw and the release of contaminants like mercury and methane, as well as other biological changes that could affect sources of country food.

Inuit Tapiriit Kanatami National Coordination under the Northern Contaminants Program

Coordination nationale de l'Inuit Tapiriit Kanatami dans le cadre Programme de lutte contre les contaminants dans le Nord

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Abstract

Since the beginning of the Northern Contaminants Program (NCP) in 1991, Inuit Tapiriit of Kanatami (ITK) has participated in the program as managing partners. This partnership continues to be fruitful and effective both for Canadian Inuit and the Northern Contaminants Program (NCP). As the national political voice for Canadian Inuit, ITK continues to play multiple roles within the NCP. First, ITK provides guidance and direction to INAC and the other NCP partner's (HC, DFO, ECCC, etc.) bringing Inuit interests to the NCP management and liaison committees of which we are a member. As a result, the NCP can better respond to the needs and concerns of Inuit. Secondly, ITK is dedicated to facilitating

Résumé

Inuit Tapiriit Kanatami (ITK) est partenaire de gestion du Programme de lutte contre les contaminants dans le Nord (PLCN) depuis la création du programme, en 1991. Ce partenariat continue d'être fructueux et efficace pour les Inuits canadiens et pour le PLCN. Porte-parole politique des Inuits du Canada, ITK continue de jouer de multiples rôles au sein du PLCN. Premièrement, ITK fournit conseils et orientations à AANC et à d'autres partenaires du PLCN (Santé Canada, Pêches et Océans Canada, Environnement et Changement climatique Canada, entre autres), dans le but d'accroître l'intérêt des Inuits pour le comité de gestion et de liaison du PLCN dont nous sommes membres. En conséquence, le PLCN peut

appropriate and timely communications about contaminants in the North. Thirdly, ITK are working with their Inuit partners at the Inuit Circumpolar Council (ICC)-Canada on the international stage to persuade nations to reduce their generation and use of persistent organic pollutants (POPs) and Heavy Metals (Mercury) that end-up in the Inuit diet. Lastly, ITK is now working with other research programs like ArcticNet, Polar Knowledge Canada, Health Canada climate change program and the Chemicals Management Plan to make sure that research on contaminants is conducted in a coordinated approach. This is done mainly through the regional contaminants committees in each of the four Inuit regions of which ITK helps assist and guide. ITK involvement in Northwest Territories Regional Contaminants Committee, Nunavut Environmental Contaminants Committee, Nunavik Nutrition and Health Committee, and Nunatsiavut Government Research Advisory Committee contaminant committees is critical in order to deliver a consistent message to Inuit regarding the NCP and contaminants.

Key messages

- Provide a voice for the Inuit of Canada during NCP discussions
- To continue to be an active and constructive member of the NCP Management Structure ensuring that contaminants issues and NCP research and results are communicated to Inuit and that Inuit are represented at key regional, circumpolar and international meetings and initiatives.
- To contextualize contaminant information in a broader communication process using the Inuit Knowledge Centre
- Enhance the confidence of Inuit in their ability to make informed decisions about Country food use.

mieux répondre aux besoins et mieux réagir aux préoccupations des Inuits. Deuxièmement, ITK s'emploie à faciliter des communications adéquates et opportunes au sujet des contaminants dans le Nord. Troisièmement, ITK collabore avec ses partenaires inuits au sein du CCI-Canada à l'international pour persuader les pays de réduire la production et l'emploi des polluants organiques persistants (POP) et des métaux lourds (p. ex. le mercure) qui aboutissent dans les aliments des Inuits. Enfin, ITK collabore maintenant avec d'autres programmes de recherche, comme ArcticNet, Savoir polaire Canada, le programme sur les changements climatiques de Santé Canada et le Plan de gestion des produits chimiques, afin de garantir que les recherches sur les contaminants s'effectuent de façon coordonnée. ITK le fait surtout par sa participation aux travaux des comités régionaux sur les contaminants dans chacune des quatre régions inuites, grâce à l'aide et à l'orientation qu'il fournit. La participation d'ITK au Comité régional des contaminants des Territoires du Nord-Ouest, au Comité des contaminants de l'environnement du Nunavut, au Comité de la nutrition et de la santé du Nunavik et au Comité consultatif de la recherche du gouvernement du Nunatsiavut est essentielle à la présentation d'un message cohérent aux Inuits au sujet du PLCN et des contaminants.

