Synopsis of Research

Conducted under the 2016–2017 Northern Contaminants Program:

Full Report

Résumé de la recherche

effectuée en 2016–2017 dans le cadre du
Programme de lutte contre les contaminants dans le Nord :

rapport complet

Synopsis of Research Conducted under the 2016-2017 Northern Contaminants Program: Full Report

Résumé de la recherche effectuée en 2016-2017 dans le cadre du Programme de lutte contre les contaminants dans le Nord : rapport complet

This is an unpublished document created internally by the Northern Contaminants Program (NCP) Secretariat.

The related publication, Synopsis *of Research conducted under the 2016-2017 Northern Contaminants Program: Abstract and Key Messages,* is available through the NCP Publications Database at www.aina.ucalgary.ca/ncp.

For information regarding this report please contact the Northern Contaminants Program Secretariat at aadnc.plcn-ncp.aandc@canada.ca.

Ceci est un document non publié créé à l'interne par le Secrétariat du Programme de lutte contre les contaminants dans le Nord.

La publication connexe, *Résumé de la recherche effectuée en 2016-2017 dans le cadre du Programme de lutte contre les contaminants dans le Nord: résumés et messages clés*, est disponible dans la base de données des publications du Programme de lutte contre les contaminants dans le Nord à l'adresse www.aina.ucalgary.ca/ncp.

Pour plus d'information concernant ce rapport, veuillez contacter le Secrétariat du Programme de lutte contre les contaminants dans le Nord à l'adresse suivante: aadnc.plcn-ncp.aandc@canada.ca.

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Foreword

The Northern Contaminants Program (NCP) works 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 *Synopsis of Research Conducted under the 2016-2017 Northern Contaminants Program: Full Report* provides a detailed summary of the activities and preliminary results of each project funded under the NCP between April 1, 2016 and March 31, 2017.

The projects described in this report cover the broad range of topics that contribute to understanding and addressing northern contaminants issues. They are arranged according to the five NCP subprograms: Human Health; Environmental Monitoring and Research; Communications, Capacity and Outreach; Community Based Monitoring and Research; and Program Coordination and Indigenous Partnerships. Specific research priorities, as outlined in the program's strategic documents (i.e. the NCP Blueprints and NCP Call for Proposals 2016-2017), included dietary contaminant exposure, choice, and risk perception; effects of contaminants on the health of people and ecosystems; contaminant levels and trends in the Arctic environment/wildlife and the influence of climate change; and the benefits/risk evaluation of country food consumption. Projects were carried out using a variety of methodologies including fieldwork, laboratory analysis, community based monitoring, Indigenous Knowledge workshops, and much more.

All projects supported by the NCP are 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 NCP and its partners. Engagement and partnership with

Avant-propos

Le Programme de lutte contre les contaminants du Nord (PLCN) travaille 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. Le *Résumé de Recherche effectuées en 2016-2017 dans le cadre du Programme de lutte contre les contaminants dans le Nord : rapport complet* présente un résumé détaillé des activités et des résultats préliminaires de chaque projet financé dans le cadre du PLCN entre le 1er avril 2016 et le 31 mars 2017.

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. Ils sont disposés selon les cinq sous-programmes PLCN: Santé humaine; Surveillance et recherche environnementales; Communications, capacité et la sensibilisation; Surveillance et recherche communautaire; Coordination du programme et partenariats autochtones. Les priorités de recherche spécifiques énoncés dans les plans stratégiques du PLCN (c›est-à-dire les plans directeurs du PLCN et l›Appel de propositions 2016-2017), notamment les suivants : l'exposition alimentaire à des contaminants, choix d'aliments et la perception du risque; les effets des contaminants sur la santé des individus et des écosystèmes; les niveaux de contaminants et les tendances dans l'environnement/ les espèces sauvages dans l'Arctique et l'influence des changements climatiques; et les avantages/ évaluation des risques de la consommation de la nourriture traditionnelle. Les projets ont été menés à l'aide de diverses méthodes, y compris le travail sur le terrain, l'analyse en laboratoire, la surveillance communautaire, les ateliers sur le savoir autochtone et bien plus encore.

Tous les projets soutenus par le PLCN font 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

Indigenous organizations, northern territorial and/or community authorities is required for all projects involving activities within northern communities, fieldwork in the North and/or analyses of samples, as a condition of approval for funding.

This report contributes to ensuring the transparency of the NCP and the timely sharing of results. A summary (abstract and key messages) report entitled *Synopsis of Research conducted under the 2016-2017 Northern Contaminants Program: Abstract and Key Messages* is available through the NCP Publications Database at www.aina.ucalgary.ca/ncp. All individual project reports were lightly edited for clarity and consistency.

In addition to the *Synopsis of Research* publications, publications related to NCP funded projects (including peer reviewed journal articles) can be searched and accessed through the NCP Publications Database at www.aina.ucalgary.ca/ncp. Also, data and metadata associated with individual projects can also be found on the Polar Data Catalogue website at www.polardata.ca.

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

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.

La présentation d'un rapport aux fins de la présente publication assure la transparence du PCLN ainsi qu'une communication rapide des résultats. Un Résumé de Recherche abrégé intitulé

Résumé de Recherche effectuées en 2016-2017 dans le cadre du Programme de lutte contre les contaminants dans le Nord : résumés et messages clés est disponible dans la Base de données des publications du PLCN à l'adresse www.aina.ucalgary. ca / ncp. Tous les rapports de projet individuels ont été légèrement modifiés pour plus de clarté et de cohérence.

En plus des publications *Résumé de Recherche*, les futures publications liées aux projets financés par le PCLN (y compris des articles publiés dans des revues examinées par des pairs) seront versés dans la base de données des publications du PLCN, à l'adresse www.aina.ucalgary.ca/ncp. De plus, les données et les métadonnées associées à chaque projet individuel peuvent également être consultées sur le site Web du catalogue de données polaires à l'adresse 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

The Abstract and Key Messages of each individual project report are provided in both English and French. The main body of each individual project report is published in the language in which it was written by the project leader. Complete individual project reports are available in both official languages, upon request. Requests for individual reports can be made to: aadnc.plcn-ncp.aandc@canada.ca.

Avertissement concernant les langues officielles

Les résumés et les messages clés de tous les rapports de projets individuels sont fournis en anglais et en français. Le corps principal de chaque rapport de projet individuel est publié 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 individuel sont disponibles sur demande dans l'une ou l'autre des langues officielles. On peut présenter une demande pour obtenir des rapports individuels à : aadnc.plcn-ncp.aandc@canada.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 Council's Arctic Monitoring and Assessment Programme (AMAP), and to international agreements such as the United Nations Environment Programme's Minamata Convention on Mercury and Stockholm Convention on Persistent Organic Pollutants, that work on a global scale 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 Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC), and consists of representatives from four federal departments (Environment and Climate Change Canada, Fisheries and Oceans, Health and CIRNAC), five territorial, provincial and regional governments (Yukon, Northwest Territories, Nunavut, Nunavik and Nunatsiavut), four northern Indigenous 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 NCP Management Committee is responsible for establishing NCP policy and science priorities and for making final decisions on the allocation of funds.

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 résidents 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 et la Convention de Stockholm sur le polluants organiques persistants du Programme des Nations Unies pour l'environnement. Ces contributions à des travaux internationaux visent à améliorer la santé des résidents et des espèces sauvages à long terme.

Le PLCN est dirigé par un comité de gestion présidé par Relations Couronne-Autochtones et Affaires du Nord Canada (RCAANC). Il compte des représentants de quatre ministères fédéraux (Environnement et changement climatiques Canada, Pêches et Océans Canada, Santé Canada et AADNC), de cinq gouvernements provinciaux ou territoriaux (le Yukon, les Territoires du Nord-Ouest, le Nunavut, le Nunavik et le Nunatsiavut), de quatre organisations autochtones nordiques (le Conseil des Premières Nations du Yukon, la Nation

The Regional Contaminants Committees in the Yukon, Northwest Territories, Nunavut, Nunavik and Nunatsiavut support this national committee with region-specific expertise and advice. Funding for the NCP's $4.1 million annual budget comes from CIRNAC and Health Canada. Details about the management structures and review processes used to effectively implement the NCP, and the protocol 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).

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 en lui fournissant de l'expertise et des conseils propres à sa région. 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 utilisé pour diffuser publiquement l'information sur la santé et la récolte produite dans le cadre du Programme.

Background

In 2016-2017, the NCP celebrated its 25th anniversary of funding contaminants research and communications activities in northern Canada. 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 Indigenous peoples. Early studies indicated that there was a wide spectrum of substances - persistent organic pollutants, heavy metals, and radionuclides - many of which had no Arctic or Canadian sources, but which were, nevertheless, reaching unexpectedly high levels in the Arctic ecosystem.

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

Under the first phase of the NCP, research was focused on gathering the data required to determine the levels, geographic extent,

Contexte

En 2016-2017, le PLCN a célébré son 25e anniversaire de financement des activités de recherche et de communication sur les contaminants dans le Nord du Canada. 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 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 of consuming traditional food, an emphasis was placed on characterizing and quantifying the benefits associated with traditional diets. Communications activities were also emphasized and supported. Under the leadership of the northern Indigenous organizations, the

collectivités de 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.

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 in dealing with specific contaminant issues at the local level.

Since 2003, the NCP has continued to contribute to assessments that synthesize data funded through the NCP program. 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.

The next reports in the CACAR series, *Contaminants in Canada's North: State of Knowledge and Regional Highlights*, and *Human Health 2017* will be released in 2018.

En 1998-1999, le PLCN a entrepris sa deuxième phase, qui s'est poursuivie jusqu'en 2002-2003 et 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 de la consommation de la nourriture traditionnelle 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 résidents 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.

Depuis 2003, le PLCN a continué de contribuer aux évaluations qui synthétisent les données financées par le programme PLCN. 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.

Les prochains rapports de la série CACAR, *Les contaminants dans le Nord canadien: État des connaissances et synthèse régionale, et Santé humaine 2017* seront publiés en 2018.

International Impact

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

1. 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.
2. 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.
3. The Minamata Convention on Mercury, a legally-binding agreement to cut emissions and releases of mercury to the environment, entered into force on August 16, 2017. The convention was signed by Canada in October 2013 and on April 7, 2017. Canada became the 41st country to ratify the treaty. The NCP made important contributions to this historic signing and ratification, through use of its data, information and expertise, and will continue to play a role in monitoring the effectiveness of the Convention. The first meeting of the Conference of the Parties to the Minamata Convention on Mercury (COP1) from September 24 to 29, 2017, discussed procedures and directions for the implementation of the Convention.

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, particulièrement dans le cadre des actions en collaboration menées dans le cadre du Conseil de l'Arctique's Programme de surveillance et d'évaluation de l'Arctique, dans les initiatives suivantes :

1. 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.
2. 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.
3. La Convention de Minamata sur le mercure, un accord juridiquement contraignant visant à réduire les émissions et les rejets de mercure dans l'environnement, est entrée en vigueur le 16 août 2017. La convention a été signée par le Canada en octobre 2013 et le Canada est devenu le 41ème pays à ratifier le traité le 7 avril 2017. Les données, les renseignements et l'expertise issus du PLCN ont grandement contribué à la signature de cet accord historique et à cette ratification de la Convention, et le PLCN continuera à jouer un rôle dans le suivi de l'efficacité de la Convention. La première réunion de la Conférence des Parties à la Convention de Minamata sur le mercure (COP1) du 24 au 29 septembre 2017 a examiné les procédures et les orientations pour la mise en œuvre de la Convention.

10 Key Findings of the Northern Contaminants Program

(from *Contaminants in Canada's North: Summary for Policy Makers, 2015*)

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 2015 *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.

Current Directions of the Northern Contaminants Program:

(adapted from *Contaminants in Canada's North: Summary for Policy Makers*, 2015)

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

- is continuing to play a critical role in the detection of new chemical contaminants of concern to the Arctic and will continuously review and refine its list of contaminants of concern.
- is enhancing the measurement of long-term trends of mercury and POPs by filling gaps in geographic coverage.
- is carrying out more research to understand the effects of climate change and predict their impacts on contaminant dynamics and ecosystem and human health risks.
- is supporting the expansion of community-based monitoring projects that build scientific capacity in the North and optimize the use of traditional knowledge.

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

- is addressing 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.

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

(orientations adaptées du rapport de 2015 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 :

- est en train de jouer un rôle crucial dans la détection de nouvelles substances chimiques contaminantes préoccupantes dans l'Arctique et va examiner et peaufiner continuellement sa liste de contaminants préoccupants;
- est en train d'améliorer la mesure des tendances à long terme du mercure et des POP en comblant les lacunes dans la couverture géographique;
- est en train d'affectuer 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;
- soutien l'élargissement de 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 :

- s'interesse, en collaboration avec les autorités sanitaires régionales et territoriales, aux préoccupations actuelles en matière de santé publique en lien avec les contaminants et la salubrité des aliments par :
  - comparer 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;
  - l'extension de la surveillance de l'exposition des populations humaines

In terms of *Communications and Outreach*, the NCP

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

- is ensuring 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.

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;

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

- est en train de communiquer 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 sont en train d »être 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;

- est en train de continuer de vérifier 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 3)

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

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Abstract

The Inuit Health Survey (2007-2008) collected data on blood levels of heavy metals and persistent organic pollutants (POPs) in adult participants from the Canadian north. The population-level risks of contaminant exposures can be assessed using biomonitoring equivalents (BEs), which are the corresponding internal concentrations of oral health-based reference values or concentrations of the points of departure (PODs) used to derive 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 BEs, 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 (2007-2008) a permis de recueillir des données sur les niveaux sanguins de métaux lourds et de polluants organiques persistants chez des participants adultes du Nord canadien. Les risques d'exposition aux contaminants pour la population peuvent être évalués au moyen d'équivalents de biosurveillance. Les équivalents de biosurveillance sont les concentrations internes correspondant aux valeurs de référence pour la santé (exposition par voie orale) ou aux concentrations des doses critiques (POD, pour points of departure) ayant servi à établir ces valeurs de référence. Ce projet vise à établir de nouveaux équivalents de biosurveillance pour le chlordane et le toxaphène, ainsi qu'à utiliser ces valeurs afin d'évaluer les risques pour la population à partir des données de biosurveillance recueillies dans le Nord canadien. Au cours

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 BEs for individual chlordane and toxaphene isomers. The BEs 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. Results were presented at the Northern Contaminants Workshop in December 2015 and at the Northern Contaminants Program: Human Health Monitoring and Risk Communication Workshop in November 2016. In the third and final year of the project, we have further refined the BEs based on population-specific body fat percentage data for the general Canadian and Inuit populations; we compared the population-specific BE values with biomonitoring data from the CHMS and HIS; we conducted a dietary analysis of important sources of those contaminants; and we developed preliminary, physiological-based pharmacokinetic (PPBPK) models that more realistically simulate chlordane pharmacokinetics.

de l'exercice 2014-2015, les renseignements nécessaires pour déterminer les équivalents de biosurveillance, tels que les normes de référence relatives à l'absorption, ont été trouvés dans la documentation publiée et non publiée. Plusieurs valeurs de référence avaient déjà été proposées par des organisations comme Santé Canada, l'Environmental Protection Agency (EPA) des États-Unis et les autorités européennes. Une stratégie de modélisation pharmacocinétique a aussi été définie, en plus de l'établissement des paramètres pharmacocinétiques nécessaires pour modéliser le comportement des contaminants internes en fonction de l'absorption, de la distribution, du métabolisme et de l'excrétion. Au cours de la deuxième année du projet, en 2015-2016, les données recueillies ont servi à réaliser une modélisation pharmacocinétique à un compartiment en vue de calculer des équivalents de biosurveillance pour les différents 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 (ESI) et du premier cycle (2007-2009) 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 en décembre 2015 et à l'atelier sur la surveillance de la santé humaine et la communication des risques tenu par le Programme de lutte contre les contaminants dans le Nord en novembre 2016. Au cours de la troisième et dernière année du projet, nous avons précisé les équivalents de biosurveillance selon les données sur le pourcentage de graisse corporelle dans la population canadienne générale et dans la population inuite. Nous avons également comparé les valeurs des équivalents de biosurveillance propres à la population aux données de biosurveillance de l'ECMS et de l'ESI, et nous avons procédé à l'analyse des principales sources alimentaires de ces contaminants. Enfin, nous avons élaboré des modèles pharmacocinétiques physiologiques préliminaires (PPBPK) qui simulent avec un plus grand réalisme la pharmacocinétique du chlordane.

Key Messages

- Population-specific BEs were developed for the general Canadian and Inuit populations 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 population-specific BEs were close to the generic BEs based on 70 kg weight and 25% body fat.
- The population-specific BE values for chlordane and toxaphene have been compared with biomonitoring data from the CHMS, Cycle 1 (2007-2009) and the IHS (2007-2008).
- The comparisons included whole population, population subgroups, and regional analyses for the Inuvialuit Settlement Region (ISR), Nunavut, and Nunatsiavut.
- Among the general Canadian population, no exceedances of BE values were observed for either chlordane or toxaphene.
- Results for the Inuit population will be presented to our Inuit partners before release.

Messages clés

- Des équivalents de biosurveillance ont été définis spécifiquement pour la population canadienne générale et la population inuite en ce qui concerne le chlordane (cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, oxychlordane) et le toxaphène (Parlar 26, 50, 62) à l’aide d’un modèle pharmacocinétique à un compartiment. Les équivalents de biosurveillance propres à la population se rapprochaient des équivalents de biosurveillance génériques, pour un poids de 70 kg et un pourcentage de graisse corporelle de 25 %.
- Les valeurs des équivalents de biosurveillance propres à la population pour le chlordane et le toxaphène ont été comparées aux données de biosurveillance provenant de l’ECMS, cycle 1 (2007-2009) et de l’ESI (2007-2008).
- Les comparaisons incluaient la population totale, des sous-groupes de population et des analyses régionales pour la Région désignée des Inuvialuit (RDI), le Nunavut et le Nunatsiavut.
- Dans la population générale du Canada, aucun dépassement des équivalents de biosurveillance n’a été observé tant pour le chlordane que le toxaphène.
- Les résultats relatifs à la population inuite seront présentés à nos partenaires inuits avant leur publication.

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 collected data on blood concentrations of environmental contaminants in 2,595 adult 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 $\mu g \bullet L^{-1}$, 70% exceeded the cadmium guideline level of 1 $\mu g \bullet L^{-1}$, 35% exceeded the dietary mercury guideline of 5.0 $\mu g \bullet kg$ body $weight^{-1} \bullet week^{-1}$, and 27.9% women of child-bearing age exceeded the Arochlor 1260 guideline of 5 $\mu g \bullet L^{-1}$ (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. As a result, 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.

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 ($mg \bullet kg^{-1} \bullet d^{-1}$) 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 propose to 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 2016-2017

In the 2016-2017 funding year, we further refined the derived BE values for cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, toxaphene Parlars No. 26, 50, and 62 based on population-specific body fat percentage and body weight. The resulting BE values are thus tailored specifically to the general Canadian population covered by the CHMS, Cycle 1 (2007-2009) and the Inuit population covered by the IHS (2007-2008). We also present here a BE value for the main chlordane metabolite, oxychlordane, based on a separate assessment of toxicological oxychlordane studies. We compared the population-specific BE values with biomonitoring data from the CHMS, Cycle 1 and the IHS for whole population, and by the pre-specified population subgroups, to determine percentage in exceedance. Additionally, for the Inuit population, we conducted individual analyses for the ISR, Nunavut, and Nunatsiavut. We presented the results of this work at the Northern Contaminants Program: Human Health Monitoring and Risk Communication Workshop in November 2016.

Using data from the Arctic Monitoring Assessment Program (AMAP), we examined which traditional foods are likely to be the greatest contributors of exposure to persistent organic pollutants. We focused our analyses on those contaminants for which we observed significant exceedances of the BEs. We also examined the food-frequency questionnaire of the IHS to identify dietary differences among those who were below and those who exceeded BEs.

A more complex modeling strategy for chlordane was explored during this year. We chose chlordane, specifically, because we observed exceedance of its BE among the Inuit. We developed a three-compartment model consisting of blood, liver, and adipose tissues and a six-compartment model consisting of blood, liver, adipose tissues, kidney, slowly-perfused (i.e. skin, muscle) and rapidly-perfused (i.e. brain). Our objective for these complex models was to explore if more accurate simulations of chlordane pharmacokinetics result in significant changes to the BE value of a simple one-compartment model. The interpretation of this work is still on-going.

Results

Table 1 presents the toxicity endpoints and points of departure (i.e. NOAEL) that were utilized to derive the BE values for chlordane and toxaphene. Tables 2 and 3 provide the derived BE values for chlordane and toxaphene, respectively. Generic BE values (based on 70 kg and 25% body fat), general Canadian population tailored BE values, and Inuit population tailored BE values are shown for both chlordane and toxaphene. A BE for oxychlordane is presented in Table 2, based on an endpoint of histopathological changes in the liver of rats, demonstrated by Bondy et al. (2003). Please note that the generic BE values for cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, and toxaphene Parlars No. 26, 50, 62, presented in the current report, differ from the values presented in the 2015-2016 report because: (i) The weight of rat and mouse were changed from 300 g to 250 g and from 30 g to 25 g, respectively, and (ii) Interspecies human variability (UF_{H-PD}) was factored in by dividing the BE values by an additional factor of three.

Table 4 presents the exceedances of general Canadian population-specific BEs for chlordane and toxaphene among the population covered by the CHMS, Cycle 1. No exceedances were found in general Canadians. Here we have not presented specific data for the Inuit because discussion with our Inuit partners is required before dissemination. We are in the process of compiling regional reports that will describe and summarize our results.

Figures 1 and 2 show the levels of chlorobenzenes (includes hexachlorobenzene) and chlordanes (includes trans-nonachlor) in Arctic marine mammals. Highest levels of chlorobenzenes are found in narwhal and highest levels of chlordanes are in polar bear. We will explore differences in diet composition among Inuit who have low and high blood levels. However, as with the biomonitoring data, we have not presented these results as discussion with Inuit partners is required.

Table 1. Human Oral Reference Doses for Chlordane and Toxaphene

	Chlordane			Toxaphene
	ATSDR 1994	JMPR 1994	EPA 2009	MATT 2012
Chemical Form	Technical	Technical	Technical	Weathered*
Animal Model	Rat	Rat	Mouse	Rat
Endpoint	Hepatocellular hypertrophy	Hepatic toxicity**	Hepatic necrosis	Altered hepatic foci expressing placental glutathione-S-transferase***
NOAEL (mg/kg/d)	0.055	0.05	0.15	1.8
Human Oral Reference Dose (mg/kg/d)	MRL: 0.0006	pTDI: 0.0005	RfD: 0.0005	pTDI: 0.018

* Technical toxaphene administered to farmed cod fish and toxaphene residues from liver extracted.
** Unpublished study submitted to FAO/WHO – specific toxicity endpoint unclear.
*** Indication of tumour promotion.

Abbreviations: ATSDR = Agency for Toxic Substances and Disease Registry; EPA = Environmental Protection Agency; JMPR = Joint FAO/WHO Meeting on Pesticide Residues; MATT = Investigation into the Monitoring, Analysis, and Toxicity of Toxaphene in Marine Foodstuffs; MRL = minimum risk level; NOAEL = no-observed adverse effect level; pTDI = provisional tolerable daily intake; RfD = reference dose; TDI = tolerable daily intake

Table 2. Derivation of BE Values for Chlordane

	Cis-Chlordane	Trans-Chlordane	Cis-Nonachlor	Trans-Nonachlor	Oxychlordane
POD (mg/kg/d)	R: 0.055; M: 0.15	R: 0.055; M: 0.15	R: 0.055; M: 0.15	R: 0.055; M: 0.15	R: 0.1*
BE_{animal} (mg/kg lipid)	R: 0.36-1.05 M: 0.94-5.00	R: 0.81-2.02 M: 3.13-5.00	R: 1.39-2.44 M: 3.57-5.71	R: 2.08-3.67 M: 6.25-10.00	R: 6.94-11.11
Allometric Scaling Factors**					
Generic	R:4; M:7	R:4; M: 7	R:4; M: 7	R: 4; M: 7	R:4
General Canadian	R:6; M:10	R:6; M:10	R:6; M:10	R:6; M:10	R:6
Inuit	R:5; M:9	R:5; M:9	R:5; M:9	R:5; M:9	R:5
UF_{H-PD}	3	3	3	3	3
BE_{human} (generic) (mg/kg lipid)	0.03-0.23 Midpoint: 0.13	0.07-0.23 Midpoint: 0.15	0.11-0.26 Midpoint: 0.19	0.17-0.46 Midpoint: 0.32	0.57-0.91 Midpoint: 0.74
BE_{human} (general Canadian) (mg/kg lipid)	0.02-0.17 Midpoint: 0.10	0.05-0.17 Midpoint: 0.11	0.08-0.19 Midpoint: 0.14	0.12-0.34 Midpoint: 0.23	0.42-0.67 Midpoint: 0.55
BE_{human} (Inuit) (mg/kg lipid)	0.02-0.18 Midpoint: 0.10	0.05-0.18 Midpoint: 0.12	0.09-0.20 Midpoint: 0.15	0.13-0.35 Midpoint: 0.24	0.44-0.70 Midpoint: 0.57

* NOAEL from Bondy et al. (2003).
** Rounded to nearest whole number.

Abbreviations: BE = biomonitoring equivalent; M = mouse; POD = point of departure; R = rat; UF_{H-PD} = uncertainty factor for human pharmacodynamic variability

Table 3. Derivation of BE Values for Toxaphene

	Parlar No. 26	Parlar No. 50	Parlar No. 62
BEPOD (mg/kg/d)	R: 1.8	R: 1.8	R: 1.8
BE_{animal} (mg/kg lipid)	10.71-150.00	25.00-75.00	25.00-60.00
Allometric Scaling Factors*			
Generic	4	4	4
General Canadian	6	6	6
Inuit	5	5	5
UF_{H-PD}	3	3	3
BE_{human} (mg/kg lipid)	0.87-12.22 Midpoint: 6.55	2.04-6.11 Midpoint: 4.08	2.04-4.89 Midpoint: 3.47
BE_{human} (general Canadian) (mg/kg lipid)	0.64-9.01 Midpoint: 4.83	1.50-4.50 Midpoint: 3.0	1.50-3.60 Midpoint: 2.55
BE_{human} (Inuit) (mg/kg lipid)	0.67-9.42 Midpoint: 5.05	1.57-4.71 Midpoint: 3.14	1.57-3.77 Midpoint: 2.67

* Rounded to nearest whole number.

Abbreviations: BE = biomonitoring equivalent; POD = point of departure; R = rat; UF_{H-PD} = uncertainty factor for human pharmacodynamic variability

Table 4. Exceedances of Chlordane and Toxaphene Concentrations in the CHMS

	CHMS, Cycle 1 (2007-2009)	
	99th Percentile (mg/kg lipid)	% Equal to or Exceeding BE*
Chlordane		
Cis-Chlordane	0.0014	0.0
Trans-Chlordane	0.00074	0.0
Cis-Nonachlor	0.0067	0.0
Trans-Nonachlor	0.040	0.0
Oxychlordane	0.021	0.0
Toxaphene**		
Parlar No. 26	0.0026	0.0
Parlar No. 50	0.0042	0.0

* Midpoint value of BE range. Percentages exclude missing values.
** Parlar No. 62 was not measured in the CHMS.