Messages clés

- Se faire le porte-parole des Inuits du Canada dans les délibérations du PLCN.
- Continuer d'être un membre actif et constructif de la structure de gestion du PLCN, et veiller à ce que les questions relatives aux contaminants et les recherches du PLCN soient communiquées aux Inuits, et à ce que les Inuits soient représentés aux principales réunions et dans les initiatives importantes à l'échelle régionale, circumpolaire et internationale.
- Mettre en contexte les renseignements relatifs aux contaminants dans un contexte général par l'intermédiaire du Centre du savoir inuit.

- Coordinate Contaminants activities in Nasivvik, ArcticNet, and HC Climate Change Program

- Renforcer la confiance des Inuits afin qu'ils prennent des décisions éclairées au sujet de la consommation des aliments traditionnels.
- Coordonner les activités liées aux contaminants avec Nasivvik, ArcticNet et le programme sur les changements climatiques de Santé Canada.

Objectives

1. Participation in the NCP Management Committee
2. Participation in Regional Contaminant Committees
3. Participation on NCP review Team
4. Participation with Inuit Research Advisors teleconference and in person meetings
5. Participation ArcticNet AGM/RMC and BOD. Review of IRIS reports

Introduction

The story of contaminants in the arctic can be one of fear of the unknown; research carried out under NCP has shown that the contaminants of most concern for Inuit are persistent organic pollutants (POPs) and Heavy Metals like mercury. The concern of these contaminants comes from the fat-rich country marine foods diet that Inuit depended upon both for nutritious food and sustaining a lively culture. As a result there are places in the Canadian Arctic where some of the Inuit population are at risk because their dietary intake of mercury is greater than the levels that are known to be safe (NCP 2012). As well, NCP health projects out of Nunavik show that Inuit children have subtle negative effects because of prenatal exposure to PCBs and mercury. Inuit want to know and have the right to know what is happening to the health of Inuit, and to the health of the arctic environment. With these alarming data it is critical that Inuit involvement throughout the program in order to provide advice, direction and information to Inuit.

Activities in 2015-2016

Funding from the NCP to ITK comes from the funding envelop National Coordination which allows ITK to assess information and research generated by the program and to play an informed role in influencing present and future NCP management priorities through the established committees that are in place.

The focus of this year's activities is around the various NCP research committees such as the Regional Contaminant Committees (RCC's) with active participation on the NWT Regional Environment Committee (NWTRCC), Nunavut Environment Contaminants Committee (NECC) meetings, Nunivak Nutrition and Health Committee (NNHC), and the Nunatsiavut Government Research Advisory Committee(NGRAC). Also, ITK is now able to bring information forward to the National Inuit Committee on Health (NICoH) and the Inuit Knowledge Center Committee as well as the recently established Amaujaq National Centre for Inuit Education. When issues arise that have a potential human health risk we go through ITK Health and Social Economic Development Department in bringing concerns to Inuit Public Health Task Group. Last year with the new formation of the Wildlife and Environment department we are developing stronger regional wildlife contacts with Wildlife workers to vent NCP environment information through. Some of the NCP information and data was used in our Polar Bear efforts and fact sheet development. We also continue to assist and help guild ICC in their global efforts in eliminating Mercury from use.

ITK also participated in all of the NCP management meetings, as well as various review committees like the Human Health review team, the Environment Trends, Community Base Monitoring and Research and Communication and Capacity Outreach teams. Participation on these committees provide a voice for the Inuit of Canada, developed priorities and issues within NCP framework, developed confidence for Inuit in making informed decisions on their food and coordinated contaminant activities with other research programs like ArcticNet and Nasivvik to ensure that the message of contaminants are placed in a wider context and the research is conducted in a responsible manner throughout the arctic. This is also done with the Inuit Research Advisors (IRA's) that are partially funded by the NCP and are assisted by ITK. The main objective here is to provide a coordinated approach towards research and communication, to provide and Inuit "voice" and direction at the NCP management table to ultimately allow Inuit to have confidence in making good informed decisions about their food use

Another role of informing the public about issues in the north, ITK gave various presentations about the NCP general contaminants primer across Canada and the USA.

Results

Part of our responsibilities with the NCP funding is to consult with the principal investigators and communities that will be engage in research in Inuit regions. This year there was close to 40 projects that are took place in the Inuit regions. ITK involvement in these projects can range from minimum advisory role to very intensive project control. ITK has guided researcher in various environmental monitoring programs on how to communicate to communities, translating scientific information, making links to other research programs, encouraging capacity building. ITK will continue to assist both the researchers and the Inuit regions and communities with the conclusion of these projects.

ITK was committed to providing a coordination role for Inuit to attend the ArcticNet in Vancouver December 2015. Led by the Department of Environment and Wildlife, an internal coordination committee was formed with representatives from the Inuit Qaujisarvingat: Inuit Knowledge Centre (IQ), Health and Social Development, Communications and Finance. All activities led by ITK were a joint effort between these departments.

Inuit and other Indigenous northerners were in attendance at this meeting their presence was noticeable and appreciated.

Discussion and Conclusions

In a time of great turn over and changing personal, ITKs engagement to the NCP committee's has been the one constant over the last 18 years. This has provided each of the contaminants committee with some record of history. This year ITK will work and help each of the four regional committee's (Nunatsiavut, Nunavik, Nunavut, and the NWT), engage with the NCP review teams, help with the development of the new Risk Communication Subcommittee, participate and help with any issues that NCP might need assistance with. ITK will continue to sit on all contaminant committees (Nunatsiavut, Nunavik, Nunavut and Inuvialuit) and NCP Management and Human Health, Community Based Monitoring, and Education and Outreach review teams and bring to these discussions and committees information learned from participation with the Inuit Public Health Task Group, Food security committee, mental wellness committees, early childhood development, Inuit Health Survey, National Inuit Committee on Health, Nasivvik, ArcticNet, FNIB community based climate change program, youth programs like NS and the National Inuit Youth Committee. Support from the NCP will allow ITK to participate in all these initiatives and be able to bring a contextualization to the NCP program and other national programs like Chemicals Management

Plan and Commission for Environment Cooperation (CEC) and to Inuit regions.

Expected Project Completion Date

Ongoing

Project website (if applicable)

www.itk.ca

http://www.inuitknowledge.ca/

http://30214.vws.magma.ca/index.php
(Niqiit the story of contaminants)

Inuit Circumpolar Council – Canada activities in support of circumpolar and global contaminant instruments and activities

Conseil circumpolaire inuit – Activités du Canada visant à appuyer les instruments et les activités de lutte contre les contaminants circumpolaires et mondiaux

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Abstract

This report outlines ICC Canada's activities funded by Northern Contaminants Program (NCP) in the fiscal year of 2015/2016. 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, and input into the Canadian Arctic Contaminants Assessment III (CACAR III) for the Highlights, and Policy maker summary reports, as well as leading Chapter 4 of the CACAR-IV Human Health report. Internationally, ICC Canada continued its activities related to the United Nations Environment Programme (UNEP). Work on the Stockholm Convention on Persistent

Résumé

Ce rapport fait état des activités du Conseil circumpolaire inuit (CCI) Canada financées par le Programme de lutte contre les contaminants dans le Nord (PLCN) pendant l'exercice 20152016. Le CCI-Canada travaille à l'échelle nationale et internationale à régler les questions relatives aux contaminants dans l'Arctique. Parmi les activités nationales, citons l'appui offert au PLCN au sein du Comité de gestion, l'examen de plans directeurs et de propositions, la contribution apportée aux faits saillants du Troisième rapport d'évaluation des contaminants dans l'Arctique canadien (RECAC III) et aux résumés à l'intention des décideurs, ainsi que la direction de la rédaction du chapitre 4 du RECAC IV en matière de

Organic Pollutants (POPs) is ongoing, with ICC Canada attending the 11th POP Review Committee (POPRC) in October 2015. ICC Canada continued to support Arctic Council activities, in particular within the Arctic Monitoring and Assessment Programme (AMAP), such as co-leading Chapter 6 on Risk Communication for the AMAP Assessment 2015: Human Health in the Arctic. ICC Canada was very active on the Sustaining the Arctic Observing Networks (SAON) Board, the SAON Executive Committee, and continues leading the SAON task on community-based monitoring. ICC Canada also co-chaired the Third Arctic Observing Summit (AOS), which took place March 16 – 18 2016 in Fairbanks, Alaska.