Abbreviations: BE = biomonitoring equivalent; CHMS = Canadian Health Measures Survey

Figure 1. Data from the Arctic Monitoring Assessment Program (AMAP) – Chlorobenzenes (Raw data courtesy of Dr. Derek Muir)

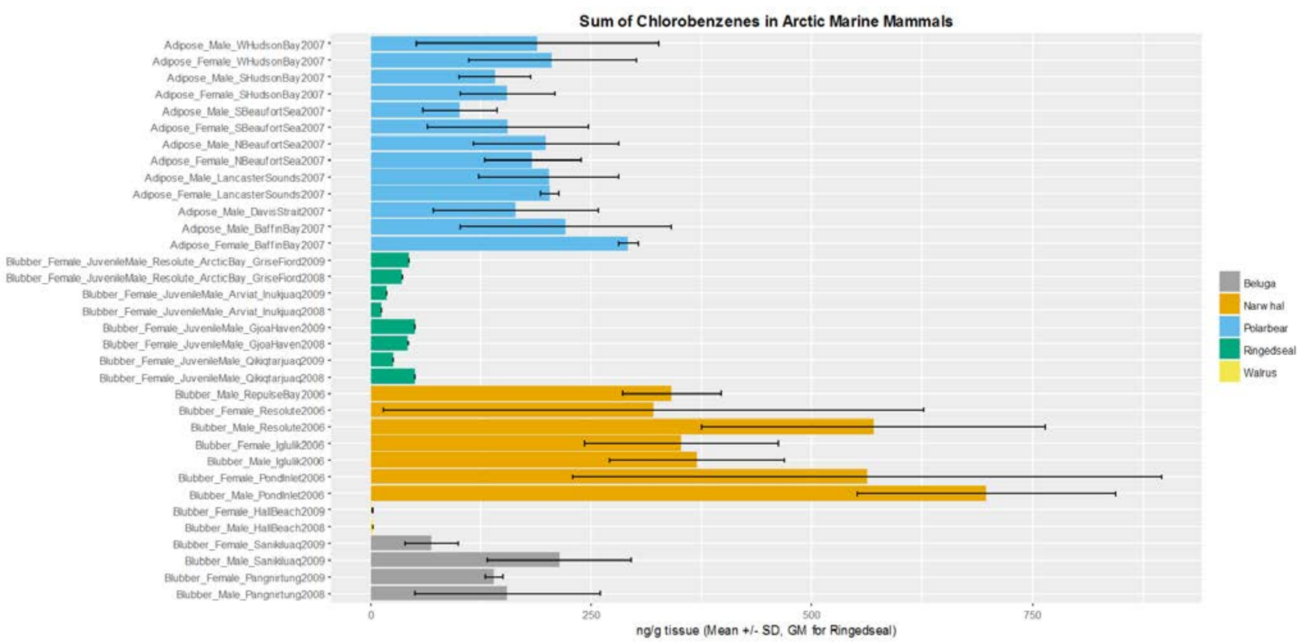
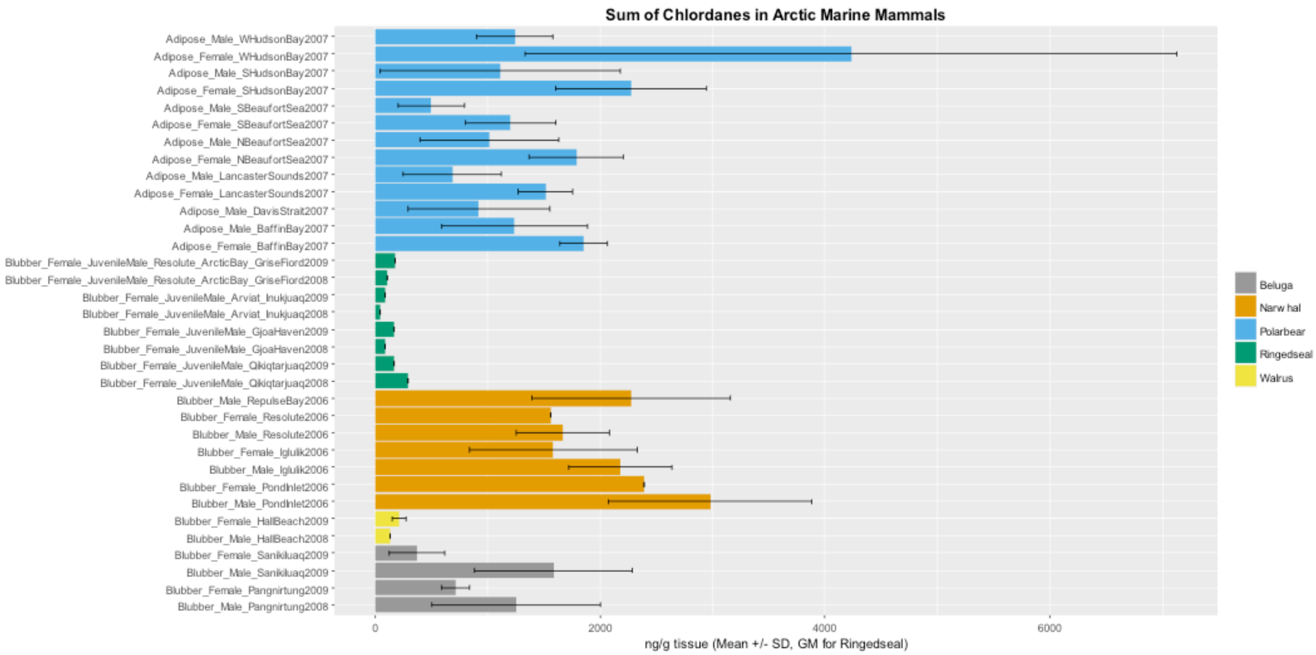


Figure 2. Data from the Arctic Monitoring Assessment Program (AMAP) – Chlordanes (Raw data courtesy of Dr. Derek Muir)



Discussion and Conclusions

During the final fiscal year of this project in 2016-2017, we have derived population-specific 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. We have also conducted subgroup analyses by sex, women of childbearing age, young adults, middle-aged, elderly and by region. None of the general Canadian population were in exceedance of the BE values, and data on the Inuit population will follow after consultation with the relevant Inuit partners.

The BE values for chlordane and toxaphene developed in this study provide a way to interpret the biomonitoring data of the IHS in a population-based health risk context. Previously, aside from oral reference doses that are not directly comparable with internal blood contaminant concentrations, no guidance was available for either chlordane or toxaphene. This study, therefore, contributes to better understanding of the persistent organic pollutant exposure data collected in the IHS 2007-2008 and provides direction for selecting contaminants for ongoing monitoring efforts.

We think it is important to inform the main communities (i.e. ISR. Nunavut, Nunatsiavut) of this research and to also obtain their input and perspectives on public health implications and future research needs relating to development of guidance values. In 2016 we developed a communication plan (Appendix 1). We are currently in the process of compiling regional-specific reports to describe the results of this work and we will apply selected components of the communication plan, as deemed appropriate by the communities.

Expected Project Completion Date:

March 2017

Acknowledgments

We thank the members of the Steering Committees of the Inuit Health Survey for their support and the NCP for funding. In-kind support from Health Canada is acknowledged. The CHMS analysis was conducted at the Carleton, Ottawa, Outaouais Research Data Centre (COOL-RDC) which is part of the Canadian Research Data Centre Network (CRDCN). The services and activities provided by the COOL-RDC are made possible by the financial or in-kind support of the SSHRC, the CIHR, the CFI, Statistics Canada, Carleton University, the University of Ottawa and the Université du Québec en Outaouais.

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Appendix 1

Development of Blood Guidance Values for Persistent Organic Pollutants for the Canadian Arctic: Communication Plan (2016-2017)

An integral component of this project is the communication of the project's concept and design, results, and interpretation of results for communities. With guidance from our partners in each region, we will work towards developing a package of communication materials in English and translated into local Inuktitut language (specific deliverable materials are described below). The communication materials will be coordinated with NCP Risk Communication SubCommittee and Regional Contaminant Committee.

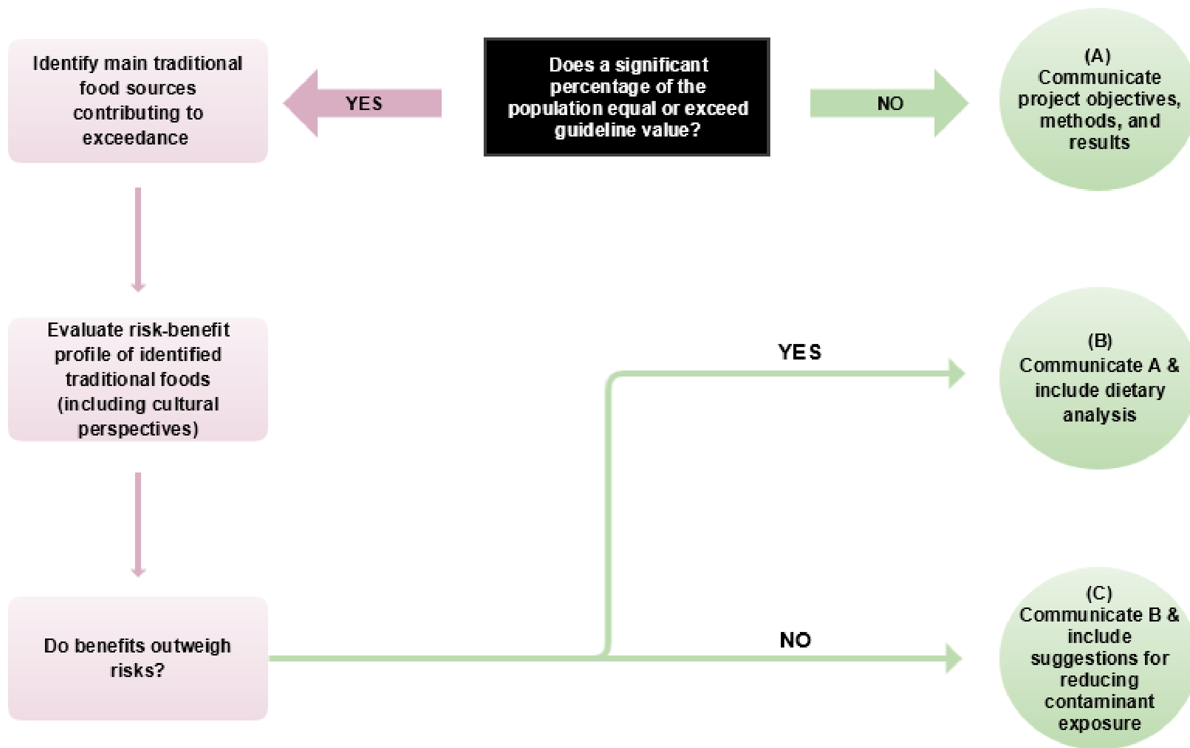
Given the project's focus on environmental contaminant levels in blood and sources of contaminants from traditional foods, we want to ensure that the communication messages are clear, scientifically-based, and reflect the perspectives of Inuit. The communication should result in positive outcomes, including:

- Understanding of persistent organic pollutants in the Arctic environment, biota, and humans.
- Understanding what guideline values for environmental contaminants are and the general process for deriving these values.
- Awareness of persistent organic pollutant levels observed in Inuit and how these levels compare with guideline values.
- Understanding the potential health risks of persistent organic pollutant levels if a significant percentage of the population equals or exceeds a guideline value.
- Balancing the benefits of traditional foods with identified health risks to make informed and health-promoting decisions about foods.

To achieve these goals, we would like to work closely with the partners in each region. This collaboration will be essential for developing communication messages and materials that are sensitive, address the needs and perspectives of Inuit, and that are effective at conveying the message. We do not want the communication to be one-sided with respect to the adverse effects of contaminants in traditional foods and to create unwarranted fear or anxiety. We understand that traditional foods have many benefits, both for the health and culture of Inuit, which must be discussed alongside any identified risks to provide an accurate and holistic picture of traditional food consumption. Ultimately, the choice of what foods to include in one's diet is a decision based on individual perspectives of risks and benefits, experiences, and priorities. We hope that this project will provide Inuit communities with more information, which can be incorporated by individuals into making informed decisions about foods.

Figure 1 shows the overall work plan for communication. The content of the communication will depend on whether a significant proportion of the population equals or exceeds the guideline values developed for persistent organic pollutants. If the majority of the population is below the guideline value, then no additional analysis is needed and the communication message will consist of a description of the project objectives, methods, and results. If a significant proportion of the population does equal or exceed a guideline value, then it will be important to identify which traditional food sources are contributing most to intake of that contaminant. For the identified traditional foods, we would also like to provide an assessment of the benefits that includes both nutritional and cultural aspects. The assessment of benefits and interpretation of benefit-risk profiles must be completed through a consultation process with regional partners. If the benefits are found to outweigh the health risks, then the communication message will consist of project objectives, methods, results, and dietary analysis. If the benefits are found to not outweigh the health risks, then the communication message will also include suggestions for reducing contaminant exposure. This message will not be framed as a consumption advisory, but rather will provide different traditional foods with their levels for the contaminant in question. We hope that this will help individuals make informed decisions.

Figure 1. Communication Work Plan- Below, we describe the individual components of our communication plan.



1. **Project objectives, methods, and results**

   A. Description of the persistent organic pollutants we examined in this project: including historical uses, levels found in Arctic environment, and why these particular contaminants were chosen.

   - Chlordane
   - Toxaphene
   - PCBs

   B. General process of how we developed guideline values

   - We will focus on providing more qualitative and visual explanation instead of technical jargon.

   C. Description of the data sources we used:

   - Inuit Health Survey (2007-2008)
   - Additional sources for dietary examination of contaminants – e.g. NCP reports and CACAR

   D. Results of comparisons of blood levels of persistent organic pollutants with guideline values

   - We will show the percentage of the whole population from the Inuit Health Survey that equals or exceeds guidelines values, as well as subgroups by region, gender, and age.

2. **Balance of health risks and benefits (consultation process)**

If a significant proportion of the population equals or exceeds the guideline value for a contaminant, then we will investigate what traditional food sources are contributing most to intake of that contaminant. The health risks and benefits of the identified traditional foods will be explored through a consultation process with regional partners.

A. **Health risks:** The risks of exposure to contaminant will be based on the endpoints used to derive the guideline values as well as data available in the literature of adverse effects in humans (case reports and epidemiological studies). As much as possible, this data will be summarized in a qualitative, visual manner to assist with comprehension of the information.

B. **Benefits:** To understand the benefits of the identified traditional foods, we will examine the nutrient content and explore the cultural benefits according to Inuit perspectives. This will require collaboration between us as the researchers, regional partners, and key Inuit group(s) who can accurately represent the Inuit perspectives of traditional foods and assess the balance of risks and benefits.

3. **Deliverable Communication Materials**

We will hold four workshops with the Regional Contaminant Committees in Yellowknife, Iqaluit, Kuujjuaq, and Nain. During these workshops we will communicate the information as presented above. In consultation with the regional partners, we will also develop communication materials (e.g. brochures, pamphlets, website, other materials as deemed appropriate) for the public in both English and Inuktitut that explains the project, process, and results in an easily accessible and understandable manner. Before launching any communication materials to the public, we would like to pilot test them to ensure that the materials are appropriate and effective at conveying the information as intended.

4. **Feedback on Communication**

We would like to obtain feedback on our communication methods to help us in understanding the effectiveness of the communication and making improvement for future projects. We will consult with our regional partners on the most suitable method (e.g. written or oral survey) and respondents for gathering this feedback.

Do country food nutrients protect against mercury toxicity and cardiometabolic diseases? Integrating data from cutting-edge science and mobilizing knowledge towards Nunavimmiut health (year 3)

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 Nunavimmiuts (troisième année)

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Abstract

Despite a decreasing temporal trend over the last decades, methylmercury (MeHg) exposure in the Inuit population of Nunavik is still among the highest in the world. Country foods from the marine food chain are the major source of this exposure, but country food are also exceptionally rich in nutrients such as selenium (Se) and omega-3 polyunsaturated fatty acids (n-3 PUFA). Through an interdisciplinary program incorporating nutrition, epidemiology, toxicology, oceanography and implementation

Résumé

Malgré une tendance à la baisse au cours des dernières décennies, l'exposition au méthylmercure (MeHg) au sein de la population inuite du Nunavik demeure parmi les plus élevées au monde. La consommation d'aliments traditionnels issus de la chaîne alimentaire marine est la principale source de cette exposition. Or, ces aliments traditionnels sont exceptionnellement riches en nutriments tels que le sélénium (Se) et les acides gras polyinsaturés oméga-3 (AGPI n-3). Grâce à un

research, we are addressing the complex issue of benefits and risks of country foods in the Inuit population of Nunavik, especially with regard to cardiometabolic diseases and Se-Hg interactions and respective toxicity. This year, in addition to continuing the integration of data obtained during our 2012-2016 program, we have conducted key work centred mainly on better defining the origin in the Arctic marine food chain of selenoneine, a new selenocompound recently identified in Inuit blood and beluga mattaaq by our team, and the interaction between this compound and methylmercury in red blood cells. These results will improve our capacity to develop and implement interventions that aim to promote the benefits of country foods of marine origin, while minimizing MeHg toxicity in this population.

programme de recherche interdisciplinaire intégrant la nutrition, l'épidémiologie, la toxicologie, l'océanographie et la recherche sur la mise en œuvre, nous abordons la question complexe des avantages et des risques associés aux aliments traditionnels chez les Inuits du Nunavik, en particulier à l'égard des maladies cardiométaboliques, des interactions entre le Se et le Hg et de leur toxicité respective. Cette année, en plus de poursuivre l'intégration des données recueillies par notre programme de 2012 à 2016, nous avons réalisé des travaux importants, qui visaient à mieux comprendre l'origine de la sélénonéine, un nouveau sélénocomposé que notre équipe a récemment détecté dans le sang des Inuits et le mattaq de béluga, de même qu'à décrire l'interaction entre ce composé et le méthylmercure dans les globules rouges. Ces résultats nous aideront à élaborer et à mettre en œuvre des interventions visant à promouvoir les avantages des aliments traditionnels provenant de la mer, tout en réduisant l'exposition au méthylmercure dans cette population.

Key Messages

- Selenoneine levels in red blood cells of Nunavimmiut are related to their beluga mattaaq consumption;
- Selenoneine levels are significantly higher in women compared to men;
- Additional country food analyses did not reveal important selenoneine sources other than beluga mattaaq;
- Preliminary in vitro experiments were conducted to study the methylmercury-selenoneine interaction.

Messages clés

- Les concentrations de sélénonéine dans les globules rouges des Nunavimmiut sont liées à leur consommation de béluga mattaaq;
- Les concentrations de sélénonéine sont significativement plus élevés chez les femmes que chez les hommes;
- D'autres analyses d'aliments traditionnels n'ont pas révélé d'autres sources importantes de sélénonéine que le béluga mattaaq;
- Des expériences préliminaires in vitro ont été menées pour étudier l'interaction méthylmercure-sélénonéine.

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 type 2 diabetes (T2D) risk issued from metabolomics studies in the same plasma samples(completed);
- To measure concentrations of selenoneine and its metabolites in red blood cells (RBCs) of NHS participants (completed);
- To examine the associations between biomarkers of methylmercury (MeHg) exposure, biomarkers of Se status and early biomarkers of T2D risk (ongoing);
- To investigate links between MeHg exposure, nutrient status, early biomarkers of TD2 risk and T2D related effects using path analyses (ongoing).

The **second section** focuses on Se and Hg concentrations, and Se speciation in Nunavik country foods. Because our recent results indicate that selenoneine is a major selenocompound in the blood of Inuit and beluga mattaaq, this section now focuses on determining its concentration in various country foods and other species that are part of the Arctic marine food web. The specific objectives of this section are:

- To collect selected country foods from several Nunavik villages in collaboration with community members and the Nunavik Research Center of Makivik Corporation (completed);
- To determine the age of the animals sampled and measure total Se and Hg concentrations in the corresponding country food samples (completed);
- To determine concentrations of Se species including selenoneine in different country foods consumed by Nunavimmiut;
- To determine concentrations of selenoneine and nutrients in a wide array of species from the marine food chain collected in Qikiqtarjuaq, Nunavut.

The **third section** consists of performing in vitro experiments with RBCs to characterize the interaction between MeHg and selenoneine that both accumulate in RBCs (ongoing).

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

- To determine whether country foods nutrients protect against MeHg toxicity and cardiometabolic diseases (ongoing);
- To mobilize this integrated knowledge towards Nunavimmiut health (ongoing).

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 cardiovascular disease (CVD) (Dewailly et al., 2001). They can also be highly exposed to MeHg, polychlorinated biphenyl (PCB), perfluorooctane sulfonate (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 selenoprotein 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).

In 2010, Japanese researchers identified a novel selenocompound, selenoneine, as the major form of organic Se in Bluefin tuna, and other marine organisms (Yamashita and Yamashita 2010). This Se-analog of ergothioneine, a powerful antioxidant molecule, could contribute to the scavenging of reactive oxygen species (ROS) 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). A subsequent study among Japanese fish-eating population showed that selenoneine is primarily found in the cellular fraction of the blood compartment. Both selenoneine and MeHg concentrations in the cellular fraction significantly increased together with marine fish consumption, while serum Se and Hg concentrations remained low despite increasing fish intake (Yamashita et al. 2013a). In vitro experiments further revealed that selenoneine can regulate the demethylation of methylmercury in human cells (Yamashita et al. 2013b).

Our research group recently found exceptionally high concentrations of selenoneine in Inuit RBCs and beluga mattaaq (Achouba et al. in preparation; Ayotte et al. 2017). Other dietary sources of selenoneine and species of marine Arctic ecosystems involved in selenoneine biosynthesis remain to be identified. Molecular physiologic and/or toxicologic mechanisms of selenoneine in human and marine species are still unclear. In vitro studies using different cell lines to understand the underlying molecular mechanisms of selenoneine and MeHg interactions are required. In addition, further studies are needed to examine associations between high Se and selenoneine intake from marine foods, new biomarkers of Se status and health issues including neurologic and cardiometabolic health.

Activities in 2016-2017

Section 1 of the project:

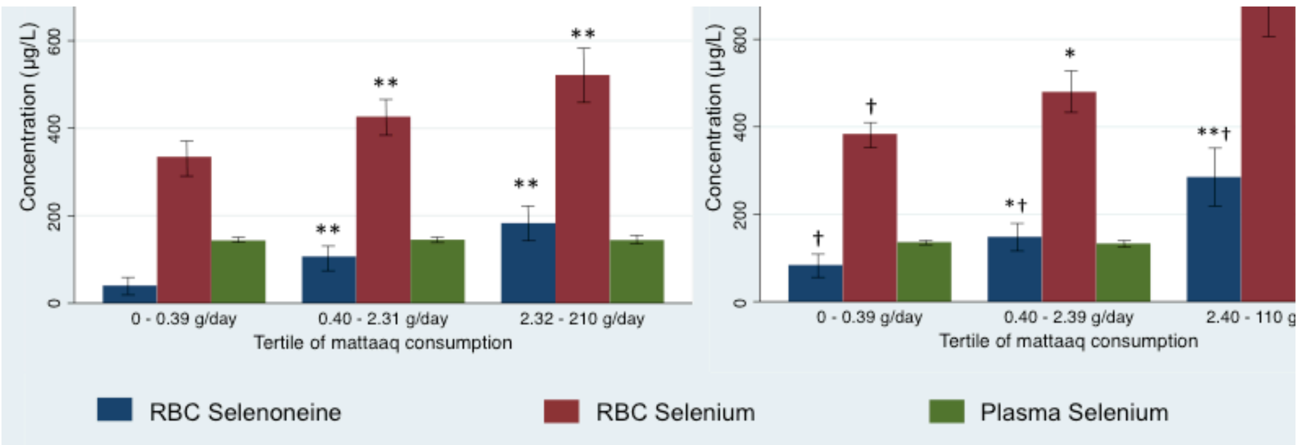
Data on Se speciation in plasma obtained in 2014-2015 showed that Se-containing proteins represent the major part of plasma Se content, indicating that concentrations of low-molecular weight Se compounds are likely very low in plasma. Furthermore, examination of the relationship between plasma and whole blood total Se concentrations revealed that individuals with high blood levels (i.e. > 1000 µg•L^{-1}) 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 that often consume these country foods (Achouba et al. 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 the completion of the development and validation of the analytical method for the quantification of selenoneine and methyl-selenoneine in RBCs at 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 were presented in theis project's 2015-2016 Synopsis Report (Ayotte et al. 2017). A scientific article is being written that describes the preparation of the standards and the procedure used to formally identify and quantify selenoneine and methyl-selenoneine in RBCs of Nunavimmiut and in beluga mattaaq. This manuscript to be submitted for publication in the near future focuses on residents of Hudson Strait communities who participated in the Qanuippitaa? 2004 survey, where marine mammal hunting and consumption are the most prevalent of all Nunavik regions.

In 2017, Matthew Little (post-doctoral fellow) examined correlations between RBC selenoneine concentration and other Se and mercury (Hg) biomarkers. Additionally, using multiple linear regression analysis, Matthew determined sociodemographic, lifestyle, and dietary factors associated with RBC selenoneine concentrations. Statistical analyses performed in 2016-2017 revealed that selenoneine accounted for on average 26% (range = 0.25 to 92%) of the total RBC Se concentration. RBC selenoneine concentrations were much higher (p=0.001) among women (250 µg•L^{-1}) than men (87.6 µg•L^{-1}) across all regions of Nunavik after controlling for age, region, and diet.

In the multiple linear regression analysis, increasing age (standardized b=0.24), higher body-mass index (BMI; b=0.07), female sex (b=0.10), living in a Hudson Strait community (compared to Hudson Bay and Ungava Bay; b=0.42), and consuming beluga mattaaq (g•day^{-1}; b=0.15) were all positively associated with RBC selenoneine concentration, whereas the consumption of market meats (g•day^{-1} b=-0.08) was negatively associated with RBC selenoneine concentration.

Among Qanuippitaa? 2004 participants, RBC selenoneine was an important biomarker of Se dietary intake from local marine foods, and in particular beluga mattaaq. These results are congruent with high concentrations of selenoneine found in beluga mattaaq samples (Achouba et al. in preparation). Adjusted self-reported consumption of beluga mattaaq was positively associated with whole blood Se (rs=0.41; p<0.001), RBC selenoneine (rs=0.42; p<0.001), and RBC selenoneine/ total Se ratio (rs=0.43; p<0.001), and these associations were not significantly different between sexes. As shown in Figure 1, for both sexes, each increasing tertile of beluga mattaaq consumption had significantly higher geometric mean concentrations of RBC selenoneine and whole blood Se concentrations (p<0.001), but not plasma Se levels. Indeed, beluga mattaaq consumption was not associated with total plasma Se levels in women (rs=-0.023; p=0.65) or men (rs=0.022; p=0.69).

Figure 1. Geometric means of RBC selenoneine, RBC Se, and plasma Se concentrations by tertile of beluga mattaaq consumption stratified by sex [men (left) and women (right)].



*p-value<0.01 compared to sex-specific lowest tertile; **p-value<0.001 compared to sex-specific lowest tertile; †significantly different at p-value<0.05 compared to tertile-matched men.