Key messages

- ICC Canada worked actively to support NCP by working on the Management Committee, Environmental Monitoring and Community Based Monitoring technical review committees, the CACAR III Highlights report and the summary for policy makers, and led Chapter 4 (on Chemical management, risk management, and contaminant communication) for CACAR IV (Human Health).
- ICC Canada attended the 11th Persistent Organic Pollutants Review Committee (POPRC) meeting, provided input in POPRC working group documents and informed the NCP about POPRC work.
- ICC Canada actively contributed to Arctic Council related work, attended the Arctic Monitoring and Assessment Programme (AMAP) Working Group and Heads of Delegation meetings, SAON meetings, and teleconferences of the SAON Executive Committee.

santé humaine. À l'échelle internationale, le CCI-Canada a poursuivi ses activités se rapportant au Programme des Nations Unies pour l'environnement (PNUE). Les travaux se rapportant à la Convention de Stockholm sur les polluants organiques persistants (POP) sont en cours, et le CCI-Canada a assisté à la 11e réunion du Comité d'examen des POP en octobre 2015. Le CCI-Canada a continué de soutenir les activités du Conseil de l'Arctique, notamment dans le cadre du Programme de surveillance et d'évaluation de l'Arctique (PSEA), comme codiriger la rédaction du chapitre 6 sur la communication des risques du rapport d'évaluation du PSEA de 2015 : Santé humaine dans l'Arctique. Le CCI-Canada continue de participer très activement aux travaux du conseil des Sustaining the Arctic Observing Networks (SAON) et du comité exécutif des SAON, et il continue de diriger la tâche des SAON concernant la surveillance communautaire. Le CCI-Canada a également coprésidé le troisième sommet sur l'observation de l'Arctique, qui a eu lieu du 16 au 18 mars 2016 à Fairbanks (Alaska).

Messages clés

- Le CCI-Canada a travaillé activement pour appuyer le PLCN en participant au Comité de gestion, aux comités d'examen technique en matière de surveillance environnementale et surveillance communautaire ainsi qu'aux faits saillants du RECAC III et au résumé à l'intention des décideurs. De plus, il a dirigé la rédaction du chapitre 4 (sur la gestion des produits chimiques, la gestion des risques et la communication des risques) du RECAC IV (Santé humaine).
- Le CCI-Canada a assisté à la 11e réunion du Comité d'examen des polluants organiques persistants, a fourni des commentaires pour les documents du groupe de travail de ce comité et a informé le PLCN au sujet des travaux du Comité.

- ICC Canada was very active in the AMAP Human Health Assessment Group (HHAG) and co-lead Chapter 6 on Risk Communication for the AMAP Assessment 2015: Human Health in the Arctic.
- Work on mercury isotopes in ice cores and snow samples to identify mercury pathways and sources to the Arctic continued, a publication (Historical variations of mercury stable isotope ratios in arctic glacier firn and ice cores, Zdanowicz et al.) was submitted March 2016 to the journal Global Biogeochemical Cycles.
- ICC Canada co-chaired the Third Arctic Observing Summit, which took place March 16 – 18, 2016 in Fairbanks, Alaska.

- Le CCI-Canada a contribué activement aux travaux liés au Conseil de l'Arctique, a assisté aux réunions du groupe de travail du PSEA et des chefs de délégation, aux réunions des SAON et aux téléconférences du comité exécutif des SAON.
- Le CCI-Canada a joué un rôle très actif au sein du groupe d'évaluation de la santé humaine du PSEA et a codirigé la rédaction du chapitre 6 sur la communication des risques pour l'évaluation du PSEA de 2015 : La santé humaine dans l'Arctique.
- Le CCI-Canada continue d'effectuer des recherches sur les isotopes de mercure dans des carottes de glace et des échantillons de neige afin de déceler les trajets du mercure et les sources du métal en Arctique; une publication (Historical variations of mercury stable isotope ratios in arctic glacier firn and ice cores, Zdanowicz et al.) a été soumise en mars 2016 à la revue Global Biogeochemical Cycles.
- Le CCI-Canada a coprésidé le troisième sommet sur l'observation de l'Arctique, qui a eu lieu du 16 au 18 mars 2016 à Fairbanks (Alaska).

Objectives

Short-term objectives of ICC's activities are:

1. to ensure that Inuit are aware of global, circumpolar and national activities and initiatives on contaminants
2. that Inuit viewpoints and interests are represented in contaminant-related matters, and are considered and included in relevant research, reports, assessments and meetings pertinent to policy development
3. to ensure that scientific research in the Arctic is addressing Inuit needs and is done with Inuit support and involvement

Long-term goals are:

1. to ensure Inuit have the capacities, resources and knowledge necessary to support their participation and involvement in national and international policy development on contaminant issues,
2. to assist in the development of a framework that allows for sustained and integrated community-based research and includes the use of traditional and scientific knowledge, and, ultimately, to reduce, and if feasible eliminate, contaminants in the Arctic environment

Introduction

Inuit are Arctic Indigenous peoples living in Russia (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 Indigenous and Northern Affairs Canada (INAC), has enabled ICC Canada to work effectively on addressing the issue of contaminants in the Arctic. ICC Canada is part of the NCP Management Committee, is directly involved with contaminant research in the Arctic, works within the Arctic Monitoring and Assessment Programme (AMAP) of Arctic Council, and represents Inuit at the United Nations Environment Programme (UNEP) and related meetings.

Activities in 2015-2016

This section gives a detailed account of ICC Canada's activities in relation to what was proposed to and funded by (in particular) the NCP in the fiscal year of 2015-2016.

1. NCP

Proposed activities:

a) ICC Canada will continue to support NCP's work through the Research Managers, blueprint and proposal review processes (particularly in the Environmental Trends Envelope) and at the annual Results Workshop, as in past years.

b) ICC Canada was involved in the development of the Canadian Arctic Contaminants Assessment (CACAR) Highlights report and was part of the advisory committee to lead the work. ICC Canada will continue to provide input for this report as necessary and possible.

c) NCP has been working to establish a Risk Communication sub-committee and a sub-committee on traditional knowledge. Given the relevance of these topics to ICC's international work, ICC Canada would like to participate in activities of the groups as much as possible.

Work undertaken:

a) ICC Canada participated in teleconferences and meetings of the Environmental Monitoring and Community-based Monitoring technical review committees and provided input, attended the NCP Research Management Meetings on April 14 – 16, 2015 and October 6 – 8, 2015 in Ottawa, reviewed proposals and documents (such as blueprints) as required, provided comments, and updates on the CACAR IV Human Health chapter (see below), the Stockholm Convention COP-7 outcomes, and POPRC activities. Eva Kruemmel further participated in teleconferences on the NCP strategic plan and provided input. ICC Canada attended the NCP Results Workshop Dec 7 – 8th, 2015 in Vancouver and gave an update on international activities together with Sarah Kalhok.

b) Eva Kruemmel sent comments on a new outline of the Highlights Report/

Summary for Policy Makers, commented on a key-findings section and provided a paragraph on Inuit involvement in the international conventions. ICC Canada has further received additional funds from Health Canada to lead a chapter on chemical management and contaminant communication for the CACAR IV Human Health report. Several drafts of this chapter have been completed, were extensively reviewed and revised. A final draft will be submitted to the NCP in May 2016.

c) Eva Kruemmel participated in a risk communication call on April 9th, 2015.