Section 2 of the project

This section presents the results pertaining to the distribution of selenium and selenoneine within marine Arctic ecosystems. A broad range of marine organisms was selected for these analyses. Our initial analyses revealed that selenoneine represents more than 50% of total Se content in beluga mattaaq samples from Nunavik (Achouba et al. in preparation). Selenoneine content found in this specific country food is higher than that reported in Bluefin tuna flesh by Yamashita et al. (2013a). Our most recent data (Table 1) also indicate relatively high concentrations of total Se in the two marine food chains of interest (pelagic and benthic), especially in marine mammal muscle and liver tissues. Walrus muscle exhibited the highest selenoneine concentrations, which on average represented 14% of total Se, and in one case reached up to 45% of total Se. At 2.1 $\mu g \bullet g^{-1}$ wet weight, the total Se content of walrus muscle is comparable to the levels found in beluga mattaaq (2.5 to 6 $\mu g \bullet g^{-1}$). However, the selenoneine content in walrus muscle is around 10 times lower than that of beluga mattaaq.

Section 3 of the project:

In 2016-2017, we started in vitro studies that aimed at deciphering the MeHg/selnoneine interaction. We first conducted experiments to determine the concentrations of MeHg to be added to the culture medium. These concentrations should allow for observation of a significant adverse effect of MeHg that would be lower than the maximal response, in order to be able to observe a protective effect of selenoneine. We used the trypan blue exclusion technique to measure the effect of MeHg on cell survival. The K562 cell line, a human immortalised myelogenous leukemia line, was selected for these experiments. Cells were incubated with concentrations of MeHg with or without cysteine ranging from 0-100 µM during 6, 24 and 48 h.

In these experiments, we noted median effective concentrations (EC50) of 9 µM and 20 µM for MeHg alone and MeHgCys (MeHg combined with cysteine), respectively. The addition of cysteine in the cell culture medium therefore increased the effective dose of MeHg on K562 cell mortality. Future experiments will focus on the effect of the MeHg/seloneine combination on cell mortality using different cell lines.

Table 1. Total Se and selenoneine concentrations (reported per grams of carbon and grams of wet weight) in marine organisms from pelagic and benthic food chain in the Arctic

Species (n total Se, n selenoneine) µg/g C		Total Se (range)		Selenoneine (range)		% Selenoneine (range)
		µg/g WW	µg/g C	µg/g WW	%	
Phytoplankton (6,1)		5.96 (4.04 – 9.75)	0.05 (0.02 – 0.07)	< LOD	< LOD	N/A
Ice algae (4, 4)		2.99 ± 2.04	0.03 ± 0.01	< LOD	< LOD	N/A
Zooplankton	1000um+ (7. 7)	5.08 (2.83 – 6.52)	0.26 (0.22 – 0.32)	0.44 (0.27 – 0.69)	0.02 (0.01 – 0.03)	8,55 (5,16 – 13,28)
	Calanus spp (2. 2)	4.60 (3.97 – 5.33)	0.18 (0.16 – 0.21)	0.40 (0.25 – 0.63)	0.02 (0.01 – 0.02)	8,60 (6,25 – 11,82)
Clams	Mya truncata (29. 29)	7.18 (5.00 – 12.11)	0.40 (0.27 – 0.97)	0.78 (0.24 – 1.61)	0.05 (0.02 – 0.10)	10,99 (4,35 – 25,42)
	Serripes groenlandicus (28. 28)	6.57 (5.01 – 10.15)	0.39 (0.29 – 0.54)	0.503 (0.19 – 1.83)	0.03 (0.01 – 0.11)	7,69 (2,30 – 25,71)
Arctic cod (13,7)		3.29 (2.76 – 3.81)	0.31 (0.24 – 0.39)	0.14 (0.08 – 0.23)	0.01 (0.01 – 0.02)	4.28 (2.90 – 6.74)
Sculpin (11, 5)		3.95 (2.98 – 5.93)	0.32 (0.25 – 0.55)	< LOD	< LOD	N/A
Walrus	Muscle (16. 16)	11.46 (2.99 – 73.12)	1.41 (0.38 – 8.84)	1.07 (0.12 – 3.59)	0.13 (0.02 – 0.45)	9,37 (1,26 – 45,95)
Seal	Muscle (3. 13)	2.57 (2.03 – 3.21)	0.38 (0.28 – 0.50)	0.12 (0.02 – 0.52)	0.02 (0.00 – 0.05)	4,80 (0,70 – 16,12)
	Liver (3. 13)	30.93 (7.72 – 89.75)	5.09 (1.14 – 13.88)	0.39 (0.25 – 0.92)	0.05 (0.03 – 0.14)	1,27 (0,60 – 3,37)
Seaweeds (4,6)		1.01 (0.39 – 1.76)	0.05 (0.03 – 0.09)	0.08 (0.00 – 0.28)	0.01 (0.00 – 0.02)	7.33 (2.57 – 73.27)

Section 4 of the project

In November 2016, the results from this project were presented at the RNUK annual general meeting. RNUK meetings are broadcasted live on the radio and can be accessed in all Nunavik villages. Results were also discussed at the annual meeting of the Board of directors of the Nunavik Marine Region Wildlife Board in December 2016. Hunters were very interested by the findings as they support the importance of local traditional activities and the consumption of beluga mattaaq. Interestingly, in 2017, when we presented the gender difference in RBC selenoneine concentrations, hunters raised the hypothesis that Inuit women primarily eat mattaaq from the tail of the whale whereas men eat mattaaq from different parts of the beluga indistinctively, and that perhaps selenoneine concentrations are higher in the mattaaq from the beluga tail. Results were also shared with the Nunavik Nutrition and Health Committee. Three manuscripts will be published shortly, including one based on our results from another NCP project (Muckle, Lemire et al) showing that higher blood Se status at birth may mitigate MeHg-induced adverse neurodevelopmental and neuromotor effects in children. Selenoneine was also confirmed as the primary form of selenium in archived children's blood samples. 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

We previously reported that plasma Se concentrations 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^{-1} (Achouba et al., 2016). An upcoming publication will highlight the presence of selenoneine as the major Se species in Inuit blood and 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. Yamashita et al. (2013b) provided evidence that selenoneine can enhance the demethylation of methylmercury in human cells. We speculate that in situ demethylation occurs, leading to a decrease in the distribution of methylmercury to target organs. We have initiated in vitro studies with different cells lines to decipher the mechanism through which MeHg and selenoneine interacts. Additional studies in laboratory animals are clearly required to test the hypothesis that selenoneine pretreatment during gestation decreases fetal brain exposure to methylmercury and in turn neurotoxicity. We are currently producing additional amounts of the purified selenoneine standard in order to conduct those additional studies.

In conclusion, we found elevated concentrations of selenoneine in red blood cells of Nunavimmiut and are currently conducting key studies to test the hypothesis that selenoneine could mitigate the toxicity of methylmercury. Our results could have a major impact on selenium risk assessment and dietary recommandations related to marine country food consumption Nunavik.

Expected Project Completion Date:

March 2017

Acknowledgments

Funding for this project was provided by the Northern Contaminants Program (Aboriginal Affairs and Northern Development Canada) and ArcticNet Network of Centres of Excellence of Canada. We thank the Nunavik Nutrition and Health Committee and the Nunavik Regional Board of Health for their support and advice. We are also indebted to Adel Achouba, Nathalie Ouellet and Pierre-Yves Tremblay (CR CHU de Québec) for their collaboration in developing the methods for Se speciation. Our thanks also go to Julie Robitaille who conducted the initial *in vitro* experiments to investigate the methylmercury/selenoneine interaction.

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Exposure to food chain contaminants in Nunavik: evaluating spatial and time trends among pregnant women & implementing effective health communication for healthy pregnancies and children (Year 1 of 3)

Exposition aux contaminants de la chaîne alimentaire au Nunavik : évaluation des tendances spatiales et temporelles chez les femmes enceintes et mise en œuvre d’une communication efficace sur la santé pour des grossesses saines et des enfants en santé (première de trois années)

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Abstract

Inuit are exposed to a wide range of environmental contaminants through their country food diet. During the past 20 years, our team has monitored the exposure of Nunavik's Inuit population to persistent organic pollutants (POPs) and metals. In this same period, a decreasing trend was confirmed in environmental concentrations and circumpolar Inuit exposure levels for most legacy POPs. Despite a decreasing trend due to reduced country food consumption, mercury (Hg) exposure remains a critical issue, particularly among pregnant women in Nunavik. As well, new chemicals are introduced on the market each year. These "New POPs and Contaminants of Emerging Concern (CECs)" reach the Arctic food chain and very little is known about their concentrations, temporal and regional trends, and Inuit exposure to them.

Since 2011, we have worked on multiple related projects to assess local country food sources of Hg and nutrients in Nunavik, and to understand the effects of Hg exposure, dietary nutrients, and food security during pregnancy on child development. Together with the Nunavik Regional Board of Health and Social Services (NRBHSS), and based on data provided by the Nunavik Research Center (NRC), we developed dietary recommendations aimed at mitigating Hg exposure while enhancing nutritional and food security status for women of childbearing-age. Recent data from medical follow-up of pregnant women continue to show high Hg concentrations and reveal that health and dietary recommendations that were provided to assist healthcare providers were not very efficient in reducing Hg exposure in these women.

This three-year project aims to contribute to on-going international biomonitoring efforts on long-range environmental contaminant exposure among pregnant women in Nunavik, and evaluate the comprehension and effectiveness of health and dietary recommendations/advice given to pregnant women, other women of childbearing age, caregivers, and members of the general population.

Résumé

Les Inuits sont exposés à une vaste gamme de contaminants environnementaux par leur régime alimentaire traditionnel. Depuis 20 ans, notre équipe surveille l'exposition de la population inuite du Nunavik aux polluants organiques persistants (POP) et aux métaux. Au cours de cette période, une diminution des concentrations environnementales et des niveaux d'exposition des Inuits des régions circumpolaires a été confirmée pour la plupart des anciens POP. Malgré une tendance à la baisse découlant d'une diminution de la consommation d'aliments traditionnels, l'exposition au mercure (Hg) demeure une question cruciale, surtout chez les femmes enceintes au Nunavik. En outre, de nouvelles substances chimiques sont commercialisées chaque année. Ces « nouveaux POP » et « nouveaux contaminants préoccupants (NCP) » atteignent maintenant la chaîne alimentaire arctique, et on en sait encore très peu sur leurs concentrations, les tendances temporelles et régionales, et l'exposition des Inuits à ces substances.

Depuis 2011, nous avons travaillé à de nombreux projets connexes pour évaluer les sources de Hg et de nutriments dans les aliments traditionnels locaux au Nunavik, ainsi que pour comprendre comment l'exposition au Hg, les nutriments alimentaires et la sécurité alimentaire pendant la grossesse influent sur le développement de l'enfant. En collaboration avec la Régie régionale de la santé et des services sociaux du Nunavik (RRSSSN) et en nous appuyant sur les données fournies par le Centre de recherche du Nunavik, nous avons formulé des recommandations alimentaires visant à atténuer l'exposition au Hg tout en améliorant l'état nutritionnel et la sécurité alimentaire des femmes en âge de procréer. Les données récentes issues des suivis médicaux de femmes enceintes continuent de révéler des concentrations élevées de Hg et montrent que les recommandations sanitaires et alimentaires qui ont été formulées afin d'aider les fournisseurs de soins ne se sont pas avérées très efficaces pour réduire l'exposition au Hg chez ces femmes.

During Year 1, a total of 97 pregnant women from 13 communities in Nunavik were recruited for biomonitoring activities. Results show that up to 23% of participants had blood Hg levels above the Health Canada guideline (≥ 8 $\mu g \bullet L^{-1}$), and among these, three participants presented very high blood Hg (≥ 20 $\mu g \bullet L^{-1}$). Sequential hair Hg analyses show important monthly variations in Hg exposure, from 0.1 to 23.1 $\mu g \bullet g^{-1}$. Temporal profiles seem to be more comparable among participants from specific communities, possibly where local country food access and consumption is more similar. A few participants had blood lead (Pb) above the most recent level of concern (≥ 5 $\mu g \bullet dL^{-1}$). Up to 60% of participants presented iron deficiency and 39% had anemia, among which almost all were classified with iron deficiency anemia. All study results will be available and presented to Nunavimmiut and health professionals in winter/spring 2018.

Ce projet de trois ans contribuera aux efforts de biosurveillance internationaux axés sur l'exposition des femmes enceintes du Nunavik aux contaminants environnementaux transportés à longue distance. Le projet permettra d'évaluer la compréhension et l'efficacité des recommandations et des conseils alimentaires et sanitaires donnés aux femmes enceintes, aux autres femmes en âge de procréer, aux fournisseurs de soins et aux membres de la population générale.

Au cours de la première année, 97 femmes enceintes provenant de 13 communautés du Nunavik ont été recrutées en vue des activités de biosurveillance. Les résultats montrent que jusqu'à 23 % des participantes avaient une concentration sanguine de Hg qui dépassait le seuil fixé par Santé Canada (≥ 8 $\mu g \bullet L^{-1}$), y compris trois participantes chez qui la concentration sanguine de Hg était très élevée (≥ 20 $\mu g \bullet L^{-1}$). L'analyse séquentielle de la concentration capillaire en Hg révèle d'importantes variations mensuelles dans l'exposition au Hg, allant de 0,1 à 23,1 $\mu g \bullet g^{-1}$. Les profils temporels semblent plus comparables entre les participantes de communautés particulières, dans lesquelles la consommation d'aliments traditionnels locaux est relativement homogène. Quelques participantes présentaient une concentration sanguine en plomb (Pb) qui dépassait le plus récent niveau préoccupant (≥ 5 $\mu g \bullet dL^{-1}$). Jusqu'à 60 % des participantes avaient une carence en fer et 39 % d'entre elles faisaient de l'anémie, considérée comme une +69dans presque tous les cas. L'ensemble des résultats de l'étude seront publiés et présentés aux Nunavimmiuts et aux professionnels de la santé à l'hiver ou au printemps 2018.

Key Messages

- Up to 23% of participants had blood Hg levels above the Health Canada guideline.
- Sequential hair Hg analyses show important monthly variations in exposure.
- A few participants still had blood Pb concentrations above the most recent level of concern.
- 60% of participants presented iron deficiency and 39% presented anemia.

Messages clés

- Jusqu'à 23 % des participantes avaient une concentration sanguine de mercure qui dépassait le seuil fixé par Santé Canada.
- L'analyse séquentielle de la concentration capillaire en mercure révèle d'importantes variations mensuelles dans l'exposition.
- Quelques participantes présentaient également une concentration sanguine en plomb qui dépassait le plus récent niveau préoccupant.
- 60 % des participantes avaient une carence en fer et 39 % d'entre elles faisaient de l'anémie.

Objectives

The **core objective of this three-year project** is to promote healthy pregnancies and child development using the highest quality evidence possible. This project focusses on the Nunavik region but it is also relevant at international and community scales. This interdisciplinary and intersectoral project is composed of **three parts**.

Part A (Year 1 and Year 3)

Part A of this project aims to contribute to on-going international biomonitoring efforts on long-range environmental contaminant exposure among pregnant women that were started in Nunavik in 1992. Part A of the project aims to recruit 100 pregnant women each year from the three sub-regions of Nunavik (Eastern Hudson, Hudson Strait and Ungava).

The specific objectives of Part A are:

- To measure pregnant women's exposure to metals (mercury (Hg) and lead (Pb) and Pb) and legacy POPs, new POPs and Contaminants of Emerging Concern (CECs);
- To evaluate temporal variations in Hg exposure using sequential Hg hair analysis by cm;
- To evaluate pregnant women's nutritional status (omega-3 polyunsaturated fatty acids (PUFAs), total selenium (Se) and selenoneine, hemoglobin (Hb), iron status and manganese (Mn));
- To account for pregnant women's country food consumption, food security and socio-demographic status, and maternal characteristics; and
- To assess the validity of an existing brief dietary questionnaire to identify women at risk of elevated Hg exposure.

Part B (Year 1 and 2)

Part B aims to: (i) evaluate the awareness, comprehension and effectiveness of health and dietary recommendations targeted at pregnant women and mitigate Hg exposure while enhancing nutritional and food security status during pregnancy in Nunavik;

and (ii) evaluate what a primary group of communicators including health practitioners (nurses, midwives and physicians) in Nunavik should know, what they currently understand and know, and would like to know or feel they need to know to support their role in providing health messaging and dietary recommendations to reduce Hg during pregnancy for Inuit women. Furthermore, as the general population (particularly the partners, and/or hunters living with pregnant women) are key individuals facilitating access to and influencing choice of country foods for pregnant women (King and Furgal 2014), we also aim to evaluate what partners/hunters would like to know in regards to health messaging and dietary recommendations related to Hg exposure during pregnancy.

The specific objectives of Part B are:

i) To evaluate pregnant women' awareness of health and dietary recommendations provided by the caregivers (included in Part A questionnaires);

ii) Through a review of clinical practice guidelines of health professional associations and training programs, identify what health practitioners "should know" and be aware of in regards to Hg exposure and nutritional status when providing dietary advice to pregnant women;

iii) Through the use of a method referred to as clinical vignettes, assess health practitioners' (nurses, doctors and midwives) current knowledge and common practices in providing advice to pregnant women in Nunavik in regards to Hg and nutritional status;

iv) Through the use of short additional survey questions, identify common information needs and desires of health practitioners in the region in regards to providing this advice and service for pregnant women;

v) Assess pregnant women' understanding of health and dietary recommendations provided by the caregivers (nurse, midwives, physician) and pregnant women's information needs to improve future communications; and

vi) Assess pregnant women's partners or hunter/provider awareness and/or knowledge of current health advice messages and information needs regarding Hg, nutrition and pregnancy in Nunavik.

Part C (Years 2 and 3)

Part C aims to: (i) Review health and dietary recommendations for childbearing-age women and the general Nunavik population according to findings from Part A and B and our other recent study results, and (ii) Based on findings from Parts A and B, develop, pilot and evaluate, new communication tools for the different target audiences for Hg and nutrition information in the region. Thus in Year 3, the project will evaluate the effectiveness of newly adapted communication approaches / tools in promoting healthy pregnancies and child development in Nunavik in light of Hg exposure, nutrient status and food security challenges.

Introduction

Early work conducted on Baffin Island and in Nunavik has demonstrated that because of their country food diet, Inuit are exposed to unusually high doses of environmental contaminants, mainly organochorines (OCs), a class of persistent organic pollutants known as legacy POPs (including polychlorinated biphenyls (PCBs)), and toxic metals such as Hg and Pb (Dewailly et al. 1993; Kinloch et al. 1992; Muckle et al. 2001). Several studies have reported different developmental, immune and/or cognitive deficits in newborns exposed to OCs during prenatal and/or postnatal development, with some of these deficits persisting in later childhood (Dewailly et al. 2000; Guo et al. 1995; Jacobson and Jacobson 1997; Winneke et al. 1998). Prenatal exposure to Hg has also been linked to impaired cognitive development, intellectual and behavioural functions as well as visual deficits later in infancy and childhood (Boucher et al. 2010; Boucher et al. 2012; Boucher et al. 2014; Ethier et al. 2012; Jacobson et al. 2015), and more recently, child postnatal Hg exposure has been linked to impaired fine motor functions at school-age (Boucher et al. 2016).

Through research over the last two decades, it has been confirmed that the Stockholm Convention on legacy POPs, which entered into force in 2004, contributed to a significant decrease in POPs environmental concentrations and circumpolar Inuit exposures to POPs (Wilson et al. 2014; AMAP 2015) This decreasing trend was also confirmed in recent years using data from pregnant women in Nunavik (Adamou et al. In revision by NNHC).

Similarly, Hg exposure among the circumpolar Inuit has also decreased considerably over recent decades (AMAP 2015). However, no clear decreasing trend in wildlife Hg concentrations has been observed in the Eastern Arctic, and even an increasing trend in marine mammal Hg concentrations has been observed lately in the Western Arctic (Braune et al. 2015). A recent study confirmed that the decreasing trend in Hg exposure among pregnant women in Nunavik primarily is related to the decreasing trend in country food consumption (Adamou et al. In revision by NNHC). However, since a high number of pregnant women and childbearing-age women continue to be detected with high Hg concentrations in Nunavik (see Table 3 below), Hg exposure remains a priority public health issue in the region. Beluga meat is known to contain elevated Hg and to be the main source of Hg exposure, particularly in Hudson Strait communities, where most of the beluga hunting activities take place in Nunavik in late spring and fall (Lemire et al. 2015). Moreover, lake trout, which also had high levels of Hg (Kwan et al. 2014) is believed to be often consumed by women in other villages, and particularly during winter, although this remains to be confirmed. The Minamata Convention on Hg emissions will enter into force on August 16, 2017 and the present work will serve as a baseline to evaluate the effectiveness of that Convention (UNEP 2017).

In addition to legacy POPs and Hg, each year a great number of new chemicals enter the market; several of these have emerged as potential threats to the Arctic. New POPs and CECs now reach the Arctic and enter the Arctic food chain. Very little is known about their concentrations and temporal and regional trends in Inuit.

Since 2011, our team has worked on multiple related projects to assess local country food sources of Hg and nutrients in Nunavik, and to understand the effects of Hg exposure, dietary nutrients and food security during pregnancy on child development. Together with the NRBHSS, and based on data from the NRC, we developed dietary recommendations aimed at mitigating Hg exposure while enhancing nutritional and food security status for women of childbearing-age (Lemire et al. 2016). However, recent data from medical follow-up of pregnant women continue to show high Hg concentrations and reveal that health and dietary recommendations that were provided to assist healthcare providers were not very efficient in reducing Hg exposure in these women. These findings raise the following questions:

- Is the information provided about Hg sources accurate and adequately conveyed?
- Do pregnant women, caregivers, and others understand the information provided to them about Hg sources?
- What are the impacts, including unintended ones, of the messages received by pregnant women about Hg, health and diet?

When it comes to assessing changes in health and dietary behaviors, most research focuses on the recipients of these messages, in this case pregnant women. While pregnant women may be particularly receptive to behavioral change messaging (Oken et al. 2003), healthcare providers appear to be one of the most important sources of health information for these women (Aaronson et al. 1988; AMAP 2009; McLean Pirkle et al. 2015). While a rich body of research exists for investigating women's (mis) interpretations of healthcare messages (Murray-Johnson and Witte 2003; Naughton et al. 2012), very little effort is geared towards the ability of health professionals to communicate these health messages. Inadequate knowledge on the part of providers and insufficient, sometimes inaccurate communication to patients have been identified in previous research (Bondarianzadeh et al. 2011; Morales et al. 2004). Food safety messages to pregnant women by healthcare providers tend to emphasize risk and which foods to avoid (Bondarianzadeh et al. 2011; McLean Pirkle et al. 2015) rather than reinforce healthy, culturally appropriate food choices. It has been suggested that professional practice guidelines are needed about food safety in pregnancy and that health professionals could benefit from food safety training (Bondarianzadeh et al. 2011).

Activities in 2016-2017

Part A

Data collection

Tools design

A consent form and questionnaire about demographic data, reproductive history and maternal characteristics, socioeconomic data, food security, practice of harvesting activities and Pb-ammunition use, health behaviors (cigarette, marijuana and alcohol consumption), housing conditions and drinking water source, country food consumption as well as awareness of health messages about country foods and contaminants was developed based on the previous pregnant women project in Nunavik (Arctic Char project) and Qanuilirpitaa? 2017. An electronic version of the questionnaire was developed using Qualtrics® survey software. Pictures were included for ammunition and country food sections. The questionnaire was administered using iPads. This format is deemed more dynamic with no data entry being required afterwards and through the use of skip patterns in the software it improves the quality of data collected by minimizing the number of incorrectly answered questions. The questionnaire was extensively tested before being applied. A data extraction form was also developed to extract data from the participant's obstetrical or medical records including pregnancy details, and information on any chronic conditions they may have.

Ethical approval

The project was presented and approved by the Nunavik Nutrition and Health Committee (NNHC) in June 2016. Ethical approval was obtained for the Research Ethics Board of the CHU de Québec in October 2016. Additionally, an authorization form was signed by the research team in order to be granted the right to access the Tulattavik and Inuulitsivik Health Center medical records. Confidentiality agreements were also signed by the research nurses and the interpreters who engaged in fieldwork activities.

Recruitment strategy

During the first phase of recruitment (October to December 2016), the research nurses did not have access to patient lists as the Tulattavik and Inuulitsivik Health Centers do not provide these to researchers anymore. This initiative was taken to better ensure patient confidentiality and promote better research practices. These lists were critical for recruitment when the project was previously led by Dr Dewailly up until 2013. As a result, we quickly had to adapt our recruitment approach, for which the inclusion criteria were: pregnant woman who were Inuk, based in Nunavik, 18 years old and over and less than 6 months pregnant. We asked midwives, nurses and/or ultrasound technicians to distribute a leaflet to pregnant women at the time of clinic visits about the project asking them if they would allow the research team to contact and invite them to participate in the project. We also created a Facebook page to promote and recruit women for the project, went on the local radio and presented the project in Inuktitut and English, and met with several partners in the communities to seek their support. Despite our diverse and repeated efforts, only six pregnant women were initially recruited through these methods for the project.

During the fall of 2016, different actions at the local and regional level were undertaken to find constructive solutions to the recruitment challenges. First, since our research nurse was not available on a full-time basis during fall and early in 2017, we recruited an extra research nurse in December, so that for January-March 2017, we had two nurses recruiting participants in different villages. Second, we broadened our recruitment criteria to include all Inuit pregnant women of 16 years of age and older, without limitation with respect to the stage of pregnancy. This way the study is also now more representative of the population of pregnant women in Nunavik. Third, together with the NNHC, we co-signed a Letter to the Editor that was published in Nunatsiaq Online news (Dec 14, 2016) entitled Nunavimmiut helping to protect people from contaminants worldwide to acknowledge the unique contributions of Nunavimmiut, and particularly pregnant women, to contaminants research and international conventions on POPs and Hg emissions. This letter was also published in the paper version of Nunatsiaq News in January and in the Air Inuit magazine in June 2017 (Annex 1). This latter one was co-signed by Sarah Kalhok Bourque on behalf of the NCP Management Committee. Fourth, in January 2017, Dr. Françoise Bouchard, the Regional Public Health Director of the NRBHSS, was well informed of the situation and agreed to write a letter requesting Nunavik hospital directors to provide access to the list of pregnant woman at the health centers to facilitate the recruitment process for the project. Fortunately, for the second phase of the recruitment (January to March 2017), we were granted access to the list of pregnant women in each village, which greatly contributed to an increase in recruitment. In some villages, when available, interpreters were hired to make the initial contact with the pregnant women.

As compensation for their participation, a food coupon of $50 was given to the pregnant women at the end of the visit, as well as some belly cream specially produced by the Uvvautik Soap Factory (Girls Project Class, Jaanimmarik School, Kuujjuaq).

Clinical follow-up of participants with anemia and/or elevated blood Hg or Pb

Hemoglobin (Hb) values were measured using an Hemocue® during the interview for Part A, and in case a participant presented Hb values below or above the recommended guidelines for her stage of pregnancy (according to Tullatavik and Inuulitsivik hospital protocols) and if the participant previously agreed to it in the informed consent form, the participant was rapidly referred to her local health provider for a clinical follow-up.

The follow-up of the participants with Hg and Pb blood results above the Quebec MADO guidelines is supervised by Sylvie Ricard (Environmental Health Officer) of the Public Health Department at the NRBHSS. The clinical follow-up algorithms for participants with blood Hg and Pb above recommended values are being revised by our team and will be updated according to the present study findings.

Samples handling and shipping

As soon as possible, all blood and urine samples collected by research nurses in community health centres were stored at -20 °C. Some samples were also temporarily stored at the NRC in Kuujjuaq at -80 °C. Blood samples were then transported to the *Centre de toxicology du Québec* (CTQ) in Quebec City in coolers with icepacks. From there, samples were shipped to the other laboratories; the *Institut universitaire de cardiologie et de pneumologie de Québec* for iron status biomarkers and the *Centre hospitalier de l'Université Laval* for PUFAs. Hair samples were stored directly at the NRC for sequential Hg analyses.

Data analyses

Biological samples

All the blood analyses for Hg, Pb, Mn, Se, PUFAs and iron biomarkers are now completed as well as the sequential hair analyses for Hg. Analyses for POPs and selenoneine will be completed by August 2017.

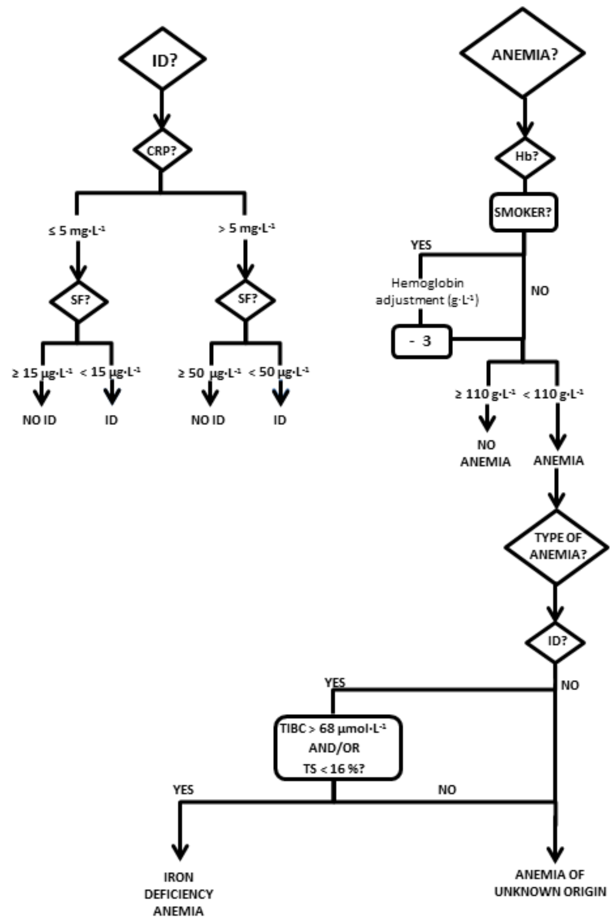
Assessment of iron status and anemia

An algorithm was developed to determine the prevalence of anemia, iron deficiency (ID) and iron deficiency anemia (IDA) among pregnant women recruited (Figure 1). According to this model, a serum ferritin (SF) < 15 µg•L^{-1} indicates depleted iron stores in the absence of inflammation (hs-C-reactive protein (hs-CRP) ≤ 5 µg•L^{-1}) (Thurnham et al. 2010; Turgeon O'Brien et al. 2016). However, in the presence of inflammation (hs-CRP > 5 mg/L(, higher cut-off values for SF were used (SF < 50 µg•L^{-1}) to diagnose depleted iron stores (Guyatt et al. 1992). Anemia will be considered if Hb is below World Health Organization (WHO) cut-off values for pregnant women (Hb < 110 g•L^{-1}) after adjusting for smoking exposures as depicted in Figure 1 (WHO 2011). To categorize anemia into iron deficiency anemia (IDA) and unexplained anemia (UA), a multiple-indices model is suggested (Patterson et al. 2001; Plante et al. 2011). In this model, WHO Hb cut-off values adjusted for smoking status combined with abnormal SF, total iron binding capacity (TIBC) > 68 µmol•L^{-1} and/or transferrin saturation (TS) < 16 % is used to diagnose IDA, otherwise UA will be considered (Cash and Sears 1989). To categorize anemia according to Hb results as mild, moderate or severe, WHO (2011) cut-off values were also used (100-19 g•L^{-1}, 70-99 g•L^{-1}, and < 70 g•L^{-1} respectively).

Databases and statistical analysis

Data cleaning from questionnaires is underway. Temporal trends for contaminants are being conducted by an experienced data analyst, Elhadji AnnasourLaouan-Sidi, which has worked on this dataset for several years. The results section presents preliminary findings for objectives 1 to 3 of Part A and objective 1 of Part B. Detailed statistical analysis to address objective 4 (nutrition and other health determinants) and objective 5 (specificity and sensitivity of a food questionnaire to identify pregnant women at risk of elevated Hg) of Part A, as well as to better document regional and temporal variations in Hg exposures and local Hg dietary sources will be conducted as part of a MSc project that started in May 2017.

Figure 1. Algorithm for the assessment of iron status and anemia among participants



Capacity building

Training of research nurses

Two nurses already working in Nunavik that had no experience in research were trained for the fieldwork. One has now been hired by the Public Health Department and the other will be involved in the recruitment for Qanuilirptaa? 2017.

Hair Hg analysis can now be conducted in Nunavik

Michael Kwan at the NRC was in charge of developing the analytical method and conducting hair Hg sequential analysis for Year 1. This was the first time that these types of analyses were conducted in Nunavik.

Info-MADO newsletter about the project

A newsletter of the Nunavik Department of Public Health on Notifiable diseases (Info-MADO) was sent to all health professionals in Nunavik June 8, 2017. This document was prepared by the Environmental Health Officer of the Nunavik Department of Public Health (Sylvie Ricard), in collaboration with the PI of the project (Melanie Lemire). It provides information on the study, as well as the actions that should be taken by the health professionals according to the pregnant woman's blood Hg or Pb levels. These actions includes the ones based on the clinical algorithms for Hg and Pb follow-ups actually available, and the ones taken by the Public Health Department when it receives pregnant women's with elevated blood Hg and blood Pb levels.

Communication

Team meeting and Nunavik partner's discussions

This project is being conducted in close collaboration with team members from the NRBHSS and the NRC to develop the multiple project tools and discuss the recruitment strategies and challenges. In addition, Carole Beaulne, a Community Health nurse in charge of the Family house in Puvirnituq for several years, agreed to join our team. Since our first community consultation conducted in 2014, Carole Beaune has raised several times the importance to know more about dietary sources of Hg in her region and to work in close collaboration with local hunters to develop adequate guidelines and communication tools.

A first meeting with midwives in Puvirnituq was held on June 28, 2016 to present the project. During that meeting, the name of the project was created: *Nutaratsaliit qanuingisiarningit niqituinnanut* - Pregnancy wellness with country foods. Carole Beaulne and several midwives were then involved in the planning, review and adaptations of our research tools. The NRC is also a key partner in fostering communication networks with other stakeholders that are usually not involved in health projects but very interested by information on Hg and nutrients in country food sources in Nunavik; these stakeholders include Nunavik Fishing and Trapping Association (NHFTA), *Regional Nunavimmi Umajulivijiit Katujiqatigininga* (RNUK), Makivik Corporation, and the Nunavik Marine Region Wildlife Board (NMRWB). Dr. Mario Brisson, physician responsible for environmental health issues at the NRBHSS, is also involved in all important decision making steps of the study. From the very beginning, doctors currently practicing in Nunavik, Geneviève Auclair, Siham Cherradi, and Nathalie Boulanger, were contacted and supported the overall initiative. They are periodically informed of the project's progress. Strong efforts will be made to continue to involve all of these great partners in the project particularly with respect to Part B activities.

When starting the data collection in October 2016 in Kuujjuaq, Annie Baron went on local radio few times to present the project in Inuktitut and invite pregnant women to participate. Later, when Mélanie Lemire visited Salluit in November 2017 to attend the RNUK meeting, where she presented the project to hunters, and also visited the Salluit Maternity ward to present and discuss the project. In January 2017, a recorded radio message about the project (by Annie Baron) was broadcast across Nunavik on CKUJ-FM radio. In February 2017, when Mélanie Lemire again visited Kuujjuaq, she met with midwives, nurses, and physicians, to promote the project on the radio and via other media.

Conferences

NCP Human Health Monitoring and Risk Communication Workshop

M. Lemire was invited to present the study history, rationale, past findings and challenges at the NCP workshop in Ottawa Nov 22, 2017, to tentatively answer these two questions:

How is human health monitoring data and information used at the local, regional, national and international levels?

What tools/resources/networks are required to ensure the effective and ethical communication of risk?

Nunavik Public Health representatives were also present and greatly contributed to discussions following the presentation. Pierre Ayotte presented the temporal trends for several contaminants' exposures and the future Qanuilirpitaa? Survey.

2017 Arctic Conference: New Lights on Northern Prevention Efforts

Following the recommendation of Drs Françoise Bouchard and Mario Brisson, *M*élanie Lemire briefly presented the project and preliminary findings at the 2017 Arctic Conference – "New Lights on Northern Prevention Efforts" that was held on April 1-2, 2017, in Montreal. This conference was targeting physicians and public health professional working in the Arctic, and this year, it was primarily attended by health professionals from the Nunavik region. Following this presentation, several physicians showed a great interest in becoming better informed about the project findings and integrate these findings in their clinical practice.

Human Health groups AMAP meetings in Copenhagen and Reston

The present project's preliminary findings were presented at the two latest HG-AMAP meetings in Copenhagen, December 5, 2016, and Reston, USA, April 24, 2017, for which Mélanie Lemire is a designated expert for Canada. The high prevalence of elevated Hg exposure in Nunavik and importance of considering seasonality of Hg exposure when assessing Hg exposure and related-health outcomes were important concerns/challenges discussed with circumpolar experts.

Presentation to several other audiences via the Nasivvik Chair activities

Nutaratsaliit qanuingisiarningit niqituinnanut project history and rationale was presented to scientific and knowledge user audiences, including Indigenous partners, during several keynote sessions aiming at presenting the Nasivvik Research Chair program and the type of collaborative projects conducted by our team. This includes the *Perspectives croisées sur la santé autochtone : problématiques, pratiques et localités* in Québec City on September 28, 2017; the *Journée en santé autochtone en sciences infirmières* in Rivière-du-Loup on November 26, 2016; the *Forum sur les besoins en recherche des Premiers Peuples* of the *Institut nordique du Québec* in Val d'or on March 8, 2017; the plenary conference *Conduire des projets de recherche interculturels : enjeux éthiques* in Québec City on May 5, 2017; and at the *Institut nordique du Québec's* special session of the *Association francophone pour le savoir* (ACFAS) on May 8, 2017.

Knowledge sharing activities in Nunavik

Together with the NNHC, we co-signed a letter to the editor that was published in Nunatsiaq Online new (Dec 14, 2016) entitled Nunavimmiut helping to protect people from contaminants worldwide to acknowledge the unique contributions of Nunavimmiut, and particularly pregnant women, to contaminants research and international conventions on POPs and Hg emissions. This letter was also published in the paper version of Nunatsiaq News in January. It will also be published June 27, 2017, in the Air Inuit magazine (Annex 1), and co-signed by Sarah Kalhok Bourque on behalf of the NCP Management Committee.

Return of Individual results to participants

Individual results letters will be sent directly to participants by mail in June 2017. The letters that also contain an "action to take" section was reviewed by all project partners and the NNHC. We also invited key partners at Tulattavik and Inuulitsivik Health Centers to provide comments and suggestions. The letter was thereafter translated into Inuktitut so that the final letters to participants will be sent in English and Inuktitut. If consent was given by the participant, these letters will also be sent to the health professional in charge of their pregnancy, together with the Info-MADO newsletter presented above, to be added to the participant's medical file. It is important to note that participants with Hg and Pb blood results above the Quebec MADO guidelines were already contacted a few days after their results were available by the *Centre de Toxicologie* (CTQ) based on the NRBHSS follow-up protocol.

Indigenous Knowledge integration

Inuit knowledge was considered at all steps while developing Part A of the study, and specific attention was given to understanding/documenting Inuit and local knowledge when conducting the interviews with the pregnant women. For example, before officially starting the project, several phone meetings were organised with midwives, nurses, physicians and hospital administrators to explain the project and seek their guidance, input and recommendations. Midwives of the Maternity in Puvirnituq proposed a new name for the project in Inuktitut: *Nutaratsaliit Qanuingisiarningit Niqituinnanut* - Pregnancy Wellness with Country Foods, and a project logo was developed together with Ulayu Pilurtuut, a well-known Inuk artist in Kuujjuaq (see Figure 2). Belly cream was specially produced by the Uvvautik Soap Factory (Girls Project Class, Jaanimmarik School, Kuujjuaq), using essential oils made using local medicinal plants. All key documents were revised and translated by Inuit workers (from or referred by the NNHC) in order to consider and include all Inuit knowledge that is relevant and useful to improve communications between researchers and community members. Project announcements via local and regional radio were done by Annie Baron in Inuktitut. When needed and available, Inuit interpreters were hired to recruit participants and translate questionnaires to participants during interviews. When developing the questionnaire and preparing the results letter, consultations were held with members of the NNHC and other health professionals in Nunavik.

Figure 2. Project logo developed together with Ulayu Pilurtuut, an Inuit artist based in Kuujjuaq.

Part B

This year we have progressed on several of the planned activities to meet objectives under Part B despite the initial challenges with participant recruitment. In 2016-17, we have met with team members and regional Public Health representatives to discuss the project, review previous findings including those on clinical follow-ups of pregnant women collected by the NRBHSS, and collectively work on questionnaires/interviews questions and criteria for the Part B of the study.

In 2016-2017 the project leaders and team have (i) completed data collection about pregnant women' awareness of health and dietary recommendations provided by the caregivers (included in Part A questionnaires); (ii) completed a data extraction form for the review of curriculum material as well as the review of McGill medical school syllabi and reading material (assigned texts related to prenatal care, nutrition, and contaminants); and (iii) completed a review of Laval nursing school curricula. Based on the review of McGill materials, it has become clear that we will need to conduct key informant interviews with instructors at major medical institutions in Quebec to further learn what trainees are taught in terms of clinical protocols for addressing environmental contaminants issues during pregnancy. As a result, an interview guide for the medical instructors has been completed. The clinical vignettes to assess health practitioner's processes and considerations for addressing issues of contaminant exposure during pregnancy have been created and we have started pre-testing those tools. All required documents have been sent to Trent University for submission to REB for approval.

Based on initial challenges with recruitment the team thought they would have to adapt recruitment processes, criteria and emphases and as a result change aspects of Part B of the project. However, due to successful adaptation and increased recruitment in the latter part of Year 1, this will not be necessary. As result, work has also gone into developing the interview / questionnaire to be used during a second visit with the project this coming year. These questions will focus on food security status, risk perception, knowledge of existing public health messages related to contaminants and health in the region, information on contaminants, nutrition and health received from their health care provider during their pregnancy, and any outstanding questions or information needs pregnant women may still have. These questions have been submitted to the Trent University REB for approval and will then be pre-tested this year before re-visits with those participants consenting to the second component of the project.

Results

Results for Part A

Study population

Between October and December 2016, we succeeded in recruiting a total of 6 participants from Kuujjuaq, Quataq, Kangiqsujjuaq, Salluit and Puvirnituq. Thanks to the letter from the NRBHSS, between mid-January and March 31, it was much easier to reach eligible pregnant women and during this period, we recruited 91 participants. Overall, among the 231 pregnant women eligible in Nunavik during this period, we succeeded in recruiting 97 pregnant women (about 42% of pregnant women at that time) to participate in Part A of the project. The percentage of participation by community was quite variable, between 17 to 71%, although globally, it ranged between 38 and 48% among the 3 study regions.

Blood Hg, Pb, and Se levels and time-trends

Table 2 presents time trends for the percentage of pregnant women and women childbearing age (18 to 39 years old) above guidelines for Hg, Pb and Se in Nunavik since 1992. These time trends involve several studies. For pregnant women, these include Nutrition Inuit Health 1996-2001, Trend 2007, MTP 2011-2012, NCP 2013 and NQN 2016-2017, whereas for women of childbearing age, these include Enquête Santé Québec 1992 and Qanuippitaa? 2004.

Table 1: Number of pregnant women eligible and recruited in Nunavik between October 2016 and March 2017

Village	Number of pregnant women eligible (estimated)	Number of pregnant women recruited	% of participation [c]
Hudson Bay region	99	38	38
Kuujjuarapik	8	4	
Umiujaq	6	3	
Inukjuak [a]	57	25	
Puvirnituq [a,b]	24	4	
Akulivik	4	2	
Hudson Strait region	77	37	48
Ivujivik	7	4	
Salluit [a]	42	23	
Kangiqsujuaq	17	6	
Quaqtaq	11	4	
Ungava region	55	22	40
Kangirsuk	7	5	
Aupaluk	0	0	
Tasiujaq	8	4	
Kuujjuaq [a,b]	23	9	
Kangiqsualujjuaq	17	4	
TOTAL	231	97	42

[a] These four communities have midwifery centres.
[b] In these communities are found Inuulitsivik and Tulattavik hospitals respectively.
[c] These numbers have to be interpreted with caution: participants were not selected on a random basis but using as a convenience sample. All Inuit pregnant women respecting selection criteria at the time of the study were invited to participate (Oct – Dec 2016: ≥ 18 years and less than 6 months pregnant; Jan – March 2017: ≥ 16 years and all trimesters).

Among the 97 participants, 84% (n=81/97) agreed to be recontacted to be invited to participate to Part B of the project.

Table 2: 1992-2017 time trends of number and percentage of women participants (pregnant women and women of childbearing age) above guidelines for Hg, Pb and Se in Nunavik.

year	N	Mean age [range]	Hg ≥ 8 µg•L^{-1} n (%)	Hg ≥ 12 µg•L^{-1} n (%)	Hg ≥ 20 µg•L^{-1} n (%)	Hg ≥ 40 µg•L^{-1} n (%)	Pb ≥ 5 µg•dL^{-1} n (%)	Pb ≥ 10 µg•dL^{-1} n (%)	Se ≥ 90 µg•L^{-1} n (%)	Se ≥ 200 µg•L^{-1} n (%)	Se ≥ 500 µg•L^{-1} n (%)	Se ≥ 1000 µg•L^{-1} n (%)
1992^{WCBA}	164	28 [18-39]	125 (76.22)	88 (53.66)	37 (22.56)	7 (4.27)	121 (73.78)	43 (26.22)	§	§	§	§
1996/97^{PW}	78	25 [15-41]	56 (71.79)	41 (52.56)	15 (19.23)	1 (1.28)	47 (60.26)	9 (11.54)	78 (100)	73 (93.59)	13 (16.67)	0 (0)
1998/99^{PW}	43	25 [15-37]	22 (51.16)	12 (27.91)	3 (6.98)	0 (0)	21 (48.84)	7 (16.28)	43 (100)	39 (90.70)	1 (2.33)	0 (0)
2000/01^{PW}	47	26 [17-39]	29 (61.70)	20 (42.55)	10 (21.28)	0 (0)	18 (38.30)	4 (8.51)	47 (100)	42 (89.36)	6 (12.77)	2 (4.26)
2004^{WCBA}	278	28 [18-39]	148 (53,24)	98 (35.25)	43 (15.47)	15 (5.14)	44 (15.83)	8 (2.88)	278 (100)	207 (74.46)	35 (12.59)	5 (1.80)
&2004^{PW}	31	27 [18-42]	16 (51.61)	11 (35.48)	2 (6.45)	0 (0)	2 (6.45))	0 (0)	31 (100)	22 (70.97)	5 (16.13)	0 (0)
2007^{PW}	42	24 [18-37]	7 (16.67)	4 (9.52)	1 (2.38)	0 (0)	2 (4.76)	0 (0)	42 (100)	22 (52.38)	2 (4.76)	0 (0)
2011/12^{PW}	111	24 [18-39]	40 (36,04)	22 (19.82)	6 (5,41)	1 (0,90)	4 (3.60)	2 (1.80)	111 (100)	84 (75.68)	25 (22.52)	5 (4.50)
2013^{PW}	95	24 [18-41]	36 (37,89)	12 (12.63)	3 (3.16)	0 (0)	1 (1.05)	0 (0)	95 (100)	67 (70.53)	18 (18.95)	2 (2.11)
2016/17^{PW}	97	25 [16-40]	22 (22.68)	10 (10.31)	2 (2.06)	1 (1.03)	5 (5.15)	0 (0)	97 (100)	53 (54.64)	3 (3.09)	1 (1.03)
P-trend*			<.0001	<.0001	<.0001	0.0531	<.0001	<.0001		<.0001	0.9720	0.3615

^{PW} = pregnant women; ^{WCBA} = women of childbearing age. $^{\&}$ Not included in the trend test;
* Based on Cochrane-Armitage trend test; § Only 8 subjects with blood Se.

Table 3: Blood Hg, Pb and Se geometric mean (GM) and range between 1992 and 2017

year	N	Mean age [range]	Hg µg•L-1 GM [range]	Pb µg•dL-1 GM [range]	Se µg•L-1 GM [range]
1992^{WCBA}	164	28 [18-39]	12.93 [2.0-72.1]	7.13 [1.45-42.9]	147.8 [115-224]
1996/97^{PW}	78	25 [15-41]	11.98 [3.81-44.29]	5.33 [1.04-25.88]	332.7 [186-976]
1998/99^{PW}	43	25 [15-37]	7.68 [2.61-31.26]	5.34 [1.86-13.3]	295.6 [150-575]
2000/01^{PW}	47	26 [17-39]	9.35 [1.60-38.1]	4.08 [1.04-13.7]	304.6 [187-1228]
2004^{WCBA}	278	28 [18-39]	8.58 [0.20-164]	2.78 [0.66-20.7]	280.8 [126-1339]
&2004^{PW}	31	27 [18-42]	7.64 [1.20-30.1]	1.85 [0.58-8.49]	265 [126-701]
2007^{PW}	42	24 [18-37]	4.05 [0.68-24.1]	1.61 [0.66-7.66]	228.9 [134-709]
2011^{PW}	111	24 [18-39]	4.97 [0.18-40.1]	1.30 [0.27-23.4]	315.4 118-2992]
2013^{PW}	95	24 [18-41]	5.20 [0.28-32.1]	1.41 [0.42-6.21]	303 [126-1417]
2016/17^{PW}	97	25 [16-40]	4.28 [0.80-40.1]	1.20 [0.41-9.25]	227.9 [118-2205]

^{PW} = pregnant women; ^{WCBA} = women of childbearing age.

In 2016-2017, up to 23% of participants still presented blood Hg equal or above the Health Canada provisional blood guidance value of 8 µg•L^{-1} (Legrand et al. 2010), and 10% had blood Hg equal or above the Quebec MADO guideline (12 µg•L^{-1} or 60 nmol•L^{-1}). As shown in Table 2 and 3, a few participants are still found with very elevated blood Hg levels above 20 µg•L^{-1} and up to 40.1 µg•L^{-1}. For this latter participant, Hg speciation analysis showed that it was 95% methylmercury.

Surprisingly, contrarily to blood Hg profile among women of childbearing age in 2004, which showed significantly higher blood Hg among women the Hudson Strait region (Lemire et al. 2015), this year, participants from the Hudson Bay region tended to present higher blood Hg compared to other two regions, although the difference was not statistically significant (Geometric mean [range]: *Hudson Bay* : 4.91 µg•L^{-1} [0.80 – 40.1 µg•L^{-1}]; *Hudson Strait:* 4.02 µg•L^{-1} [1.00 – 26.1 µg•L^{-1}]; and *Ungava Bay:* 3.77 µg•L^{-1} [1.00 – 16.0 µg•L^{-1}].). These results suggest that local important sources of Hg other than beluga meat have been consumed during the sampling months (primarily between January and March).

The most recent data analyses by Adamou et al. (in revision by NNHC) on blood Hg time trends between 1992 and 2013 show a significant decreasing trend in Hg exposure since 1992, and that this trend is primarily associated with a decreasing trend in marine food consumption. Between 2004 and 2017, a mild but constant decreasing trend in blood Hg seems to be observed. However, as detailed in the next section, these time trends need to be interpreted with caution since considerable monthly variations in Hg exposure are also found.

Se status in Nunavik is known to be among the highest in the world, primarily due to the consumption of marine foods that are exceptionally high in Se such as beluga mattaaq, walrus meat, marine mammal organs, and fish eggs (Lemire et al. 2015). As expected, no participant was found to present deficient blood Se levels (below 80 µg•L^{-1}). A significant declining trend of Nunavik women with Se levels above the Canadian average concentrations (200 µg•L^{-1}) was found (CHMS 2010, 2013), possibly reflecting the declining trend in marine food consumption as presented above. Still, more than half (55%) of participants had blood Se above the Canadian average and no time trend was observed for participants with exceptional Se status (above 500 and 1000 µg•L^{-1}), suggesting that marine foods rich in Se had been consumed by some participants. Like for Hg, the seasonality of country food may lead to significant monthly variation in Se status, although this needs to be confirmed. Selenoneine, a potent antioxidant accumulating in red blood cells and possibly acting against Hg, was found to be the major form of Se in Inuit adult blood (Lemire and Ayotte, in preparation), and results for the present participants are expected shortly. As shown in Table 4 below, not surprisingly, blood Se and Hg were strongly correlated and both well correlated with Hb ($\rho > 0.30$), since both selenoneine and Hg are known to accumulate in red blood cells (Yamashita et al. 2013).

With respect to Pb exposure, no participant presented blood values above the Health Canada and Quebec MADO guidelines of 10 µg•dL^{-1}. However, a few participants (5%; n=5/97) still presented above 5 µg•dL^{-1}, the most recent level of concern for Pb exposure among pregnant women and children since no safe level of Pb exposure have been found for the foetus and children, and even below 5 µg•dL^{-1} (CDC 2012). Blood Hg and Pb were also well correlated (Table 4), possibly reflecting the fact that some country foods hunted with Pb-ammunitions also present high Hg levels.

ID, Anemia and IDA prevalence and blood Mn levels

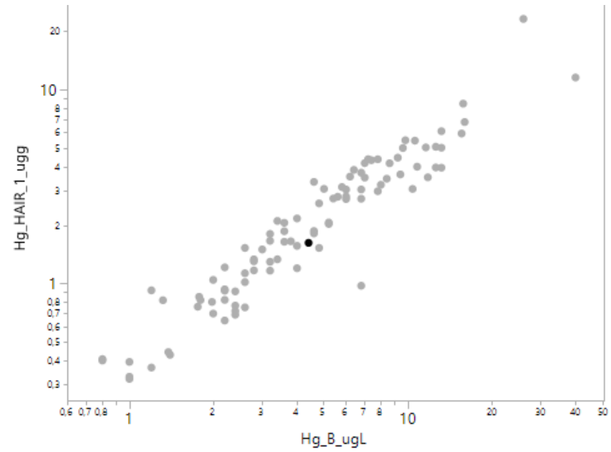
Up to 60% of participants presented ID (n=58/97). Close to 40% of participants had anemia (39%, n=38/97). Among the participants who had anemia, 24% had mild anemia (n=23/97) and 15% (n=15/97) had moderate anemia. According to the World Health Organisation, anemia prevalence between 20 and 39% represents a moderate public health problem, whereas a prevalence above 40% highlight a severe public health problem (WHO 2011). Most common type of anemia was IDA (30% of total; n=29/97; 76% of anemic participants; n=29/38), whereas nine participants were classified with UA (9% of total; n=9/97; 24% of anemic participants; n=9/38).