2. AMAP

Proposed activities:

a) **General:** ICC Canada will attend Working Group meetings and Heads of Delegation meetings if resources permit, and will review and comment on related documents, as necessary and possible

b) **AACA-C:** ICC Canada was part of the development process, is part of the Integration Team, and coordinated activities with the other ICC offices. ICC-Canada will continue this work, as resources permit.

c) **Sustaining the Arctic Observing Network (SAON):** Eva Kruemmel is part of the SAON Board, the SAON Executive Committee, continues as SAON's co-chair of the organizing committee for the Arctic Observing Summit (AOS) and will attend the relevant meetings.

d) **Health Expert Group:** ICC Canada remains active with the SDWG and AMAP Human Health Expert Groups and will attend meetings as possible. ICC Canada has funding confirmed from Health Canada until end of March, 2015 to lead the risk communication chapter of the AMAP Health Assessment. However, funding from Health Canada for this work is not yet certain for next fiscal year (2015/2016).

e) **POPs Expert Group:** Eva Kruemmel has been nominated as an expert for AMAP's POPs Expert Group by Canada and will be involved in the development of the upcoming AMAP POPs Assessment as much as possible. Time and funding permitting, she will work on the inclusion of the Inuit perspective on POPs, review chapter drafts, include content related to the Stockholm Convention on POPs and the POP Review Committee, and attend meetings.

Work undertaken:

a) **General:** ICC Canada participated in the AMAP Heads of delegation meeting June 18 – 19, 2015 in Washington, DC and the AMAP Working Group meeting September 13 – 15, 2015, in Tromsø, Norway. ICC also reviewed and provided input into AMAP documents before and after the meetings, such as for AMAP reports, such as the Arctic Pollution Issues summary report. Eva Kruemmel further participated in teleconferences on the POPs/Hg Biological Effects assessment and provided comments.

b) **AACA-C:** ICC Canada continues to be involved in the process, and Stephanie Meakin is a member of the integration team, organized and attended teleconferences. ICC attended AACA-related meetings in Tromsø, and provided comments for the pan-Arctic prospectus and regional reports.

- **SAON:** Eva Kruemmel took part in teleconferences and face-to-face meetings of the SAON Executive Committee and SAON Board (teleconference June 10th, 2015, face-to-face meeting March 16-17, 2016 during the AOS in Fairbanks, Alaska), as well as the AOS organizing committee. As part of the AOS organizing committee and co-chair of the AOS 2016, she helped to organize the working group and session on traditional knowledge and community-based monitoring ("Theme 6: Interfacing Indigenous Knowledge, Community-based Monitoring and Scientific Methods for sustained Arctic observations"). Details and recordings of the AOS are available on its website: http://www.arcticobservingsummit.org/

– As part of the SAON task, ICC and partners completed a review on Community-Based Monitoring (CBM) and Indigenous knowledge in a Changing Arctic. An Executive Summary was submitted to the third AOS in Fairbanks as a white paper. Both documents are available on the ICC Canada website (see Communication section below).

c) **Health Expert Group:** ICC Canada is active in the SDWG and AMAP Health Expert Groups (AHHEG and HHAG, respectively). ICC Canada received funding from Health Canada to co-lead Chapter 6 on Risk Communication for the AMAP Assessment 2015: Human Health in the Arctic, has worked extensively on the chapter, sent drafts out for review and revised the chapter, reviewed the other chapters, and provided comments. The assessment is now published an available from AMAP's website (www.amap.no). Eva Kruemmel further attended meetings of both human health expert groups (separate HHAG and AHHEG as well as one combined) that took place in conjunction with the International Congress on Circumpolar Health (ICCH) June 7 – 9, 2015 in Oulu, Finland. She presented the findings of the AMAP Health Assessment risk communication chapter during a special session of the ICCH. Eva Kruemmel was not able to attend a fall meeting of the HHAG, but provided written input for the white paper for future work.

d) **POPs Expert Group:** Eva Kruemmel attended POPs Expert Group teleconferences and provided comments and input for the Biological Effects Assessment that is currently in development.

3. UN related

Proposed activities:

a) **Minamata Convention:** ICC Canada will continue to work on the issue, review documents and attend related meetings as necessary and possible. ICC Canada will continue to be active in the government and stakeholder consultation process and related work.

b) **Persistent Organic Pollutants Review Committee (POPRC):** ICC Canada will attend the 11th POPRC meeting October 19 – 23, 2015 in Rome, Italy, and is looking forward to keep its partners and the NCP Management Committee updated on this work. ICC Canada is also involved in several of the POPRC working groups which provide input on candidate chemicals and other issues throughout the intersessional period, and will ensure NCP data is included in the POP candidates review documents (such as Risk Profiles and Management Evaluations). ICC Canada will particularly work with scientists to provide input into the risk profile development of short-chained chlorinated paraffins (SCCPs) and dicofol, and the risk management evaluation of deca-bromodiphenyl ether (deca-BDE).

c) **Stockholm Convention on POPs:** The Stockholm Convention on POPs will have its 7th Conference of the Parties (COP) from May 5 – 8, 2015 in Geneva, Switzerland. This conference will for the second time be part of a "triple COP", where three conventions (Basel, Stockholm and Rotterdam) will meet back-to-back. A "Science Fair", reflecting the COP theme of "From Science to Action: Working for a Safer Tomorrow," will take place associated with the triple COP from 7-9th May, 2015. ICC Canada is planning to attend the Stockholm Convention COP and to participate in the Science Fair.

Work undertaken:

a) **Minamata Convention:** So far there was very little development on further work, but ICC Canada continues to review the progress and read associated documents.

b) **POPRC:** ICC Canada reviewed draft risk profiles on dicofol and SCCPs and submitted comments and new information to the POPRC. Eva Kruemmel keeps in touch with AMAP and NCP scientists for new data and additional research needs. Eva Kruemmel participated in a webinar organized by the Basel-Stockholm-Rotterdam (BSR) Convention secretariat and presented on effective participation of NGOs. ICC Canada attended the 11th POPRC meeting October 19 – 23, 2015 in Rome, Italy.

c) **Stockholm Convention on POPs:** Eva Kruemmel attended COP-7 of the Stockholm Convention May 5 – 8, 2015 in Geneva and the Science Fair on May 8th, 2015. During the plenary discussions, ICC gave an intervention on the addition of the new POPs candidates.

ICC Canada participated in a Stakeholder Workshop on Multilateral Environmental Agreements (MEAs) organized by Environment and Climate Change Canada on February 26th, 2016. At the meeting, ICC highlighted the value and importance of the NCP for Canada's contributions to MEAs. A report of the meeting was forwarded to the NCP secretariat.

4. Other mercury and POPs related work

Proposed activities:

ICC Canada is continuing to analyze results from the mercury study investigating the sources of mercury to the Arctic. A publication on some of this work has been published, and another one (on mercury isotopes) is currently being developed. Results of this study will feed into ICC Canada's general work, in particular with regards to NCP, AMAP and the Minamata Convention, and will be used in policy development and ICC Canada's consultation and communication efforts. ICC Canada will also monitor and review other contaminant research that is accessible from journals, meetings, conferences and workshops, and by directly discussing research with scientists conducting relevant studies. This work will also feed into ICC Canada's communication efforts.

Work completed:

ICC Canada created a Polar Data Catalogue entry for the results of the study in March 2015. The data analysis continued, and a paper on the mercury isotope results (Historical variations of mercury stable isotope ratios in arctic glacier firn and ice cores, Zdanowicz et al.) was submitted in March 2016 to the journal Global Biogeochemical Cycles, and conditionally accepted (pending revisions) in April 2016.

Eva Kruemmel further undertook literature searches, contacted scientists for information as needed, and reviewed publications for input into work on contaminant-related meetings, briefing notes, and other relevant items.

5. Communication

Proposed activities:

ICC Canada has been improving its web presence with a revamped website (http://www.inuitcircumpolar.com) and now also has Facebook and Twitter accounts. Beginning early 2015, ICC Canada will start to publish newsletters that give regular updates and brief overviews of the most recent activities.

Further communication efforts that are being conducted as part of ICC Canada's regular work include the preparation of meeting reports, press releases, newsletter contributions, briefing notes, presentations, reporting on ICC's work in face-to-face meetings, teleconferences etc.

Work completed:

ICC Canada's general communication efforts are ongoing, and ICC Canada continues to work on its general presence on the internet (such as the ICC Canada Facebook-site, and Twitter account). Information is prepared and disseminated regularly through the internet, meetings, emails and teleconferences, in form of briefing notes, presentations, meeting reports and press releases, etc., as required and possible. ICC Canada is further planning to launch a newsletter soon that will likely be prepared on a bi-annual basis.