ID status has been reported to cause up-regulation of a transport protein common to iron, Mn, and Pb (Bannon et al. 2002; Roth and Garrick 2003). Therefore, if Mn and/or Pb are found in the diet, as it is the case of ID, Mn, and Pb intestinal absorption and concentration inside the body and blood may be upregulated (Finley 1999; WHO 2001). Contrarily to Pb, Mn is an essential element often found in several foods. Few participants (9%; n=9/97) were found with Mn levels above the former Quebec MADO guidelines of 20 μg•L^{-1}, most of which presented ID (78%, n=7/9). As shown in Table 4, blood Mn was significantly negatively correlated with SF, although it was not the case for blood Pb.

Hair Hg concentrations and monthly variations in exposure

Hair Hg (1st cm) geometric mean and range are 1.86 μg•g^{-1} [0.32 – 23.2 μg•g^{-1}] (n=95). As shown in Figure 3, a strong association was found between blood Hg and hair Hg (1st cm) (Pearson's ρ = 0.95, p<0.0001). The blood-to-hair Hg ratio is known to be about 4:1 (blood Hg in **μg**•L^{-1} to hair Hg in μg•g^{-1}), although there may be important inter-individual variation in the blood-to-hair mercury (Legrand et al. 2010; Liberda et al. 2014). However, in the present study population, the blood-to-hair ratio was 2.3 [1.1 – 7.7], suggesting an excretion rate twice as high as in other populations, although this remains to be confirmed.

Figure 3. Association between blood Hg and hair Hg (1st cm) (n=95). Both variables were log-transformed.



Important monthly variations in Hg exposure (by cm) were found for most participants, from 0.1 to 23.1 μg•g^{-1}. Moreover, as shown in Figure 4a and 4b, preliminary results suggest that when looking at retrospective monthly hair Hg concentrations (by cm) of participants from the same communities, some similar monthly patterns in Hg exposure emerged. As in Figure 4a, Hg exposure would be higher between June and October in this community. Conversely, in another community, two possible peaks in Hg exposure could be found: one in May-June and one November-January (Figure 4b). However, in other communities, despite important intra-participant monthly variations, no clear common trend between participants was found. In summary, monthly profiles seem to be more comparable among participant from some specific communities (possibly where local country food access and consumption is more homogeneous between participants). In depth statistical analysis will be conducted over the coming months.

Table 4. Non-parametric correlation matrix (Spearman's ρ correlations) between blood Hg, Pb, Se, Mn, Hb and SF among study participants (n=97)

	Hg	Pb	Se	Mn	Hb	SF
Hg		**0.33***	**0.67*****	- 0.08	**0.32****	0.19†
Pb			- 0.03	- 0.17†	0.18†	0.10
Se				0.05	**0.38****	0.19†
Mn					- 0.05	**- 0.21***
Hb						**0.34****

*** p<0.0001; ** p<0.01; * p<0.05; † p<0.10

Figure 4a: Example of four participants' hair Hg monthly profile from one community with one peak in Hg exposure between June and October.

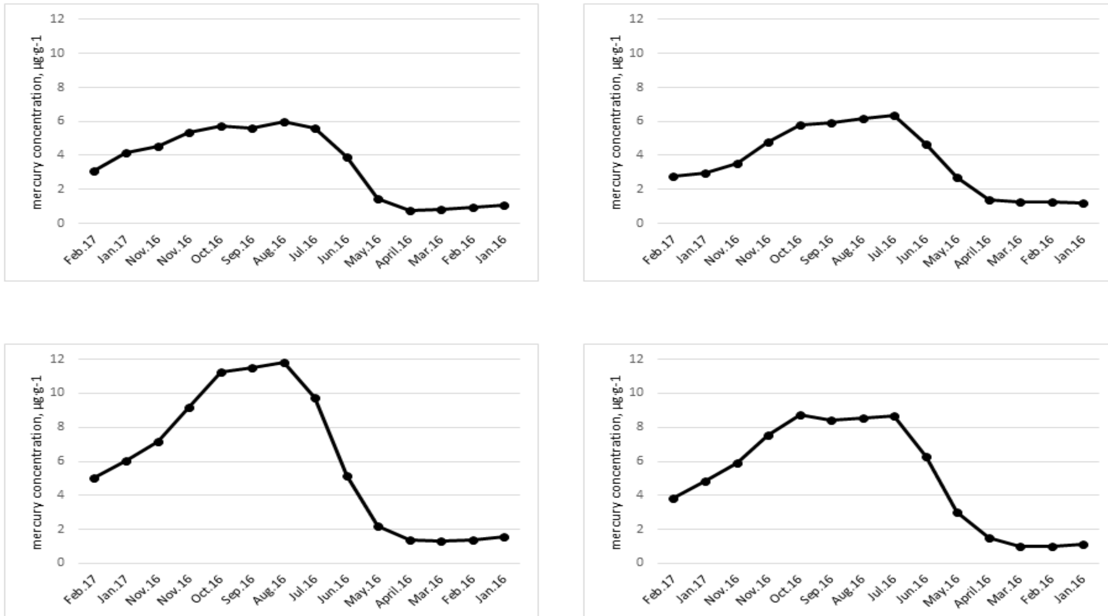
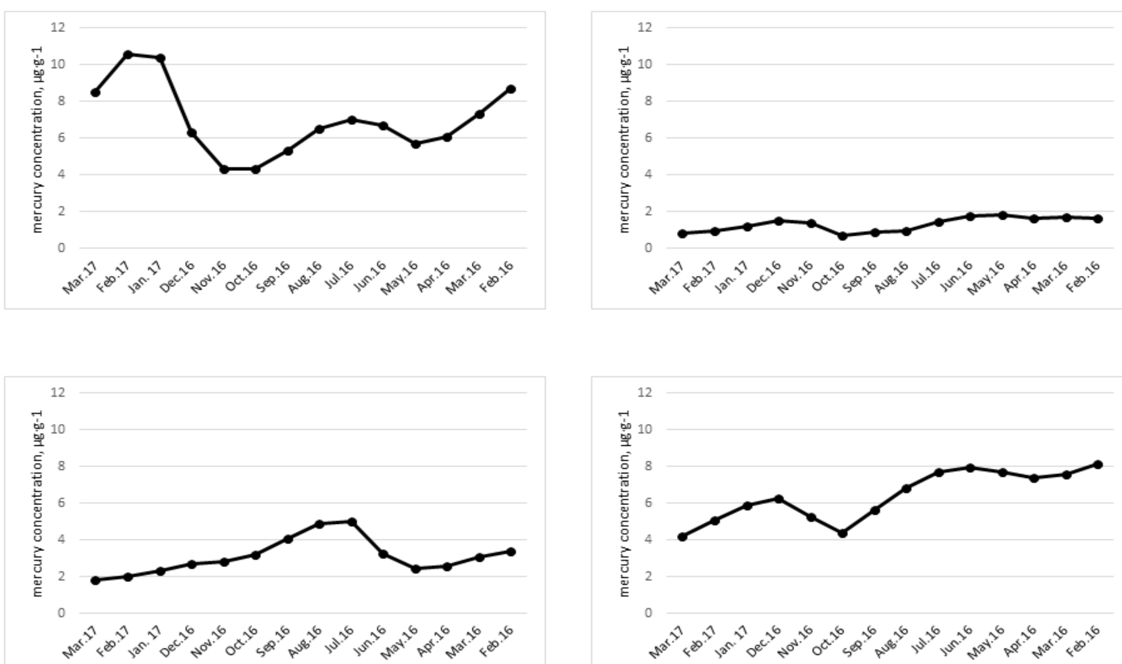


Figure 4b: Example of four participants' hair Hg monthly profile from one community with two peaks in Hg exposure between May-June and November-January.



Awareness of health messages (Part B)

As shown in Table 5 below, whereas most pregnant women (≥ 78%) were well aware of that eating country food is good for health and a good source of healthy fats, only a third (36%) had heard the public message about beluga meat consumption to prevent acute Hg exposure and even less (16%) were aware of the importance of avoiding lead shots (pellets) for hunting to prevent Pb exposure.

Discussion and Conclusions

Hg exposure is still very elevated in Nunavik (23%) compared to the Canadian population, among which the majority (97.8%) of women aged 16 to 49 years, including pregnant women, had blood Hg below 8 μg•L^{-1} in 2007-2009 (Lye et al. 2013). Considering the important regional and monthly variations in Hg exposure in Nunavik, further analyses are needed to: (i) better characterise regional and monthly variations in Hg exposure and identify local sources of Hg exposure; and (ii) develop a screening questionnaire to be used by health professionals to identify with high sensitivity and specificity the pregnant women at risk of elevated Hg exposure. Our preliminary findings highlight that further data analysis for Hg time trends should take into account the month of recruitment and/or the region of origin in order to tentatively better assess time trends in Hg exposure among women in Nunavik.

A few participants (5%) were still found with blood Pb above the most recent level of concern. This emphasizes the importance of promoting lead-free ammunitions to prevent the contamination of local wildlife by lead pellets and bullets, and to promote the consumption of country foods while avoiding Pb exposure. Iron-deficiency anemia is very prevalent among pregnant women in Nunavik (39%) and several country foods are known as excellent sources of iron. Moreover, as promoted by NRBHSS, country foods may also better prevent anemia than market foods and supplements. Joint efforts involving several Nunavik partners including the NRBHSS, the NRC and RNUK are important to jointly address contaminant exposure and anemia issues in Nunavik.

More data on selenoneine, legacy and new POPs and CECs are expected shortly. Further analysis to document pregnant women's food security, housing conditions, drinking water source, practice of traditional activities and Pb-ammunition use, health behaviors (cigarette, marijuana and alcohol consumption) and country food consumption, awareness of health messages, and its associations with contaminants exposure (Hg, Pb and others) and nutrient status (iron status, selenoneine, omega-3 fatty acids) will be conducted over the coming months.

Table 5. Percentage of awareness of about health messages among pregnant women that participated in the project (n=97)

Advices or messages*	Yes (%)	No (%)	Don't know (%)
Country foods are a good source of healthy fats	78	19	3
Generally, eating country foods is good for pregnant women	90	8	2
Generally, eating country foods is good for a developing foetus (the baby developing inside the mother)	85	9	6
Pregnant women should reduce the amount of beluga meat they eat	36	57	7
Hunters should avoid the use of lead shot for hunting	16	69	14

*Question: Have you heard any of the following advice or messages?

Expected Project Completion Date

All the other laboratory analysis for Part A will be completed by August 2017 (selenoneine, legacy and new POPs and CECs) and Part A study results will be available and presented to Nunavimmiut and health professionals in fall 2017 – winter 2018. Fieldwork for Part B of the project will begin in fall 2017.

Project website

The project Facebook page is untitled Nutaratsaliit Qanuingisiarningit Niqituinnanut, and a short project summary is presented on the Nasivvik Research Chair website.

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Annex 1

Thank you Nunavimmiut for your invaluable collaboration!

Over the past 30 years, more than 3,000 Nunavimmiut have participated in studies that revealed high levels of persistent organic pollutants (POPs) and mercury in their blood. This information was used by the Inuit Circumpolar Council, the Government of Canada and other organizations to advocate for a global ban on production and use of POPs, leading to the adoption of the Stockholm Convention in 2004. Nunavimmiut who participated in these studies directly helped to reduce exposure to POPs in the Arctic and worldwide!

Ratified by Canada on April 7, 2017, the Minamata Convention to reduce mercury emissions should enter into force shortly. The collaboration of Inuit is still very much needed to monitor the efficacy of global efforts aimed at reducing mercury in wildlife and protecting the health of Nunavimmiut.

Thanks from all of us and our organizations

Elena Labranche, Chairperson of the NNHC, on behalf of Nunavik Nutrition and Health Committee members.

Mélanie Lemire, Titular of the Nasivvik Research Chair and Assistant Professor at the Université Laval, on behalf of Gina Muckle, Pierre Ayotte, Chris Furgal, Amanda Boyd, Richard Bélanger, Michel Lucas, Catherine Pirkle, professors from the Université Laval, Trent University, Washington State University, and the University of Hawai'i at Manoa.

Sarah Kalhok Bourque, Chair - Northern Contaminants Program, Indigenous and Northern Affairs Canada, on behalf of the Northern Contaminants Program Management Committee.

Merci à vous, Nunavimmiut, pour votre précieuse collaboration !

Au cours des 30 dernières années, plus de 3000 Nunavimmiut ont participé à des études qui ont révélé des niveaux élevés de polluants organiques persistants (POP) et de mercure dans leur sang. Le Conseil circumpolaire inuit, le gouvernement du Canada et d'autres organismes ont utilisé cette information pour plaider en faveur de l'interdiction dans le monde entier de la production et de l'utilisation de POP, jusqu'à l'adoption de la Convention de Stockholm en 2004. Les Nunavimmiut qui ont participé à ces études ont directement contribué à la réduction de l'exposition aux POP, dans l'Arctique bien sûr, mais aussi partout sur la planète !

La Convention de Minamata visant à réduire les émissions de mercure, ratifiée par le Canada le 7 avril 2017, devrait entrer en vigueur sous peu. La collaboration des Inuits est encore une fois indispensable pour surveiller l'efficacité des efforts planétaires visant à réduire les émissions de mercure dans l'environnement et à protéger la santé des Nunavimmiut.

De la part de nous tous et de nos organismes : un grand merci !

Elena Labranche, présidente du CNSN, au nom des membres du Comité de la nutrition et de la santé du Nunavik.

Mélanie Lemire, titulaire de la chaire de recherche Nasivvik et professeure adjointe à l'Université Laval, au nom de Gina Muckle, Pierre Ayotte, Chris Furgal, Amanda Boyd, Richard Bélanger, Michel Lucas, Catherine Pirkle, professeurs à l'Université Laval, à la Trent University, à la Washington State University et à l'*University of Hawaii at Manoa*.

Sarah Kalhok Bourque, présidente du Programme de lutte contre les contaminants dans le Nord, Affaires autochtones et du Nord Canada, au nom du Comité de gestion du Programme de lutte contre les contaminants dans le Nord.

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Sarah Kalhok Bourque, Chair - Northern Contaminants Program, Indigenous and Northern Affairs Canada, on behalf of the Northern Contaminants Program Management Committee.

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 persistants et au mercure

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Abstract

The "Arctic dilemma" describes the difficulty of weighing the benefits of country foods with concerns about contaminants. Indigenous Arctic populations gain tremendous nutritional and cultural benefits from eating traditional foods derived from marine mammals, while, at the same time, these food items are a significant source of exposure to persistent organic pollutants (POPs) and methylmercury (MeHg). We have developed numerical modeling tools that relate contamination of food (including traditional country food and food imported from the South) to contaminant concentrations in humans. With the help of

Résumé

Le « dilemme arctique » décrit la difficulté que pose l'évaluation des avantages de l'alimentation traditionnelle par rapport aux préoccupations relatives aux contaminants. La consommation d'aliments traditionnels provenant de mammifères marins procure des avantages nutritionnels et culturels majeurs aux populations autochtones de l'Arctique. Toutefois, ces aliments sont une source importante d'exposition aux polluants organiques persistants (POP) et au méthylmercure (MeHg). Nous avons mis au point des outils de modélisation numérique qui associent la contamination des aliments

these models it is possible to assess the impact of dietary adjustments on contaminant exposure and nutrient intake. In this project year, we developed a numerical modeling tool for MeHg, which is very easy to use, and applied this tool for POPs to explore the effect of substituting one traditional food item with other items. We further explored how traditional preparation techniques for beluga whale blubber impact its nutritional value and contaminant load. Because of their limited effect on contaminant burden, preparation methods cannot serve as a means to mitigate contaminant exposures. Instead, it may be advisable to have vulnerable subpopulation eat foods from younger, male animals.

(dont les aliments traditionnels locaux et les aliments importés du Sud) et les concentrations en contaminants chez les humains. Avec l'aide de ces modèles, il est possible d'évaluer les répercussions de modifications de l'alimentation sur l'exposition aux contaminants et sur l'apport nutritionnel. Cette année, nous avons conçu un outil de modélisation numérique pour le MeHg, qui est très facile à utiliser, et nous l'avons appliqué aux POP afin d'étudier l'effet de la substitution d'un aliment traditionnel par d'autres aliments. Nous avons en outre étudié comment les techniques traditionnelles de préparation du lard de béluga modifient sa valeur nutritionnelle et sa teneur en contaminants. En raison de leur incidence limitée sur la charge de contaminants, les méthodes de préparation ne permettent pas d'atténuer l'exposition aux contaminants. En revanche, il pourrait être souhaitable de recommander aux sous-populations vulnérables de manger des aliments provenant de jeunes animaux mâles.

Key messages

- We have developed a 'user-friendly' modeling tool for assessing human exposure to methylmercury via the diet. We plan to engage in an external review of the tool during the 2017-18 project year followed by wider efforts to disseminate the model to interested parties and other stakeholders.
- Temporary substitution of traditional food items derived from marine mammals can have beneficial impacts on exposure to methylmercury in the short-term, but need to be balanced against the potential changes to intake of key nutrients. Establishing baseline exposure to contaminants and nutrient intake is key when attempting to devise beneficial dietary substitution advisories.
- Traditional preparation techniques for beluga whale blubber were found to have only a limited effect on contaminant burden. It appears that preparation methods cannot serve as a means to mitigate

Messages clés

- Nous avons mis au point un outil de modélisation convivial pour évaluer l'exposition humaine au méthylmercure par le régime alimentaire. Nous prévoyons soumettre cet outil à une évaluation externe au cours de l'année 2017-2018 du projet, avant de distribuer le modèle à plus grande échelle aux parties intéressées et aux autres intervenants.
- La substitution temporaire d'aliments traditionnels provenant de mammifères marins peut avoir une incidence positive sur l'exposition au méthylmercure à court terme, mais sa pertinence doit être évaluée en tenant des effets potentiels sur l'apport en nutriments essentiels. Il est indispensable d'établir des valeurs de référence concernant l'exposition aux contaminants et l'apport en nutriments si l'on cherche à formuler des recommandations relatives aux substitutions alimentaires bénéfiques.

contaminant exposures and it may therefore be advisable to recommend that vulnerable subpopulations consume younger, male animals when possible.

- Les techniques traditionnelles de préparation du lard de béluga n'ont eu qu'un effet limité sur la charge de contaminants. Il semble que les méthodes de préparation ne permettent pas d'atténuer l'exposition aux contaminants. Par conséquent, il pourrait être souhaitable de recommander que les sous-populations vulnérables privilégient la consommation de jeunes animaux mâles, autant que possible.

Objectives

Long-Term Objectives (2013-present)

- To provide simulation tools that assist in quantitatively addressing the "Arctic dilemma", namely partaking in the nutritional and cultural benefits of traditional food consumption while protecting vulnerable sub-populations from the detrimental effects of contaminant exposure; and
- To build capacity for assessing and predicting human exposures in northern communities to mercury (Hg), persistent organic pollutants (POPs) and new and emerging chemicals of concern via the diet and other potential routes.

Short-term Objectives (2016-17 project year)

- To code steady-state and time-variant bioaccumulation models for methylmercury (MeHg) in humans using Microsoft Excel/VBA. These models relate concentrations in the whole-body, blood, breastmilk, hair, and selected tissues (e.g., liver, kidney, brain) to a given intake rate;
- To disseminate accessible, 'user-friendly' versions of the bioaccumulation models to support efforts by other researchers, territorial health authorities, Indigenous organizations, and individuals from Northern communities to conduct and improve dietary exposure assessments; and
- To publish the results of work on POPs completed during the last year of the project, specifically (i) the simulation of the polychlorinated biphenyl (PCB) exposure observed in two Northern regions (Inuvik and Baffin Island) using reported food intake rates; (ii) the model-based evaluation of the impact of temporary dietary transition on PCB exposure and the intake of Hg and nutrients; and (iii) the experimental determination of the effect of preparation techniques on the levels POPs, Hg, and selected nutrients in beluga whale blubber.

Introduction

Exposure to contaminants in the environment such as POPs and MeHg remains a concern to all Canadians. Exposure in the North is of particular concern because of the relatively high concentrations of contaminants present in marine mammals consumed as part of traditional diets. The overall objective of this ongoing project (2013-present) is to develop and apply mathematical models describing the foodweb bioaccumulation of POPs and MeHg in order to assist in quantitatively addressing the "Arctic dilemma". The main focus of the 2016-17 project year with respect to model development was the coding of mathematical tools for simulating human exposure to methylmercury and inorganic mercury via the diet. Other important research activities conducted during the 2016-17 project year include (i) the application of models to assess the impact of intergenerational and temporary dietary transitions on exposure to POPs and mercury; and (ii) experimental work aiming to assess potential changes to nutrient and contaminant levels in marine mammal blubber during preparation for human consumption using traditional methods.

Activities in 2016-17

Development of Bioaccumulation Modeling Approaches for Human MeHg Exposure

We developed two types of MeHg bioaccumulation models for humans and implemented them as Excel/VBA applications in the 2016-17 project year. The first type is a time-variant physiologically-based pharmacokinetic (PBPK) model based on publications by Carrier et al. (2001ab) and Clewell et al. (1999). This model allows the user to simulate the accumulation and internal tissue distribution of methylmercury and inorganic mercury over time for a given exposure scenario, and also relate concentrations in blood to those in hair. Other tissues simulated in the model include liver, kidney, and brain.

The second type is a steady-state single-compartment bioaccumulation model that allows the user to calculate the concentration of methylmercury at the whole body level, and also in blood and hair, for a given exposure scenario. The modeling approach is consistent with recent publications in the peer-reviewed literature. The current implementation of the steady-state model allows the user to rapidly calculate the body burden of methylmercury based on reported or estimated food consumption rates, concentrations in key food items, and assumptions about the gut uptake efficiency of methylmercury. The modeling tool also reports the relative contribution from store-bought and country foods (based on user input) to the total body burden of MeHg, and compares the calculation concentration in blood to numerical thresholds established by various regulatory authorities. To support the application of this tool, we have also compiled monitoring data characterizing the concentrations of methylmercury in various store-bought foods. Data characterizing the concentrations of methylmercury in country foods from certain locations in the North have also been collected.

Use of numerical models to assess the impact of intergenerational and temporary dietary transitions on exposure to POPs

With the publication of two peer-reviewed papers, this part of the project has been brought to a successful completion. Binnington et al. 2016a describes the simulation of the PCB exposure observed in two Northern regions (Inuvik and Baffin Island) using reported food intake. It also describes in detail the expanded version of the ACC-human Arctic model that was developed within this project. In Binnington et al. (2016b) we used that model to evaluate the impact of temporary dietary transition on PCB exposure and the intake of Hg and nutrients among Northern Indigenous Peoples. The results from Binnington et al. (2016b) are discussed in additional detail below.

We also contributed a section to the biomonitoring chapter of the recent CACAR Human Health Assessment that summarizes efforts to develop and use mechanistic models of contaminant exposure in Indigenous people of the Arctic region. That section has been converted into a review paper that underwent internal peer review by Health Canada and was published in the journal *Environmental Reviews* (Wania et al. 2017).

Measuring Changes to Nutrient and Persistent Organic Pollutant Availability from Preparing Marine Mammal Blubber for Human Consumption

This project element has also been brought to successful completion with the submission of a manuscript to a peer-reviewed journal (Binnington et al. 2017). This paper describes in detail the impact of various food preparation techniques on the contaminant and nutrient content of beluga whale blubber. The list of analytes included selenium, polyunsaturated fatty acids, organochlorine pesticides, perfluoroalkyl and polyfluoroalkyl substances, polybrominated diphenyl ethers, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, and mercury.

Capacity Building

Over the period of 2013-2016, our goal with respect to capacity building and training was to promote the value of exposure modeling to key stakeholders in Northern communities. This effort has been represented in part by the short, plain language research summaries that were broadly distributed via e-mail and reviewed during our annual Summer Stakeholder Update Meetings. Matt Binnington also participated in the Beluga Communication Summit, Feb. 22-26, 2016 in Inuvik, ISR.

For the 2016-2017 project year specifically, our goal with respect to capacity building and training was to provide a user-friendly model for conducting dietary exposure assessments (Figure 1, below). Model predictions that translate MeHg intake rates into human body burdens can then be compared to the various thresholds of concern defined by regulatory agencies (e.g., Health Canada). We plan to finalize the model, databases and guidance documents by Summer 2017 and then publicize availability of the tool at the Annual NCP Workshop in Sept 2017.

Communications

Table 1. A summary of communications activities undertaken during the 2016-2017 project year.

Winter 2016	Communication of results to Northern stakeholders Matt Binnington participated in the Beluga Communication Summit, Feb. 22-26, 2016 in Inuvik, ISR.
Summer 2016	NCP Stakeholder Update Meeting (July 2016, chaired by MC) Summarized previous modeling work on human exposure to POPs (maternal exposure), influence of dietary transition on POP exposure and nutrient uptake Presented the final results on the beluga blubber food preparation project Introduced rationale and main objectives for project year 2016-17 (MeHg exposure assessment tools for humans)
Fall 2016	Human Health Monitoring and Risk Communication Workshop James M. Armitage, Frank Wania, and Meredith Curren attended the NCP workshop, Nov 22-23, 2016 in Ottawa, ON and also communicated with 2016-17 project partners on progress and outstanding biomonitoring data needs.
Spring/ Summer 2017	End of Year synopsis report on human MeHg dietary exposure assessment tools Uploading of mercury exposure assessment tools and instruction manuals to Wania Group website Stakeholder Update Meeting (teleconference) to i) introduce and discuss mercury exposure assessment tools and ii) discuss proposed work for 2017-18 project year

Indigenous Knowledge Integration

Indigenous Knowledge (IK) has had an important role in this project, particularly during the data interpretation in our publications as the modeling speaks to the dietary choices of northerners and the importance of food advisories locally. The annual presentations to the northern representatives have also been a good forum to obtain feedback on how we may obtain and incorporate IK that will enhance the project outcome, particularly with regards to contemporary dietary preferences and dietary changes.

As the mercury exposure assessment tools we have developed are generic (i.e., do not presuppose consumption rates of any food item), the main role of IK in the 2016-17 project year has been to inform the list of food items included in the food basket. Ideally, individuals and organizations interested in conducting dietary exposure assessments in the future will be able to define their own scenarios based on IK and other information pertinent to their food choices.