Some communication examples (please also see table under "NCP Project Statistics and Information" below):

Press releases related to NCP work (available on ICC's website at http://www.inuitcircumpolar.com/press-releases.html):

- Dec 8, 2015: "ICC Canada and ITK Urge the Government to Enhance the Northern Contaminants Program"
- Mar 23, 2016: "Inuit Circumpolar States the Need for Inuit Knowledge in Evidence Based Decision Making" (leading to a Nunatsiaq News article: "ICC supports call for pan-Arctic climate change monitoring system", available online: http://www.nunatsiaqonline.ca/stories/article/65674icc_supports_call_for_pan-arctic_climate_change_monitoring_system)
- ICC and its partners published the full review and Executive Summary on Community-Based Monitoring (CBM) and Indigenous knowledge in a Changing Arctic (available on ICC Canada's website: http://www.inuitcircumpolar.com/…/3054…/cbm_final_report.pdf http://www.inuitcircumpolar.com/uploads/3/0/5/4/30542564/cbm_executive_summary_final.pdf).

Examples of presentations given:

- February 25th, 2016: Guest lecture by Eva Kruemmel on "Inuit Circumpolar Council's Involvement in Research and Policy Development on Contaminants" at University of Ottawa course "Toxicology and Regulation"
- December 7 - 8, 2015: Presentation on International Activities by Sarah Kalhok and Eva Kruemmel at the NCP Results Workshop in Vancouver, B.C.
- 8 October, 2015: Presentation by Eva Kruemmel on "Effective Participation of NGOs in POPRC" at a POPRC Webinar organized by the BRS (Basel-Rotterdam-Stockholm Conventions) Secretariat
- 9th June, 2015: Presentation by Eva Kruemmel on "Risk Communication Chapter, AMAP Health Assessment" at the 16th International Congress on Circumpolar Health in Oulu, Finland

Discussion and Conclusions:

With support from NCP, ICC Canada worked very successfully in many international fora to ensure that Inuit perspectives were brought forward. Examples include the Stockholm Convention COP-7, where ICC Canada gave an intervention on POPs proposed for addition and outlined how Inuit are affected. At the end of the meeting, three additional chemicals were added to the Stockholm Convention's Annex A for elimination. At POPRC-11, ICC Canada brought forward Arctic research (such as from NCP and AMAP) and the Inuit perspective on POPs under review, and POPRC decided to advance several chemicals in the review process. At the Arctic Council, ICC Canada contributed to AMAP assessments (such as the 2015 Human Health Assessment) and to other initiatives, such as SAON (such as the Arctic Observing Summit) and AACA. ICC Canada is active to support and strengthen the utilization of community-based monitoring (CBM) and Indigenous knowledge, for example through the creation of the Atlas on CBM and Indigenous Knowledge in a Changing Arctic (www.articcbm.org) and the development of the accompanying review paper. ICC Canada supported the NCP with contributions to CACAR III and IV, the Results Workshop and in the management of the program. ICC Canada is looking forward to continue these activities in the next years to ensure that Inuit perspectives are recognized in international policy development on contaminants and Arctic research.

Project website

ICC Canada's website:
www.inuitcircumpolar.com

References:

Zdanowicz, C., Krümmel, E.M., Poulain, A.J., Yumvihoze, E., Chen, J., Štrok, M., Scheer, M., Hintelmann, H. Historical variations of mercury stable isotope ratios in arctic glacier firn and ice cores. Submitted in March 2016 to Global Biogeochemical Cycles.

Krümmel E.M. and A. Gilman. 2015. Chapter 6, Risk Communication. In: S. Donaldson and J.Ø. Odland (eds.), AMAP Assessment 2015: Human Health in the Arctic. Arctic Monitoring Assessment Programme (AMAP), Oslo, Norway. p 111 – 125.

Johnson, N., Behe C., Danielsen F., Krümmel E.M., Nickels, S., Pulsifer, P.L. 2016. Community-Based Monitoring and Indigenous Knowledge in a Changing Arctic: A Review for the Sustaining Arctic Observing Networks. Available on the internet: http://www.inuitcircumpolar.com/…/3054…/cbm_final_report.pdf