Results

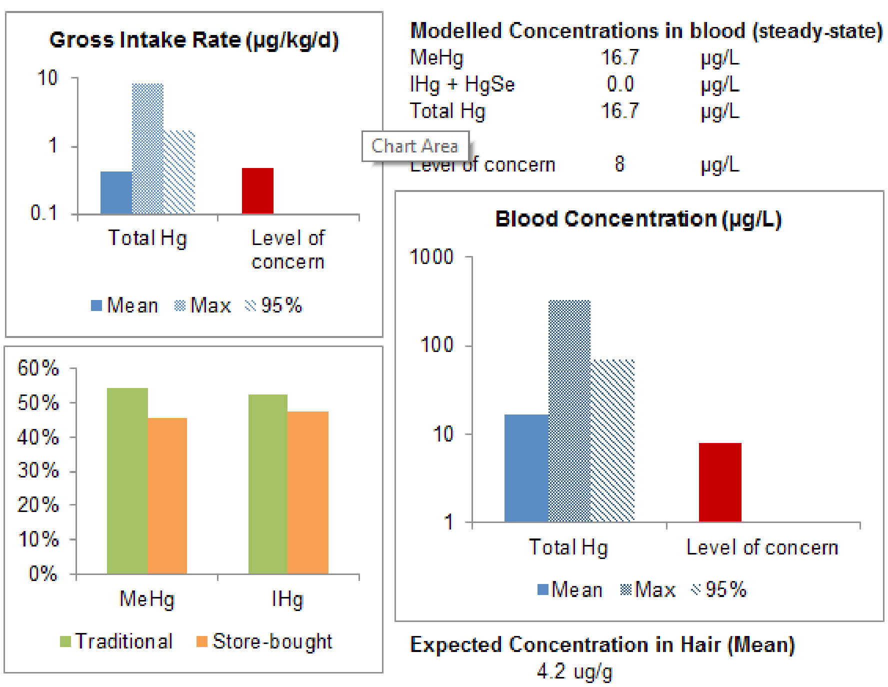
Development of Bioaccumulation Modeling Approaches for Human MeHg Exposure

Illustrative output from the steady-state bioaccumulation model for methylmercury in humans is shown in Figure 1. The model calculates and outputs intake rates and corresponding concentrations in blood and hair for a given exposure scenario. The relative contribution from traditional and store-bought items is also displayed. Traditional and store-bought food items can also be ranked in terms of individual contributions to total intake (data not shown).

Use of numerical models to assess the impact of temporary dietary transitions on exposure to POPs

Output from a fate and transport model (GloboPOP) and a food web bioaccumulation model (ACC-Human Arctic) were used to simulate exposure to polychlorinated biphenyls (PCBs) amongst female participants of the 2007-08 Inuit Health Survey. Daily mercury and nutrient intake rates were also calculated using biomonitoring and nutritional data. These calculations demonstrate that while temporary reductions in the consumption of marine mammals can result in substantial decreases in the exposure to mercury, the long elimination half-life of PCBs prevent similar gains from being achieved in the short-term. Temporary reductions in the consumption of marine mammals also lowered intakes of iron, manganese, selenium, and some polyunsaturated fatty acids, which could not be replaced by the substituted food items.

Figure 1. Illustrative (i.e., hypothetical) output from the human MeHg dietary exposure assessment tool developed during project year 2016-17.



The calculations conducted in this exercise demonstrate the importance of establishing baseline traditional food intake rates, nutrient intake, and contaminant exposure before devising dietary adjustment strategies for women of childbearing age.

Measuring Changes to Nutrient and Persistent Organic Pollutant Availability from Preparing Marine Mammal Blubber for Human Consumption

Blubber was collected from two male beluga whales harvested during the 2014 summer hunting season in Tuktoyaktuk, Northwest Territories. The blubber was then processed according to the local traditional techniques to produce muktuk and uqsuq. Raw and prepared blubber samples were then analyzed for a suite of nutrients (e.g., selenium, polyunsaturated fatty acids) and contaminants (organochlorines, brominated compounds, per- and polyfluorinated compounds, mercury).

The impacts of beluga blubber preparation methods on nutrient and contaminant levels were not consistent, as the majority of processes either did not have a significant influence or affected the samples from the two belugas differently. Differences in contaminant concentrations between the two males were greater than any difference found due to preparation methods. When considering methods to minimize human exposure to contaminants while maximizing nutrient intake, consumption of aged liquid blubber extract from younger, male animals would be preferred, based on the enhanced levels of polyunsaturated fatty acids and selective depletion of some contaminants observed in this study.

Discussion and Conclusions

The modeling work conducted during this project over the past four years has demonstrated the value of applying quantitative tools to assist in addressing the "Arctic dilemma". For some contaminants of concern (e.g., PCBs), the persistence of these chemicals in the environment and in humans (i.e., long elimination half-life in excess of a few years) requires the use of models to interpret contemporary body burdens and also predict the influence of potential changes in exposure in the future. For other contaminants (e.g., methylmercury), the relatively short elimination half-life of less than a year means that contemporary body burdens largely reflect contemporary exposure and the magnitude and time-scale of potential changes in exposure can more readily be assessed. Differences in the environmental fate and bioaccumulation behaviour of organic contaminants preclude a 'one size fits all' approach to devising recommendations for dietary substitution. In all cases, the influence of any recommended changes in diet and/or frequency of consumption need to be balanced with the impact on nutrient intakes (e.g. polyunsaturated fatty acids, trace metals).

Our experiences over the course of this ongoing project (2013-present) have highlighted the importance of establishing baseline intake rates for traditional food items and associated nutrients and contaminants but also the challenges to accurately doing so at the individual and population level. Nevertheless, quantitative tools are necessary complements to the collection of biomonitoring data and dietary survey data as, among other roles, they can be used to synthesize and bring cost-effective additional value to the available data and help identify key uncertainties in exposure estimates (e.g., bias in reported consumption rates). It is clear that further collaboration and sharing of data and quantitative approaches for addressing the "Arctic dilemma" will remain vital to the Northern Contaminants Program in the future.

Expected Project Completion Date

We have received funding from the NCP for the 2017-18 project year to focus on the communication and dissemination of the modeling tool for assessing human exposure to methyl mercury through the diet (Figure 1).

Acknowledgements

We thank the Northern Contaminants Program for their continuing financial support for research activities conducted over the period of 2013-17. We also thank all Inuvik and Baffin biomonitoring individuals and investigators for their critical contributions to the maternal datasets used in this work, and the Government of the Northwest Territories and the Government of Nunavut for their support and assistance in using these archived datasets.

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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 goal of this three-year project is to better understand how Inuit biologically 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 single nucleotide polymorphisms (SNPs) in environmentally-responsive genes that help the body 'process' toxicants will increase understanding and utility of exposure

Résumé

Ce projet de trois ans vise à mieux comprendre la façon dont les Inuits métabolisent les contaminants. Son objectif ultime est de fournir aux décideurs en santé publique des connaissances qui les aideront à déterminer les sous-populations les plus vulnérables et à effectuer des évaluations des risques éclairées et objectives. Notre principale hypothèse était que l'analyse des polymorphismes mononucléotidiques (SNP) présents dans des gènes en interaction avec l'environnement qui

biomarkers of mercury, PCBs, and other persistent organic pollutants. Over the past three funding years we have collected samples from some members of the Inuvialuit community (N=288 participants) who participated in the 2007-2008 International Polar Year Inuit Health Survey as well as participants from Nunavik (N=669 participants) as part of the 2004 Qanuippitaa Survey. In most participants blood contaminants (Hg, Cd, Pb, Se, DDE, PCB-153) and fatty acids (DHA, EPA) levels were related to genetic polymorphisms (~150 SNPs), while considering pertinent covariates. Several polymorphisms emerged to be influential thus indicating that environmentally responsive genes can influence contaminant and nutrient biomarker levels. Reports are currently being finalized and shared with community members prior to broader dissemination.

aident l'organisme à « gérer » les substances toxiques augmenterait la compréhension et l'utilité des biomarqueurs de l'exposition au mercure, aux BPC et à d'autres polluants organiques persistants (POP). Au cours des trois dernières années de financement, nous avons recueilli des échantillons auprès de quelques membres de la collectivité des Inuvialuit (N= 288) ayant participé à l'Enquête sur la santé des Inuits lors de l'Année polaire internationale en 2007-2008, de même qu'auprès de participants du Nunavik (N = 669 participants) dans le cadre de l'Enquête Qanuippitaa de 2004. Chez la majorité des participants, les niveaux de contaminants sanguins (mercure, cadmium, plomb, sélénium, DDE, BPC-153) et d'acides gras (ADH/AEP) étaient associés à des polymorphismes génétiques (~150 SNP), en tenant compte des covariables pertinentes. Plusieurs polymorphismes semblaient avoir une influence, ce qui indique que les gènes qui réagissent à l'environnement peuvent influer sur les niveaux des biomarqueurs associés aux contaminants et aux nutriments. Les rapports seront bientôt prêts à être présentés aux membres de la communauté avant leur distribution à grande échelle.

Key Messages

- ~150 genetic polymorphisms were characterized in Inuit who participated in the 2007-2008 International Polar Year Inuit Health Survey and the 2004 Qanuippitaa Survey
- These polymorphisms hail from biological pathways associated with, for example, the transport and metabolism of contaminants and cardiovascular health.
- Composition of many of the genetic polymorphisms was different when compared against other populations such as Caucasians and Asians.
- Some genes are associated with changes in blood levels of mercury, cadmium, lead, DDE, PCB153, and fatty acids DHA and EPA.

Messages clés

- ~150 polymorphismes génétiques ont été caractérisés chez les Inuits ayant participé à l'Enquête sur la santé des Inuits au cours de l'Année polaire internationale en 2007-2008 et à l'Enquête Qanuippitaa en 2004.
- Ces polymorphismes se rapportent aux voies biologiques associées, par exemple, au transport et au métabolisme des contaminants et à la santé cardiovasculaire.
- La composition de bon nombre des polymorphismes génétiques différait en comparaison d'autres populations, comme les Caucasiens et les Asiatiques.
- Certains gènes étaient associés à des changements dans les concentrations sanguines de mercure, de cadmium, de plomb, de DDE, de BPC-153 et d'acides gras ADH et AEP.

- This type of information needs to be considered in risk assessments and decision making.

- Ce type d'information doit être pris en compte dans les évaluations des risques et la prise de décisions.

Objectives

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

- **The short-term objective** is to test the hypothesis that analysis of genetic polymorphisms (focusing 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 acids (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-analysis 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 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 2016-2017

This was the final year of the project, and a majority of the time was spent (i) finalizing the dataset collected from the second year of the project (i.e., information and samples collected from the 2004 Qanuippitaa Survey); and (ii) generating summary and detailed reports of the findings for presentation to the involved communities and following necessary consulting, then to other stakeholder groups. The overall 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 have a robust sample size of approximately 1,000 participants which enables us to explore gene-environment interactions with greater confidence. In the final year of this project the following papers are planned: (i) genetic polymorphisms and toxicant biomarkers in ISR; (ii) genetic polymorphisms and nutritional biomarkers in ISR; (iii) genetic polymorphisms and toxicant biomarkers in Nunavik; (iv) genetic polymorphisms and nutritional biomarkers in Nunavik; and (v) genetic polymorphisms in association with exposure biomarkers and cardiovascular measures in Nunavik.

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 these polymorphisms hail from biological pathways associated with, for example, the transport and metabolism of contaminants and cardiovascular health. The analysis of genetic polymorphisms 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 lifestyle and diet information. The merged database has undergone statistical analyses by Dr. Parajuli (postdoctoral fellow, McGill University) and Dr. David Hu (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 polymorphisms 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 lifestyle 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

This was summarized in last year's report.

Nunavik Study (2004 Qanuippitaa Survey)

Characteristics of Nunavik study participants have been outlined elsewhere (Dewailly et al. 2007). In brief the Nunavik study population for this study largely consisted of females (56.2%) that were mostly middle-aged though the age distribution was wide (Mean (*SD*)= 37.23(14.09), range 18-76 years). Total biomarker concentrations were measured in blood samples. Geometric means (SD) were 11.07 (1.02) $\mu g \bullet L^{-1}$ for bHg, 2.82 (0.98) $\mu g \bullet L^{-1}$ for bCd, 301.20 (0.48) for bSe, 39.94 (0.68) $\mu g \bullet L^{-1}$ for bPb, 2.92 (1.04) $\mu g \bullet L^{-1}$ for DDE, 1.10 $\mu g \bullet L^{-1}$ for blood PCB 153, 5.13 % / total fatty acid (TFA) for DHA and 1.31 % /TFA for EPA.

We used ANOVA tests to compare the mean bHg, bCd, bPb and bSe levels among SNP genotypes. Among 106 SNPs studied, 42 SNPs indicated significant differences ($p<0.05$) by genotype for at least one metal (bHg, or bCd or bPb or bSe) biomarker; 20 SNPs for Hg, 15 SNPs for bCd 14 SNPs for bPb, and 2 for bSe levels. A similar approach was taken for the organic chemicals, DDE and PCB153, and in doing so 27 SNPs (18 SNP for DDE and 23 SNPs for PCB 153) showed significant differences.

For red blood cell omega-3 fatty acids (DHA and EPA), 16 SNPs indicated significant differences by genotype; 10 SNPs for DHA, 9 SNPs for EPA levels. Compared to last year's report less detail is provided here so as to ensure that we first consult with the community before widely disseminating the findings.

Discussion and Conclusions

The analysis of the ISR and Nunavik data confirm 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 both populations we observe significant associations between SNPs and metals, POPs and fatty acid biomarker levels as well as in the ISR study we observe 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.

Expected Project Completion Date

The three-year project officially ended during the current 2016/2017 NCP funding cycle. There are a number of draft manuscripts we have in preparation, and are starting to share these with the two communities, and eventually the broader community of stakeholders.

Acknowledgments

We thank all the 2007-2008 Inuit Health Survey participants from Inuvialuit, and the participants from the 2004 Qanuippitaa Survey. We specially thank Shannon O'Hara, the Inuit Research Advisor for the Inuvialuit Regional Corporation and member of the ISR Steering Committee, for the support of this project. We also thank members of the Nunavik Nutrition and Health Committee for consulting with our team, and supporting the work. Funding for this project was provided by the Northern Contaminants Program, as well as with resources and funding from the Co-PIs (Basu, Chan, Ayotte), including, for example, Canada Foundation for Innovation (CFI) and the Canada Research Chair program.

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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 Nord-Ouest : étude des liens qui existent entre l'exposition aux contaminants, l'état nutritionnel et les aliments traditionnels

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Abstract

Throughout the second year of the study, we implemented biomonitoring research in five communities in the Northwest Territories and visited a total of nine communities. Our team consulted with three Sahtú communities (Norman Wells, Tulita, Fort Good Hope) and four Dehcho communities (Hay River First Nation, West Point First Nation, Kakisa, Fort Providence) regarding the expansion of the project and their potential participation in 2016-2018. Building upon prior consultations in 2015-2017, our research team traveled to the participating communities (Hay River Reserve, West Point, Fort Providence, Kakisa and Deline, NT) for data and sample collection.

Résumé

Au cours de la deuxième année de l'étude, nous avons lancé des recherches de biosurveillance dans cinq collectivités des Territoires du Nord-Ouest et nous avons visité neuf collectivités au total. Notre équipe a consulté trois collectivités du Sahtú (Norman Wells, Tulita, Fort Good Hope) et quatre collectivités du Dehcho (Hay River First Nation, West Point First Nation, Kakisa, Fort Providence) au sujet de l'élargissement du projet et de leur participation éventuelle de 2016 à 2018. À la suite des consultations menées précédemment de 2015 à 2017, notre équipe de recherche s'est rendue dans les collectivités participantes (réserve de Hay River, West Point, Fort Providence, Kakisa

Additionally, our research team traveled to the first participating community of last year (Jean Marie River First Nation, NT) to return results to the leadership and participants, during a public meeting and during one-to-one sessions. With the assistance of local research coordinators and nurses, we collected blood, urine, and/or hair samples from 314 participants. Participants also completed a risk perception questionnaire and two dietary surveys (24-hr Recall, Food Frequency Questionnaire). Data analysis of the Year 2 results (metals in blood/urine; persistent organic pollutants (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 2 participating communities in Fall 2017.

et Deline, Territoires du Nord-Ouest) afin de recueillir des données et des échantillons. De plus, notre équipe de recherche est retournée dans la première communauté ayant pris part au projet l'an dernier (Jean Marie River First Nation, Territoires du Nord-Ouest), afin de présenter les résultats aux dirigeants et aux participants à l'occasion d'une réunion publique et de séances individuelles. Avec l'aide du personnel infirmier et des coordonnateurs de recherche locaux, nous avons recueilli des échantillons de sang, d'urine et de cheveux auprès de 314 participants. Ces derniers ont aussi rempli un questionnaire sur leur perception des risques et deux sondages sur leur alimentation (relevé de 24 h et fréquence de consommation). L'analyse des données recueillies lors de la deuxième année est en cours (métaux dans le sang et dans l'urine; polluants organiques persistants dans le sang; mercure dans les cheveux, questionnaires sur l'alimentation). En collaboration avec les partenaires régionaux, territoriaux et fédéraux, les résultats seront communiqués aux collectivités ayant participé à la deuxième année du projet à l'automne 2017.

Key Messages

- Additional consultations with leaders and community members were held in Deline, Norman Wells, Tulita, Hay River, West Point, Kakisa, and Fort Good Hope to discuss their potential participation in the biomonitoring project in 2016-2018.
- Year 1 results were returned to participating individuals and communities in fall 2016.
- Between November 2016 and February 2017 (Year 2), 314 participants from K'atl'odeechee First Nation, West Point First Nation, Fort Providence, Kakisa and Deline, NT provided hair, blood, and/or urine samples for contaminants and nutrients analyses.
- Year 2 samples are currently being analyzed for mercury (hair), metals and metalloids (blood, urine), and POPs (blood).

Messages clés

- Des consultations additionnelles ont eu lieu avec les dirigeants et les membres des collectivités de Deline, Norman Wells, Tulita, Hay River, West Point, Kakisa et Fort Good Hope afin de discuter de leur participation éventuelle au projet de biosurveillance en 2016-2018.
- Les résultats obtenus durant la première année ont été communiqués aux personnes et aux collectivités qui ont participé au projet à l'automne 2016.
- Entre novembre 2016 et février 2017 (deuxième année), 314 participants de la K'atl'odeechee First Nation, la West Point First Nation, Fort Providence, Kakisa et Deline, dans les Territoires du Nord-Ouest, ont fourni des échantillons de cheveux, de sang ou d'urine à des fins d'analyse des contaminants et des nutriments.

- Year 2 results will be returned to participating individuals and communities in fall 2017.

- Les échantillons recueillis au cours de la deuxième année font actuellement l'objet d'analyses en vue de détecter le mercure (cheveux), les métaux et les métalloïdes (sang et urine) et les polluants organiques persistants (sang).

- Les résultats seront communiqués aux personnes et aux collectivités qui ont participé à la deuxième année du projet à l'automne 2017.

Objectives

The short term objectives for this research project were to:

- Refine with the local partners a result dissemination strategy developed in 2015-2016 with the Dehcho Health and Social Services Authority and the Government of the Northwest Territories Department of Health and Social Services;

- Evaluate country food usage patterns, contaminant exposure profiles, and nutritional biomarkers in participating communities of the Dehcho Region and the Sahtú Region; and

- Consult with additional communities regarding the expansion of the project in subsequent years.

The long term objectives of this research project are to:

- Return results to all individuals and communities who take part in the project;

- Implement the biomonitoring study in up to four additional, previously-consulted Dehcho and Sahtú communities;

- Create a public health screening tool that can be used to characterize those most at risk of facing elevated contaminant exposures in the Dehcho and Sahtú Regions; and

- 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 NWT (Berti et al. 1998; Kuhnlein et al. 2004; Kuhnlein et al. 2007; Nakano et al. 2005). Further, the consumption of such country foods has been associated with lower risk factors for cardiovascular disease and diabetes (Dewailly et al. 2002; Kuhnlein and Chan 2000; Receveur et al. 1997). 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 (DHSS 2012). Additionally, elevated Cd levels have been recorded in the organs (e.g. kidneys, livers) of moose from some parts of the Dehcho region (DHSS 2009). 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 (Sexton et al. 2004). 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 2016-2017

NCP funding in 2016-2017 was used to work on three components of this contaminant biomonitoring research project in the Dehcho and Sahtú Regions of the Northwest Territories.

Component 1: Partnership Development and Consultation

These activities included participation in the 2016 Sahtú Cross Cultural Camp, engagement with the Sahtú Environmental Research and Monitoring Forum, and community consultation visits with several Dehcho and Sahtú communities. In July and August 2016, community consultations were held with several communities (Norman Wells, Fort Providence, K'atl'odeechee First Nation, West Point First Nation, and Hay River Metis). During these visits, through a series of public forums and leadership meetings, Drs. Laird and 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, arsenic, and POPs. Additionally, community members stressed the importance of promptly returning results in plain language. The result of these meetings indicated that leaders as well as the public from numerous communities had a strong interest in participating in the research project. Given the importance of the dissemination of the results to all involved, a health and risk communication survey (based in part on similar studies in Nunavik) designed by researchers at the University of Waterloo, Trent University, and Washington State University was developed for use in the project.

Component 2: Biomonitoring Implementation

In preparation of the project, we received ethics clearance from the University of Waterloo Research Ethics Committee and a research license from the Aurora Research Institute. During this process, we conversed with local leaders, administrators and resources coordinators to adapt Community Research Agreements (CRAs) that clarify the responsibilities and expectations of the research team and each participating community. The CRAs defined the scope of the work, expected benefits and outcomes, principles of informed consent, as well as the data management plan. Community partners provided input on several aspects of the CRAs, including translation of documents, sampling dates, and local research coordinator recruitment to ensure the CRAs were written in a culturally appropriate manner. In Year 2, we implemented the biomonitoring sample and data collection in a five communities (K'atl'odeechee First Nation, West Point First Nation, Fort Providence, Kakisa and Deline). A local research coordinator was hired from each participating community to support the recruitment of participants for the collection of blood, urine, and hair samples and for the completion of the surveys. Samples have been sent to collaborative analytical laboratories and the data will be received in the next few weeks. Additionally, we received supplemental funding from Health Canada to measure other contaminants (e.g. cotinine, phthalates, PAHs, arsenic species) from previously collected samples.

Component 3: Building of a communication strategy

After the data has been analysed, results are returned to the participating communities and individuals before dissemination or publication. Each study participant that provided a hair, urine, and/or blood sample will receive 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 was formed to guide the knowledge translation of results. We returned results to Year 1 participants with one-on-one meetings in November 2016. Also, we held both public and leadership meetings to discuss the overall findings of the research within participating communities. Also the research team developed a risk perception and messaging questionnaire in order to adapt the communication strategy to regional and cultural preferences. Finally a North Slavey terminology workshop, was organized by the University of Waterloo team and the Sahtú Renewable Resources Board, in Deline, NT in order to further refine knowledge translation and communication approaches.

Capacity Building

NCP funds were used to hire one or two local research coordinators in participating communities. These coordinators assist with the implementation of the project by overseeing participant recruitment and assisting participants with completing the surveys. These research coordinators' were invaluable to the project and assisted with participant recruitment, sample collection, translation, and administration of questionnaires.

Communications

We provided our contacts within the Northwest Territories Health and Social Services Authority,

Dehcho Aboriginal Aquatic Resources and Ocean Management, Sahtu Renewable Resources Board, Dehcho Health and Social Services Authority, and other organizations with monthly phone/email updates of the research progress. Additionally, we participate in the monthly Sahtú Environmental Research and Monitoring Forum, which provides additional opportunities to liaise with other researchers, local organization members and community leaders. Furthermore we developed factsheets describing the contaminants and biomonitoring approaches in order to support Northern medical practitioners who receive questions from patients who heard and/or participated in the project. Work was done to design the community reports, and the participants' letters to be returned. During the research trip for community consultations and implementation of the biomonitoring study, Dr. Laird also conducted interviews to local media including the Fort Good Hope Radio, and Deline Radio. Additionally, we introduced the project more broadly to northern public health practitioners through participation in a meeting held by the Northwest Territories and Nunavut Public Health Association.

Indigenous Knowledge Integration

The project will rely upon local and traditional knowledge communicated through the community consultations completed in 2014-2017 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. Previously, 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 proper names for foods that will be recognized by members of the participating communities. More lately, a terminology workshop was organized in Deline, NT, in order to discuss translation issues and local perceptions of concepts relevant to the study of contaminants. For example, it was learned that contaminant was often translated locally into *'a substance that kills'*. Less inflammatory, alternative translations for contaminants were discussed among workshop participants. 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

Participation rates in communities have ranged between 12 and 37%. Depending on community size, the research team spent between two and eight days in the communities to implement the biomonitoring research with the assistance of local research coordinators. Between January 2016 and February 2017, a total of 279 hair samples, 149 blood samples, and 127 spot urine samples were collected. In November 2016, the research team visited Year 1 participants to return and discuss results. A follow-up plan based upon Year 1 results was designed and implemented with community leaders and the Government of the Northwest Territories Department of Health and Social Services. The CRAs established with each participating communities preclude the research team from publishing: (i) community-specific biomonitoring results and (ii) any results that have not yet been returned to participating individuals and communities. As such, no biomarker results can yet be included within this synopsis report. However, analyses synthesizing results from Year 1 and Year 2 participants will be prepared and disseminated (according to the terms of the CRA) following the return of results to participants in 2017-2018. Please see Table 1 for an overview of the analyses completed or underway among participants in the Northwest Territories biomonitoring project.

In co-located environmental monitoring research, fish composition analysis (e.g. total mercury (HgT) and omega-3 fatty (*n*-3) fatty acids) was completed for muscle tissue of Burbot, Cisco, Lake Trout, Lake Whitefish, Longnose Sucker, Northern Pike, and Walleye harvested from eight lakes (Ekali, Trout, Sanguez, Tahlina, McGill, Gargan, Mustard, and Kakisa) in the Dehcho Region, Northwest Territories, Canada. Total mercury and EPA+DHA are shown in Table 2. In summary, the average HgT concentrations in the piscivorous fish (Northern Pike, Walleye, Lake Trout) were up to 7.3-fold higher than observed in benthivorous and planktivorous fish species. Additionally, there were substantial differences in the fatty acid profiles among fish species (Table 2). Interestingly, significant negative correlations were observed between mercury and lipid content in particular fish species in particular lakes. For example, negative correlations were observed between HgT and EPA+DHA content for Lake Trout) harvested from Trout Lake (ρ = -0.951, $P<0.001$) and Mustard Lake (ρ = -0.513, $P<0.05$).

These analyses of fish tissues indicated that, on average, Lake Whitefish, Cisco, and Lake Trout, and Sucker had the highest nutrient levels relative to their HgT content. A *de minimus* approach (Tsuchiya et al. 2008), adapted for Health Canada's Toxicological Reference Value (TRV) for methylmercury (Health Canada 2007) and the most current dietary recommendations for omega-3 fatty acids , were used to determine which fish species that would best enable individuals to meet nutritional sufficiency in terms of omega-3 fatty acids while not exceeding the MeHg TRV. Of the species collected in this research, Lake Whitefish, Cisco, Lake Trout, and Suckers generally exceeded DHA:Hg (15:1) and EPA+DHA:Hg (19.1) *de minimus* ratios. In contrast, only Whitefish and Cisco exceeded the total n-3 FA:Hg (38:1) *de minimus* ratio (Figure 1). In summary, many wild-harvested fish species in the Dehcho, including the most widely consumed fish (Lake Whitefish) in the territory, can help individuals and communities meet nutritional recommendations without exceeding the Health Canada methylmercury TRV. While *de minimus* values provide a preliminary means of evaluating species-and lake-specific nutrient contaminant ratios, it is important to remember that the *de minimus* ratios are subject to the uncertainty within the nutritional and toxicological reference values used in their derivation. As such, it would be inappropriate to treat *de minimus* ratios as bright lines between net benefit and net risk. Further research using probabilistic dose reconstruction and optimization software (Optquest, Crystal Ball, Oracle) is underway to further explore the intersection of contaminant risks and nutritional benefits from traditional food consumption in the Northwest Territories.

In parallel with the human monitoring and the environmental monitoring, we continued the consultation with communities. The outcome of the community consultations was that leaders and community members from Trout Lake, Tulita, and Fort Good Hope confirmed a desire to see a biomonitoring study take place in order to address community concerns regarding current contaminant exposures.

Table 1. Analyses completed or underway among participants in the Northwest Territories biomonitoring project (Years 1 &2; 2015-2017).

	Hair (n = 279)	Blood (n = 149)	Urine (n = 127)
Metals[1]			
Mercury	√	√	√
Cadmium		√	√
Lead		√	√
Uranium		√	√
Selenium		√	√
Arsenic[3]		√	√
POPs[2]			
Arochlor 1260		√	
PCB Congeners[4]		√	
PBDEs[5]		√	
Chlordane[6]		√	
Hexachlorobenzene		√	
Hexachlorocyclohexane[7]			
DDT[8]		√	
Mirex		√	
Toxaphene[9]		√	

1 Metals have been analyzed in whole blood (µg•L^{-1}) and spot urine (µg•g^{-1} creatinine) samples of participants

2 Persistent organic pollutants have been analysed in blood plasma (µg•L^{-1}; µg•g^{-1} plasma lipid).

3 All blood and urine samples have been analyzed for total arsenic. Additionally, supplemental funding from Health Canada has enabled arsenic speciation analyses in a subset of urine samples.

4 PCB Congeners include PCB138, PCB146, PCB153, PCB156, PCB163, PCB170, PCB180, PCB187, PCB194, PCB201, PCB203, AND PCB206

5 Biomarkers include PBDE #15, #17, #25, #28, #33, #47, #99, #100, and #153

6 Biomarkers include cis-nonachlor, trans-nonachlor, gamma-chlordane, alpha-chlordane, and oxy-chlordane

7 Biomarkers include gamma-HCH and beta-HCH

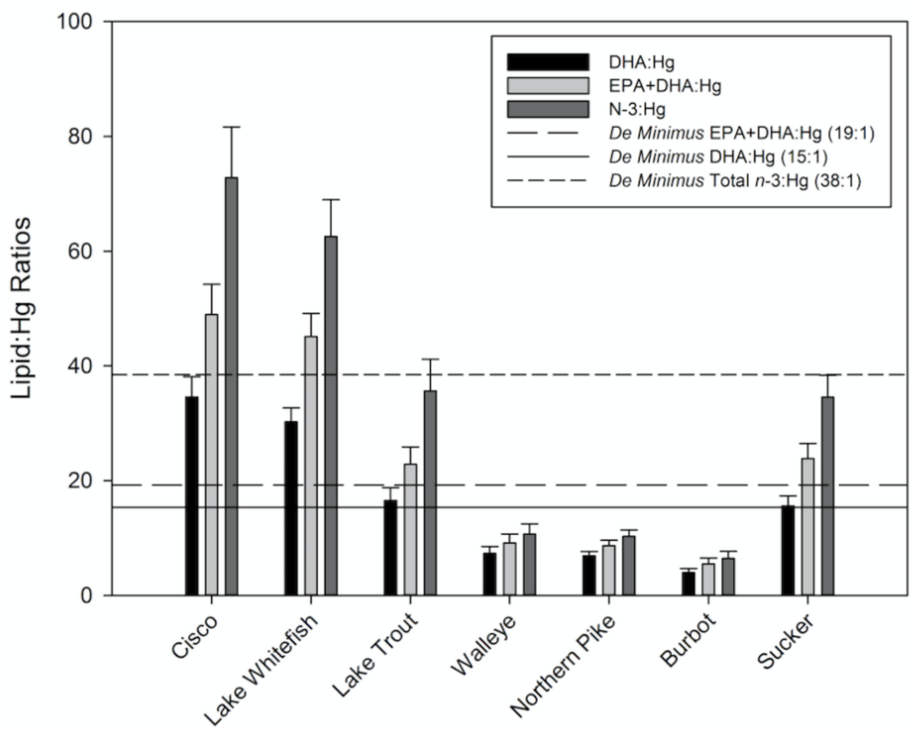
8 Biomarkers include DDE and DDT

9 Biomarkers include Parlar no. 26 and 50.

Table 2. Total mercury concentration in wild-harvested freshwater fish caught in the Dehcho Region, Northwest Territories, Canada (2013-2015).

Fish Species	n	Mercury (µg•g⁻¹)		EPA+DHA (mg•100 g⁻¹)	
		Range	Mean ± SD	Range	Mean ± SD
Burbot	14	0.09 - 0.55	0.24 ± 0.13	57.3 - 127.6	94.4 ± 18.6
Cisco	21	0.03 - 0.19	0.06 ± 0.04	144.6 - 380.0	235.3 ± 61.3
Lake Trout	51	0.08 - 0.64	0.22 ± 0.12	165.4 - 2331.7	424.3 ± 427.6
Lake Whitefish	68	0.02 - 0.32	0.09 ± 0.06	181.5 - 1047.7	288.0 ± 121.7
Northern Pike	85	0.04 - 3.12	0.47 ± 0.50	100.0 - 706.6	181.1 ± 88.3
Sucker	35	0.02 - 0.37	0.14 ± 0.08	148.3 - 589.4	262.1 ± 89.4
Walleye	59	0.04 - 1.43	0.46 ± 0.32	87.5 - 806.6	194.1 ± 117.3

Figure 1. Lipid:HgT ratios for fish species harvested in freshwater lakes of the Dehcho Region, Northwest Territories, Canada, as compared with *de minimus* ratios



Discussion and Conclusions

This 2016-2017 NCP research focused on the implementation of the biomonitoring project in five communities in the Dehcho and Sahtú Regions of the Northwest Territories, which will be continued in 2017-2018 in up to four additional communities. Results will provide a better picture of the contaminant issue in the Canadian subarctic. 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 Metis 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 at the highest risk of contaminant exposure. This screening tool, which has been labeled as a critical outcome by 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, 2019

Project Website

Facebook: BiomonitoringNT
Twitter: @NTBiomonitoring

Acknowledgments

We would like to thank all leaders, participants and local coordinators in the Dehcho and Sahtú Region for making this work possible. We are grateful for assistance from the following organizations: the Government of Northwest Territories Department of Health and Social Services, the Dehcho Aboriginal Aquatic Resources and Ocean Management (AAROM), the Sahtú Renewable Resources Board, the Sahtú Secretariat and the University of Waterloo. Funding was provided by the Northern Contaminants Program (which is jointly supported by Aboriginal Affairs and Northern Development Canada and Health Canada).

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Community Based Monitoring and Research

Surveillance communautaire et recherche

Variable fish mercury concentrations in the Dehcho: Effects of catchment control and invertebrate community composition

Concentrations de mercure variables dans les poissons de la région du Dehcho : effets du contrôle des bassins versants et composition de la communauté d'invertébrés

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Abstract

Fish, benthic invertebrate, zooplankton, sediment, and water samples were collected from Sanguez Lake and Willow Lake in the Dehcho region, NT in August 2016. Water and sediment samples were also opportunistically collected at Big Island and/or Ekali lakes. Laboratory analyses are ongoing, and sample collections will continue at Big Island and Ekali lakes in 2017. Preliminary analyses reveal that fish mercury concentrations are higher in Sanguez Lake than in Willow Lake. Catchment characteristics differ substantially between the two geographic regions of interest in this study (Mackenzie lowlands and Horn Plateau). Higher methylmercury in sediment than water in the Horn Plateau lakes suggests in-lake control on mercury availability

Résumé

Des échantillons de poissons, d'invertébrés benthiques, de zooplancton, de sédiments et d'eau ont été prélevés dans les lacs Sanguez et Willow dans la région du Dehcho (T.N.-O.) en août 2016. Des échantillons d'eau et de sédiments ont également été recueillis de façon opportuniste dans les lacs Big Island et Ekali. Les analyses en laboratoire sont en cours, et les prélèvements d'échantillons se poursuivront aux lacs Big Island et Ekali en 2017. Les analyses préliminaires montrent que les concentrations de mercure chez les poissons sont plus élevées dans le lac Sanguez que dans le lac Willow. Les caractéristiques des bassins versants diffèrent considérablement entre les deux régions géographiques ciblées

to biota, while the opposite in the lowland lakes suggests a strong catchment source of methylmercury. Current and future results in this combined catchment and food web study will be used to better understand spatial differences in fish mercury concentrations in the region, and to generate better predictions of fish mercury concentrations resulting from anthropogenic stressors, such as climate change and resource development.

par cette étude (basses terres du Mackenzie et plateau Horn). La présence de concentrations plus élevées de méthylmercure dans les sédiments que dans l'eau des lacs du plateau Horn donne à penser qu'il y a un contrôle dans les lacs de la disponibilité du mercure dans le biote, tandis que l'inverse dans les lacs des basses terres dénote une forte source de méthylmercure. Les résultats actuels et futurs de cette étude combinée sur les bassins versants et le réseau trophique serviront à mieux comprendre les différences spatiales de concentrations de mercure chez les poissons de la région et à produire de meilleures prévisions des concentrations de mercure découlant de facteurs de stress anthropiques chez les poissons, comme les changements climatiques et l'exploitation des ressources.

Key messages

- In lake sediments, the Horn Plateau Lake (Willow) had lower total mercury, but higher methylmercury than the Lowland lakes (Ekali and Sanguez).
- In contrast, mercury concentrations in water were lower in the Horn Plateau lakes (Big Island and Willow) than the two lowland lakes (Sanguez and Ekali), both for total mercury and methylmercury (dissolved and unfiltered).
- Northern Pike and Lake Whitefish had higher concentrations of total mercury in Sanguez Lake compared to Willow Lake.
- Catchment characteristics differ between the Mackenzie lowlands lakes (Sanguez and Ekali) and the Horne Plateau lakes (Big Island and Willow).

Messages clés

- Dans les sédiments lacustres, le lac du plateau Horn (Willow) contenait moins de mercure au total, mais plus de méthylmercure que les lacs des basses terres (Ekali et Sanguez).
- En revanche, les concentrations de mercure dans l'eau étaient plus faibles dans les lacs du plateau Horn (Big Island et Willow) que dans les deux lacs des basses terres (Sanguez et Ekali), tant pour le mercure total que pour le méthylmercure (dissous et non filtré).
- Les concentrations totales de mercure chez le grand brochet et le grand corégone étaient plus élevées dans le lac Sanguez que dans le lac Willow.
- Les caractéristiques des bassins versants diffèrent entre les lacs des basses terres du Mackenzie (Sanguez et Ekali) et les lacs du plateau Horn (Big Island Willow).

Objectives

Long Term:

- To develop a mechanistic understanding of the factors which explain variable mercury concentrations in food fishes in the DehCho region of the Northwest Territories.

Short Term:

- Sample and measure mercury and methylmercury in a range of food fish species in two pairs of lakes of cultural importance.
- Characterize the distribution of mercury and methylmercury in sediment, water, invertebrates, and plankton in the study lakes to determine if lower food web characteristics are linked to variability in food fish mercury.
- Characterize dissolved organic carbon quality in lake waters to assess the relative importance of catchment contributions of carbon and mercury.
- Assess basic lake catchment characteristics (area, slope, percent forest, and wetland cover) using remote sensing data products to determine if catchment factors influence food fish mercury concentrations.

Introduction

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.

Results from research previously conducted between 2013 and 2015 on eight lakes (funded by Cumulative Impacts Monitoring Program (CIMP), Northern Contaminants Program (NCP), and Health Canada) indicate that a significant amount of the variation in fish mercury concentrations among lakes is **not explained by any of the variables that affect bioaccumulation and biomagnification of mercury**. The variables that affect bioaccumulation and biomaginification are mercury and methylmercury in surface waters, fish growth rates, fish trophic position, fish age, and fish size.

Without a complete understanding of the factors controlling food fish mercury concentrations, effective management plans cannot be developed, and the impacts of climate change on fish mercury concentrations cannot be reasonably predicted. In this study, we are conducting an intensive investigation on two pairs of traditional fishing lakes in two distinct geographic and geologic regions (Horn Plateau headwaters and Mackenzie Valley Lowlands (near Jean Marie River)) in the Dehcho region of the NT. Results will allow us answer the following monitoring- and management-relevant questions:

1. Between lakes with similar hydrology and geology, is variation in food fish mercury dominantly controlled by differences in invertebrate and planktonic community composition, and consequently are there different methylmercury concentrations at the base of the food chain?
2. Between lakes with different hydrology, geology, and catchment characteristics, are differences in food fish mercury dominantly controlled by lake and catchment physico-chemical characteristics (e.g., catchment size, percent area of wetlands in catchment, quantity and quality of dissolved organic carbon)?

Activities in 2016-2017

Field Activities

A joint University (Waterloo and Western University) and resource monitor (Deh Gah Gotie First Nation and Jean Marie River First Nation) crew performed field sampling in August and September 2016. Fish, invertebrates, zooplankton, and sediment were sampled in Sanguez Lake and Willow Lake. Bathymetric mapping was completed on Sanguez Lake and Ekali Lake, and bathymetric transects were completed on Willow Lake. Water samples were collected from Willow, Sanguez, Ekali, and Big Island lakes.

Laboratory Activities

Benthic invertebrate samples from Sanguez and Willow lakes were analyzed for community composition and are currently undergoing analysis to determine concentrations of methylmercury (Western University, Biotron Laboratory) and stable isotope ratios (University of Waterloo). Fish were analyzed for total mercury concentration (Western University, Biotron Laboratory), and stable isotope ratios (University of Waterloo). Preliminary bathymetric maps were produced for Ekali and Sanguez Lakes. Catchments of all four lakes were delineated, and catchment and lake areas were determined. Both filtered and unfiltered water samples were analyzed (ultra-trace) for concentrations of total and methylmercury at Western University (Biotron Laboratory). Sediment samples were analyzed for loss-on-ignition, and concentrations of total and methylmercury (Western University, Biotron Laboratory).

Capacity Building

The project leaders and project team worked closely with fish harvesters and community members from Deh Gah Gotie First Nation during the fly-in sampling camp on Willow Lake, NT on the Horn Plateau (August 2016) and worked closely with fish harvesters and community members from Jean Marie River and Fort Providence First Nations during sampling at Sanguez Lake near Jean Marie River. The project leaders and project team collaboratively developed research plans for Tathlina and Kakisa lakes with Melaine Simba from Ka'a'gee Tue First Nation.

Communications

Interim results on this project, along with results of the previously-funded portion of the project, were presented at the regional Aboriginal Aquatic Research and Oceans Management (AAROM) meeting in Hay River on March 6, 2017. In addition, oral presentations about both previous and ongoing research were made by Swanson and Low in the communities of Kakisa, Fort Providence, and Jean Marie River from November 28-30th, 2016.

Posters have been prepared and are currently under review by the Government of Northwest Territories Health and Social Services (some information from the posters includes data from previously-funded CIMP project 00154).

Traditional Knowledge Integration

This project was developed in response to community concerns about levels of mercury in subsistence food fishes. Related collaborative projects (Brian Laird) have involved food recall interviews, and quantification of traditional food harvest and consumption. Results of this research and local knowledge about harvest pressure have resulted in a (pending) population estimate and pilot fish-down of large Northern Pike in Sanguez Lake, NT. A related project on human biomonitoring in Dehcho communities involves interviews with knowledge holders.

Results

Water Column Structure

At the time of sampling (late August), water temperature at Willow Lake was 14°C from surface to 20 m, and waters were well-oxygenated (no stratification observed). At the time of sampling (early September), the water column of Sanguez Lake was stratified, and waters were poorly oxygenated below 7 m.

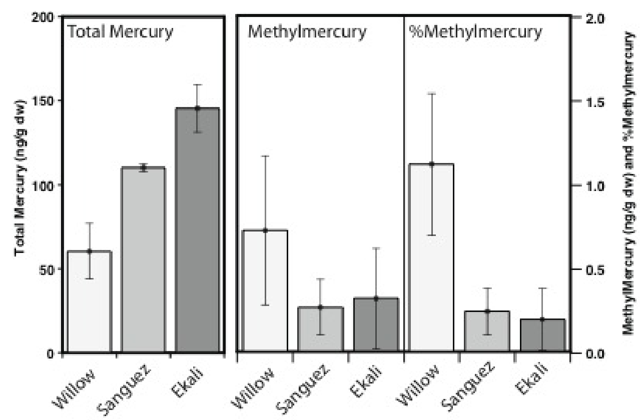
Invertebrate Community Composition

Invertebrate community composition differed between the Horn Plateau Lake (Willow) and the lowland lake (Sanguez). In the profundal zone, the benthic invertebrate community was more diverse and denser in Willow Lake than in Sanguez Lake. Chironomids were the dominant invertebrate in the profundal zones of both lakes (78% and 43% of individuals in Sanguez and Willow lakes, respectively). In the littoral zone, Sanguez Lake had a more diverse but less dense benthic invertebrate assemblage than Willow Lake.

Lake Sediment Total Mercury and Methylmercury (Figure 1)

Analysis of lake sediment mercury concentrations showed differences between the Horn Plateau Lake (Willow), and the two lowland lakes (Ekali, Sanguez). Total Mercury in sediment was similar, and significantly higher in Ekali and Sanguez lakes, than in Willow Lake (~2x). However, the concentration of methylmercury was approximately 3 times higher in Willow Lake than in either Sanguez or Ekali lakes, and % methylmercury of total mercury was 5 times higher in Willow Lake than in either Sanguez or Ekali lakes.

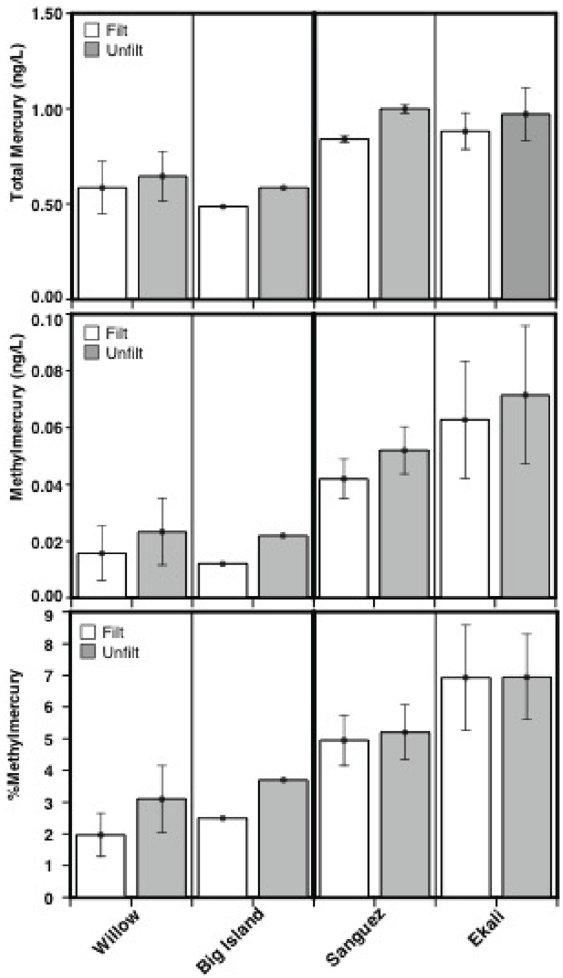
Figure 1. Mean Total Mercury concentrations (left), Methylmercury concentrations (middle) and %Methylmercury (right) in sediments from Willow, Sanguez, and Ekali Lakes. All data are expressed in dry weight concentration (ng•g^{-1}). Error bars indicate standard error.



Lake Water Total Mercury and Methylmercury (Figure 2)

Unfiltered Total Mercury in water was similar for the two lowland lakes (Sanguez and Ekali; Mean = 0.99 ng•L^{-1}), while total mercury in water from the two Horn Plateau lakes (Big Island and Willow) was lower (Mean = 0.62 ng•L^{-1}) (Figure 2). Methylmercury in lake water was lowest in the two Horn Plateau Lakes (Big Island and Willow), while the lowland lakes (Sanguez and Ekali) were significantly higher (Figure 2). The % Total Mercury and %Methylmercury in the dissolved form was similar for all lakes (85-90%). The %Methylmercury was very different between the two geographic regions. Willow and Big Island lakes had the lowest %Methylmercury in water (~2.0% as filtered, and ~3% as unfiltered), whereas Sanguez and Ekali Lakes had %Methylmercury levels of 5 and 7% respectively, with no difference between filtered and unfiltered fractions.

Figure 2. Mean filtered and unfiltered total mercury concentrations (top), methylmercury concentrations (middle), and %methylmercury (bottom) for Willow, Sanguez, Ekali, and Big Island Lakes. Bars indicate standard error.



Mercury Concentrations in Fish (FIGURES 3-7)

Food fishes captured in Sanguez Lake included Lake Whitefish (n=10), Northern Pike (n=27), and Walleye (n=9) (Figure 3). Food fishes captured in Willow Lake included Lake Whitefish (n=44), Northern Pike (n=24), and Lake Trout (n=3) (Figure 4).

Mean wet mercury concentrations (not size-adjusted) for Lake Whitefish were 0.082 ppm for Willow Lake (fork length range 85-506 mm) and 0.141 ppm (fork length range 385-560 mm) for Sanguez Lake. All Lake Whitefish captured had mercury concentrations below the commercial sale guideline.

Mean wet mercury concentrations (not size-adjusted) for Northern Pike were 0.352 ppm (fork length range 165-888) for Willow Lake and 0.453 (fork length range 240-1004 mm) for Sanguez Lake. In Sanguez Lake, Northern Pike exceeded the commercial sale guideline for mercury at a fork length of approximately 535 mm (Figure 5). In Willow Lake, Northern Pike exceeded the commercial sale guideline for mercury at a fork length of approximately 660 mm (Figure 6).

In Sanguez Lake, Walleye exceeded the commercial guideline for mercury at a fork length of approximately 475 mm (Figure 7). Mean wet mercury concentration for Walleye in Sanguez lake was 0.29 (fork length range 102-610 mm).

Mean wet mercury concentration for Lake Trout in Willow Lake was 0.532 (fork length range 615-740 mm).

Figure 3. Boxplot of fish mercury concentrations (ppm wet weight) for fish captured from Sanguez Lake. The dotted blue line represents the commercial sale guideline.

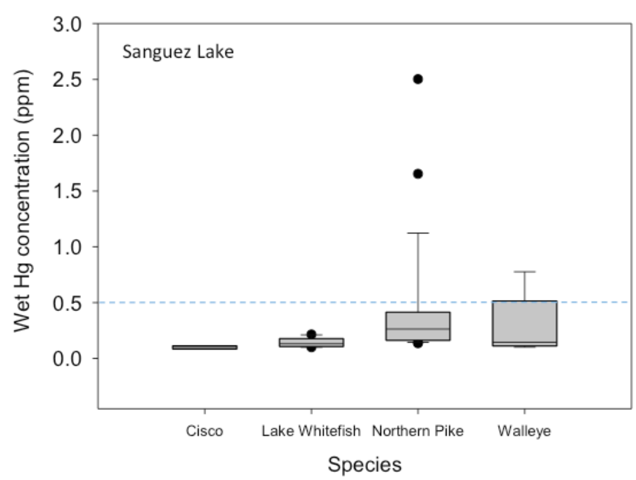


Figure 4. Boxplot of fish mercury concentrations (ppm wet weight) for fish captured from Willow Lake. The dotted blue line represents the commercial sale guideline.

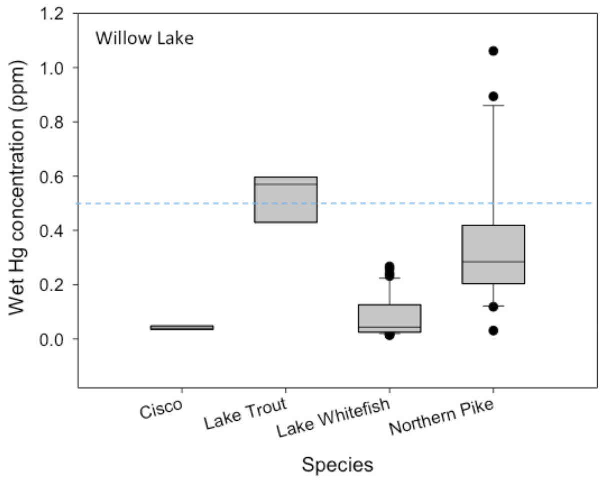


Figure 6. Regression between log fork length and log mercury concentration in Northern Pike from Willow Lake. Blue dotted lines indicate the commercial sale guideline (-0.3= log10(0.5)) and the approximate fork length at which Northern Pike are predicted to exceed this guideline.

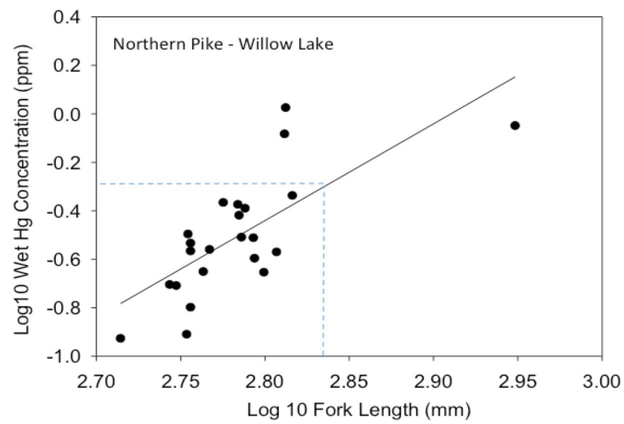


Figure 5. Regression between log fork length and log mercury concentration in Northern Pike from Sanguez Lake. Blue dotted lines indicate the commercial sale guideline (-0.3= log10(0.5)) and the approximate fork length at which Northern Pike are predicted to exceed this guideline.

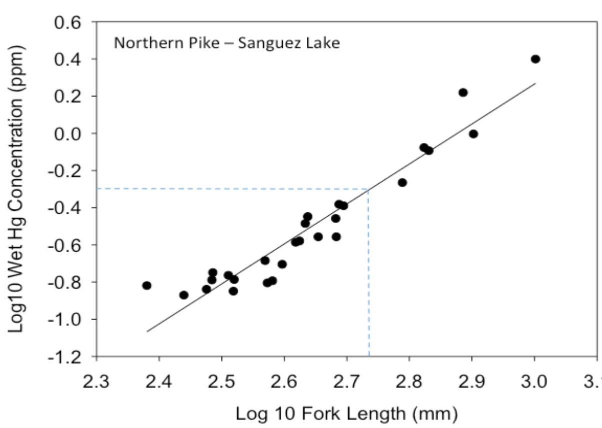
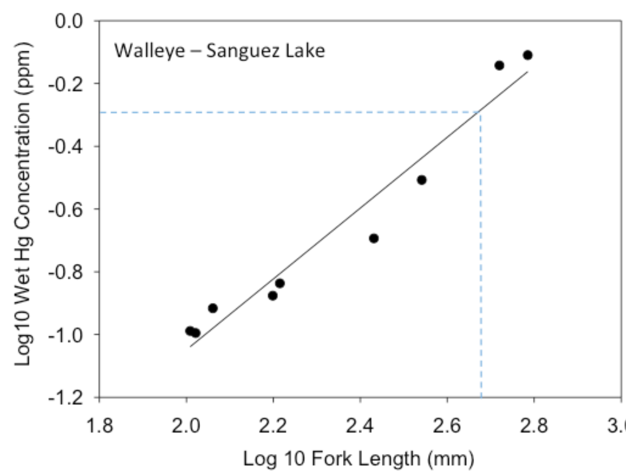


Figure 7. Regression between log fork length and log mercury concentration in Walleye from Sanguez Lake. Blue dotted lines indicate the commercial sale guideline (-0.3= log10(0.5)) and the approximate fork length at which Walleye are predicted to exceed this guideline.



Preliminary Catchment Delineation (Table 1)

Table 1. Preliminary estimates for Lake Area, Catchment Area, and Catchment/Lake Area in the study lakes; catchment characteristics will be related to mercury bioaccumulation in future analyses.

Lake	Lake Area (km^2)	Catchment Area (km^2)	Catchment Area/Lake Area	%Wetland
Willow	121.1	1188.51	9.81	0.62
Big Island	17.15	105.20	6.13	0
Ekali	1.77	62.37	35.2	11
Sanguez	1.49	33.37	22.3	13

Discussion and Conclusions

This project is in Year 1 of 2, and continues on a previous three-year project aimed at investigating causes of lake variation in food fish mercury concentrations in the Dehcho region, NT. Preliminary analysis on two of the four study lakes reveals that species-specific fish mercury concentrations are higher in Sanguez Lake than in Willow Lake. Analyses also reveal that fork length is a better predictor of fish mercury concentrations in Sanguez Lake than in Willow Lake. Future analyses will include fish age, trophic position, and carbon source as covariates, and fish will be collected from Big Island Lake and Ekali Lake in 2017 and added to the analysis.

Analyses of mercury in sediment and water for the lakes sampled thus far reveal important differences between the Horn Plateau and the Mackenzie Valley lowland lakes that will contribute to a better understanding of the controls on mercury in fish in the Dehcho region of the NT. The higher methylmercury in sediment than water in the Horn Plateau lakes suggests in-lake control on mercury availability to biota, while the opposite in the lowland lakes suggests a strong catchment source of methylmercury. The catchment to lake area ratios, as well as metrics such as %wetland cover (both significantly higher for the lowland lakes than the Horn Plateau) support this interpretation, particularly since wetlands are known sites of mercury methylation.

The combined catchment-food web approach taken in this study will lead to the ability to better predict mercury levels in fish among lakes and among different geographic regions in the Dehcho region (and potentially beyond). Importantly, this work may also reveal which lakes in the Dehcho are going to be more responsive to changes in atmospheric mercury deposition (less catchment controlled) versus those with a considerable lag time (more catchment controlled). Sampling for this two-year phase will continue in 2017, with pending expansion to Mustard and McGill lakes in 2018.

Expected Project Completion Date

December 31, 2018.

Acknowledgments

Cumulative Impacts Monitoring Program, Northern Contaminants Program, NSERC Discovery Program, Dehcho AAROM Program, NSERC Northern Research Supplement Program, Western University, University of Waterloo.

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

Surveillance communautaire de l'omble chevalier au Nunatsiavut : accroître les capacités, renforcer les 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 due to the drastic reduction of the George River Caribou herd and subsequent ban on hunting of the herd imposed by the Newfoundland and Labrador Government in 2013. 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 and Climate Change 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 they returned inland from feeding in the ocean. The char were caught and processed by local community members, with support from staff at the Nain

Résumé

Le phoque annelé et l'omble chevalier anadrome continuent de constituer une part importante du régime alimentaire des Inuits du Labrador en raison de la réduction marquée du troupeau de caribous de la rivière George et de l'interdiction de chasser imposée par le gouvernement de Terre-Neuve-et-Labrador en 2013. 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 chevalier 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

Research Centre, Parks Canada and Nunatsiavut Conservation Officers. The data from this project are being used for a variety of purposes including providing the necessary information for dietary advice, understanding contaminant loads, and investigating how contaminant loads are changing as a result of regional changes being experienced due to climate change and increased industrial development.

deux ans à présent. Vingt poissons ont été capturés dans deux sites différents, soit Nain et Saglek Fjord, juste avant qu'ils ne retournent dans la partie continentale après une période d'alimentation dans l'océan. Les ombles chevaliers ont été capturés et traités par des membres de la collectivité locale, avec l'aide du personnel du Centre de recherches de Nain, Parcs Canada et des agents de conservation du Nunatsiavut. Les données recueillies dans le cadre de ce projet sont utilisées à différentes fins et fourniront, notamment, de l'information qui permettra de formuler des conseils en matière d'alimentation, de mesurer les concentrations de contaminants et de comprendre comment ils évoluent par suite des changements qui surviennent à l'échelle régionale à cause des changements climatiques et de l'intensification du développement industriel.

Key Messages

- This project is 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.
- This project is result of collaboration of harvesters, community members, youth, Conservation Officers, Parks Canada, Environment and Climate Change Canada and staff of the Nain Research Centre.
- 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.

Messages clés

- Ce projet est 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.
- Ce projet est le fruit d'une collaboration entre des chasseurs, 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.
- 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 d'un suivi et qu'elle soit propre à la consommation.

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 of the diet of Labrador Inuit. Torngat Fish Producers Cooperative operate a char processing plant seasonally in Nain, and in partnership with the Nunatsiavut Government, established a Social Fishing Enterprise. Since 2013, the Social Fishing Enterprise has distributed 55,000 pounds of arctic char to the five communities within Nunatsiavut through the community freezers established in each community.

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 to progress, 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 Community-based monitoring 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 2016-2017

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 ECCC'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 abnormalities 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, to the Co-Management Board of Torngat Mountains National Park 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.

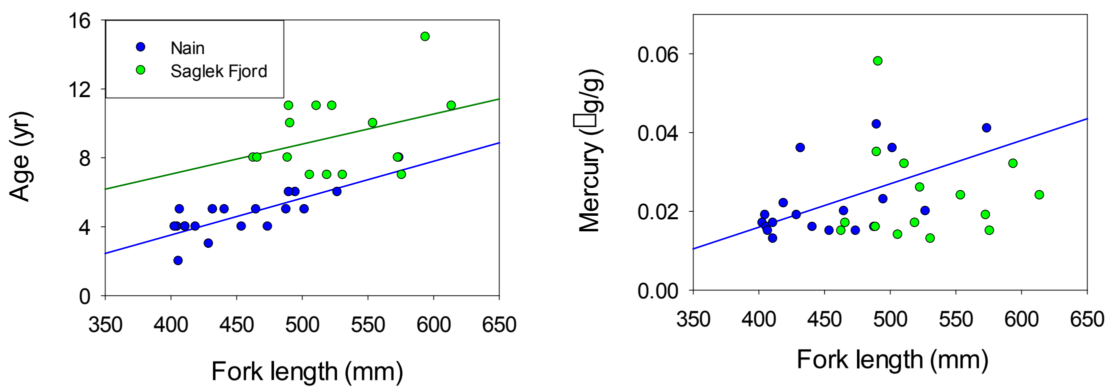
Results

Nain char were of similar lengths in 2014 and 2015 as in historic collections (the exception is 2006 when small char were provided). Nain char were younger than the 1998-2013 average and mercury concentrations were slightly lower. Saglek Fjord char were larger and older than Nain char. When char age versus length was examined, Saglek Fjord char were observed to be older at the same length as Nain char which suggests a slower growth rate (Figure 1). Analysis of 2015 specimens will elucidate whether this was a chance observation or is a consistent difference between locations. Mercury concentrations increased with length for Nain char but no relationship was evident for Saglek Fjord char (Figure 1). Overall char at Nain were very young and very low in mercury concentrations as previously reported (Muir et al. 1999, 2000; Evans et al. 2014).

Table 1. Life history parameters of sea-run char collected from Nain and Saglek Fjord in 29014 and 2015. Also shown is the historic record for Nain with the exclusion of 2006 caught fish which were atypically small (375 ± 21 mm).

	Nain			Saglek Fjord	
Parameter	1998-2013	2014	2015	2014	2015
Fork length (mm)	477 ± 73	454 ± 49	445 ± 45	527 ± 46	495 ± 98
Condition factor	1.28 ± 0.20	1.02 ± 0.18	1.15 ± 0.15	1.11 ± 0.12	1.30 ± 0.12
Age (yr)	7.06 ± 2.0	4.75 ± 1.3	-	9.3 ± 2.3	-
δ13C (‰)	-20.9 ± 3.5	-19.9 ± 0.5	-	-	-
δ15N(‰)	14.0 ± 0.9	14.1 ± 0.4	-	-	-
Hg (µg/g)	0.03 ± 0.01	0.02 ± 0.01	-	-	-

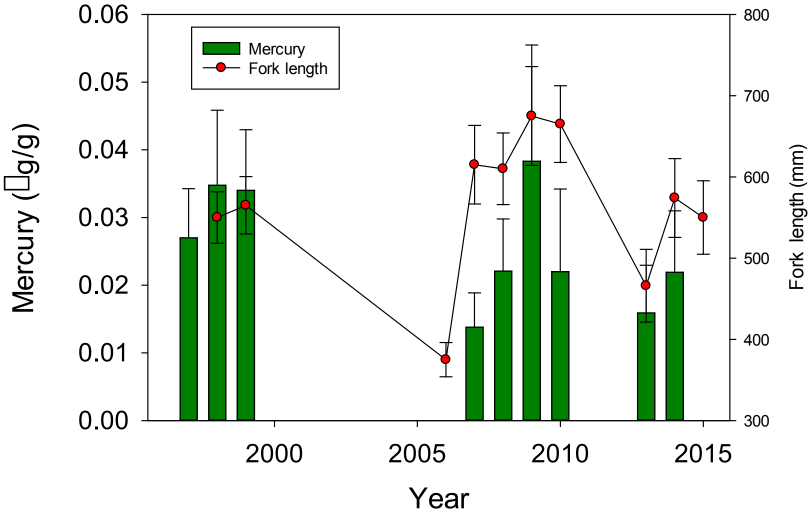
Figure 1. Fork length versus age and mercury concentration for Nain and Saglek Fjord char caught in 2015.



The long term record of mercury measurements in char at Nain shows a general pattern of higher average mercury concentrations in years when larger fish were caught. Nevertheless, there was a statistically significant decline in mercury concentrations over 1999-2014 (fish length was not determined in 1998) when fish length was included in the model (equation 1). Additional variance was explained by the inclusion of condition factor (Equation 2), i.e., higher mercury concentrations occurred in char with lower condition factors. Evans et al. (2014) previously reported declining mercury concentrations in Nain char.

Log Hg = 20.010 -0.011*Yr + 0. 001*Fl (n = 91; R^2 =0.53, F = 17.3, $p<0.001$) Equation 1
Log Hg = -15.469 + 0.001*Fl - 0.16*CF (n = 91, R^2 =0.67, F =23.7, $p<0.001$) Equation 2

Figure 2. Long-term variations in mercury concentrations and fork length in char harvested from Nain.



Discussion and Conclusions

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. The results are currently being used to communicate the low-levels of contaminants in char, and will be used in conjunction with Nunatsiavut's new Food Security Survey results to inform food programming.

Project Completion Date

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

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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 aquatic environments, and builds on work carried out since 2010. TAEMP, a successful community-driven program, meaningfully involves community members in conducting contaminants-related research, including the science-based collection of samples, and observations using both Tłı̨chǫ and scientific knowledge to address the question: «Are the fish safe to eat and the water safe to drink?»

In September 2016, a five-day on-the-land monitoring camp returned to Snare Lake, near the community of Wekweètì, with the camp situated further west than where the 2012 TAEMP camp was located. The 2016 participants returned to locations on Snare Lake where sediment and water sampling occurred in 2012 to allow for

Résumé

Le Programme de surveillance de l'écosystème aquatique des Tłı̨chǫ (PSEAT) continue d'offrir un moyen de réagir aux préoccupations que nourrit la collectivité à l'égard des changements dans les environnements aquatiques, et s'appuie sur les travaux réalisés depuis 2010. Couronné de succès, ce programme communautaire bénéficie d'une participation considérable des membres de la collectivité aux activités de recherche sur les contaminants, notamment au prélèvement scientifique des échantillons et aux observations, en utilisant les connaissances du peuple Tłı̨chǫ et scientifiques pour répondre à la question : est-ce que les poissons et l'eau sont propres à la consommation?

En septembre 2016, les participants d'un camp de surveillance terrestre de cinq jours sont retournés au lac Snare, près de la collectivité de Wekweètì, le camp étant situé plus à l'ouest

comparative sampling, as well as to three new locations as requested by community members. Elders and community members spoke about fish and aquatic ecosystem health, passed on their knowledge to participants, and ensured safe camp operations and transport to and from sampling locations. Science–based 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. Gravesites were visited by camp participants, though unfortunately youth had to depart camp a day earlier than expected, preventing participation in all planned cultural activities. A results workshop open to the public was held in Wekweètì in March 2017 to present the results to camp participants and to interested community members. Elders and support staff also visited Alexis Arrowmaker School to talk with students.

Fish tissue analysis indicated mercury levels were low in both Lake Trout (łiwezǫ̀ǫ̀) and Lake Whitefish (łih), with Lake Trout samples having the highest concentrations overall. None of the species' tissue samples showed levels of mercury that were considered abnormal for northern lakes. Comparison of 2016 results to 2012 results showed no appreciable change in mercury concentration. Water and sediment results supported the expectation that water and sediment quality is "good" (i.e. not abnormal) in Snare Lake.

que l'endroit où se trouvait le camp du PSEAT en 2012. Les participants de 2016 sont retournés à des endroits du lac Snare où des échantillons de sédiments et d'eau ont été prélevés en 2012 pour permettre un échantillonnage comparatif, ainsi qu'à trois nouveaux endroits à la demande des membres de la collectivité. Les aînés 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 des opérations dans le camp et du transport vers les lieux d'échantillonnage et à partir de ceux-ci. On a effectué une démonstration des méthodes scientifiques 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. Les participants au camp ont visité les lieux de sépulture mais, malheureusement, les jeunes ont dû quitter le camp un jour plus tôt que prévu, ce qui les a empêchés de participer à toutes les activités culturelles au programme. Un atelier ouvert au public s'est tenu à Wekweètì en mars 2017 afin de présenter les résultats aux participants du camp et aux membres de la collectivité intéressés. Les anciens et le personnel de soutien ont également visité l'école Alexis Arrowmaker pour discuter avec les élèves.

L'analyse des tissus de poisson a révélé que les concentrations de mercure étaient faibles chez le touladi (łiwezǫ̀ǫ̀) et le grand corégone (łih), les concentrations globales observées chez le touladi étant généralement les plus élevées. Aucun des échantillons de tissus des espèces ne présentait des concentrations de mercure considérées comme anormales pour des lacs du Nord. La comparaison des résultats de 2016 avec ceux de 2012 n'a révélé aucun changement notable dans la concentration de mercure. Les échantillons d'eau et de sédiments ont permis de valider l'hypothèse selon laquelle la qualité de l'eau et des sédiments du lac Snare est « bonne » (c.-à.-d. non anormale).

Key Messages

- The fish tissue analyses showed that mercury levels were low in both Lake Trout and Lake Whitefish, fish species typically consumed by residents of Wekweètì. No contaminant levels measured in any of the species' fish tissue samples were considered to be abnormal.
- Water and sediment quality results support the expectation that water quality and sediment quality are good in Snare Lake. No water or sediment contaminant levels were considered to be abnormal.
- Wekweètì community members were pleased with the implementation of the program, citing the importance of continued monitoring near their community.
- Community members were pleased that results of sampling were presented in Wekweètì, and that analyses indicated that fish, water, and sediment quality were good (i.e. not abnormal).
- Non-statistical comparison of the 2012 to 2016 results suggests that there are no major changes in the quality of fish, water, or sediment. A return to Wekweètì in 2020 will allow for further tracking of potential changes.

Messages clés

- Les analyses de tissus chez les poissons ont montré que les concentrations de mercure étaient faibles chez le touladi et le grand corégone, deux espèces de poissons généralement consommées par les résidents de Wekweètì. Aucune des concentrations de contaminants mesurées dans les tissus des espèces de poisson n'est considérée comme anormale.
- Les résultats de l'analyse de la qualité de l'eau et des sédiments confirment l'hypothèse selon laquelle cette qualité est bonne dans le lac Snare. Aucune des concentrations de contaminants mesurées dans l'eau et les sédiments n'est considérée comme anormale.
- Les membres de la collectivité de Wekweètì se sont dits satisfaits de la mise en œuvre du programme, soulignant l'importance d'une surveillance continue près de leur collectivité.
- Les membres de la collectivité étaient également satisfaits que les résultats aient été présentés à Wekweètì et du fait que les analyses révélaient que le poisson, l'eau et les sédiments étaient de bonne qualité (c.-à.-d. non anormale).
- La comparaison non statistique des résultats de 2012 à 2016 donne à penser qu'il n'y a pas eu de changements importants de la qualité du poisson, de l'eau et des sédiments. Un retour à Wekweètì en 2020 permettra d'assurer le suivi des changements potentiels.

Objectives

- Collaborate with TAEMP partners for the long-term implementation of this community-based monitoring program;
- Develop long-term aquatic ecosystem monitoring datasets in Wek'èezhìı, and contribute to concurrent monitoring initiatives in the Northwest Territories (NT);
- 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 TAEMP is to continue to build and maintain a successful monitoring program that meets the needs of the Tłı̨chǫ people in determining whether fish, water, and sediment quality are changing over time. The program rotates community-based fish, water and sediment sampling through each of the four Tłı̨chǫ communities so that every community has samples taken and analyzed once every four years. As a successful community-driven program, the TAEMP meaningfully involves community members in conducting contaminants-related research, through the collection of samples and observations using both Tłı̨chǫ and scientific knowledge. The purpose of the project is to address the question: "Are the fish safe to eat and 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 2016 fish camp near Wekweètì continued the comparative sampling phase of the TAEMP, further providing information to allow for comparative analysis of sampling results collected in each of the four communities. The comparative sampling will continue to provide a way to address community concerns related to changes in the environment.

Activities in 2016-2017

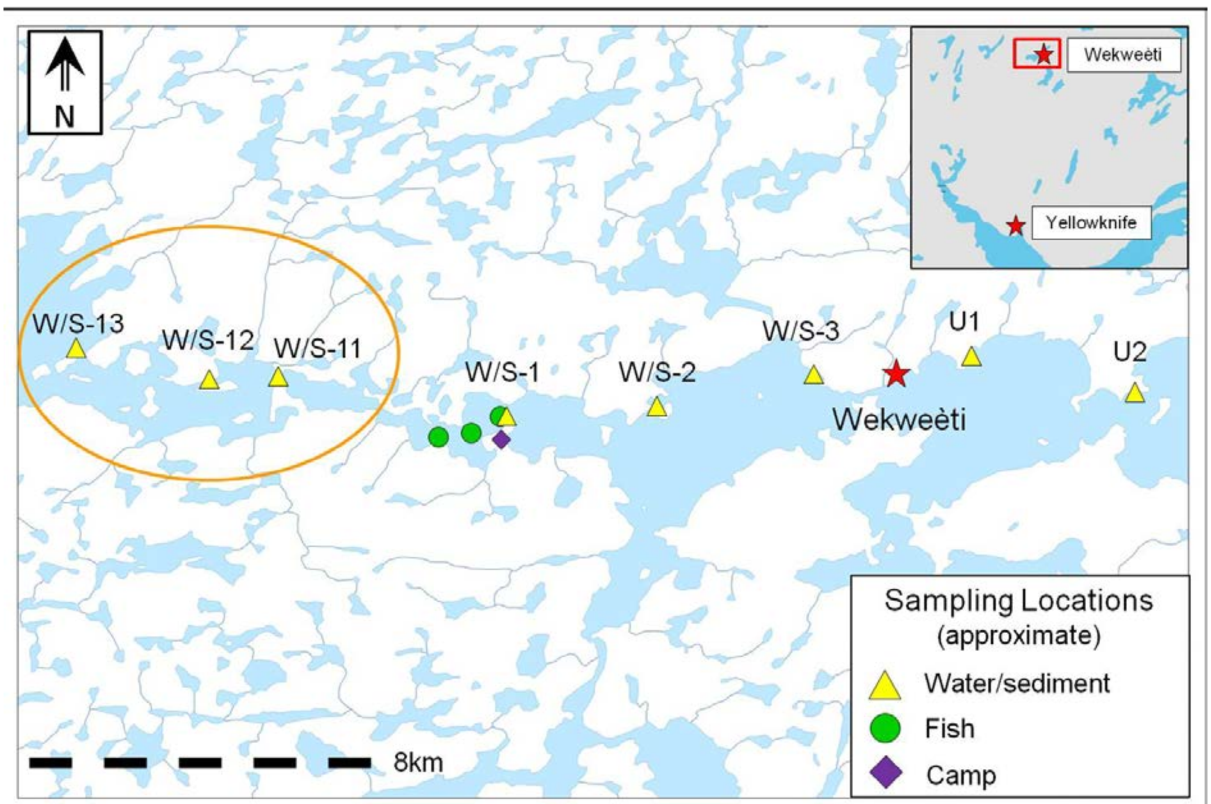
Introductory / Planning Workshops

Workshops were held in early August and early September of 2016 to discuss the TAEMP with community members in Wekweètì. The meetings provided a means to reacquaint community members with objectives/ approach of the TAEMP (i.e. the TAEMP had last occurred near Wekweètì in 2012), and begin planning for the on-the–land camp. During the planning meetings, there was compromise on the timing of the camp given the schedules of support staff, availability of community participants, and community concerns about the fall weather. Selection of participants was discussed and preliminary selection was determined based on relevant expertise/need/availability. Discussion of the preparation at camp (e.g. building of outhouses, meeting tent set-up) required prior to arrival of all the participants also occurred.

Monitoring Camp (i.e., "fish camp")

A five-day on-the-land camp was held September 2016 to conduct fish, water and sediment sampling. All sampling locations and the location of the on-the-land camp were chosen in consultation the community members. It was decided that the camp location should be further west of the location used in 2012 as it was close to a number of sampling locations and culturally important sites, provided better options for boat landing/launch, and provided ample space for tents. Water and sediment samples were collected from the 2012 sampling locations, as well as three new locations (Figure 1). Overall, the fall weather was spectacular, but weather/safety considerations affected water/sediment sampling nearest Wekweètì on the last day of camp. Fish tissue samples were collected from Lake Trout and Lake Whitefish, the fish species regularly consumed by Wekweètì residents, using the guidelines established by Environment and Climate Change Canada and the Golder Associates Ltd. technical protocols. All fish captured were identified according to species, then measured and weighed. Additional data collected included: gender, stage of maturity, gonad weight, and general descriptions of the stomach contents and the presence/location of parasites. Fish samples collected included otoliths for aging, and tissue samples for metals analysis. Water quality indicators included standard physical and chemical parameters, such as: temperature, pH, conductivity, clarity, turbidity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), alkalinity, dissolved Oxygen, major nutrients, ions, and trace metals. Samples were analyzed for standard physical and chemical properties as well as trace metals. Unfortunately, challenges with the lab did not allow for replicate samples, and QA/QC procedures were limited to field approaches.

Figure 1. Location of the on-the-land camp, and locations where samples of fish, water, and sediment were collected on Snare Lake during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near the community of Wekweètì, September 2016. Water/sediment locations circled furthest west were added in 2016, where others overlapped with locations sampled in 2012.



The five-day camp provided educational opportunities focused on ways of understanding aquatic ecosystems and assessing the health of the ecosystems. Participants worked collaboratively, and Tłı̨chǫ knowledge and science-based monitoring approaches were shared. For example, youth gained hands-on experience with sampling methods and elders provided demonstration of dry-fish preparation techniques. An unfortunate challenge arose when students participating at the camp left a day earlier than expected in order to attend a regional hand games tournament. The loss of the students prevented youth from participating in planned cultural activities, such as gravesite visits and stories provided by the elders, much to the disappointment of community members and support staff. The challenge was addressed, in part, by support staff and two elders visiting Alexis Arrowmaker School to present on fish and water-related subjects, both from the Tłı̨chǫ knowledge and science perspectives. Though unfortunately youth were not available to visit cultural sites, support staff took the opportunity on the last full day to accompany community members in their gravesite visits. This provided considerable benefit to support staff members that previously were unable to participate in cultural activities as a result of focusing on sampling and camp-related duties.

Results Meeting

A results meeting open to the public was held in Wekweètì in March 2017, and a presentation providing a comparison of the 2012 to 2016 results for fish, water, and sediment was given. Two elders who participated at the camp along with TAEMP support staff also visited Alexis Arrowmaker School and shared information with students about the fish camp. The elders shared their perspectives in Tłı̨chǫ (with translation), and a slide show was given on fish ecology by the fish biologist.

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, and fish tissue sampling for contaminant analysis. Demonstrations and activities built on knowledge transferred in 2012, and increased understanding of standard methods and the interpretation of results allows community members to become more knowledgeable 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. Importantly, youth were exposed to and provided basic training on, standardized methods for the collection of samples. 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. Though youth who participated in 2016 were not the same youth who were present in 2012, the possibility that youth may continue with more specific training is strengthened by the availability of training initiatives via the Tłı̨chǫ Government (TG). The direct involvement of community members hired in support of the camp benefits future initiatives in Wekweètì by having community members available and experienced in assisting the operations of a monitoring camp. The TAEMP also involves staff from organizations inherently linked to Tłı̨chǫ communities such as the Wek’èezhìı Land and Water Board (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 WRRB staff on a regular basis.

Communications

Communications with the community of Wekweètì occurred primarily through the face-to-face interactions at the planning workshop, at the on-the-land camp, at the results meeting and at the visit to the school. Collaboration with GNWT Health and Social Services (HSS), along with other TAEMP partners helped ensure appropriate messaging and communication at the results meeting. 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). This appropriate messaging also informed all WRRB communications regarding 2016 results (e.g. social media).

Social media provided communications channels to both community members and a wider audience. The WRRB website and Facebook page have featured a series of stories related to the TAEMP which build interest and provide updates. Previously, 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 Northwest Territories Environmental Research and Monitoring Results Workshop on February 1, 2017 in Behchokǫ̀. The overview of the TAEMP was well received by participants. WRRB staff also participated at the Marian Watershed results workshop March 22, 2017, and spoke about the possibility of posting TAEMP fish-related data online via the Mackenzie DataStream. Tłı̨chǫ community members were in favour of "getting their information out there".

The *Common Fish of the Tłı̨chǫ* Region, a basic field guide to fish found in Wek'èezhìı, is available on the WRRB website. The 2016 version includes information on fish habitat in addition to basic information on the characteristics of common fish species in Wek'èezhìı, including internal / external anatomy and names of fish provided in Tłı̨chǫ dialect. The guide has been distributed at workshops, camps, meetings, and to all four community schools.

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 in communities, and are available on the WRRB website. In addition, two educational videos have been developed that provide a summary of fish, water and sediment sampling. These videos are also available on the WRRB website. Printed DVDs have been sent to all four community schools, and have been provided to community members and youth as part of planning and results meetings.

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 2012, though three new locations were added in 2016 at the community members request), 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 – with a particular focus on safety. 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.

As requested by the NCP Management Committee, TAEMP staff asked community members about their perspectives regarding how to properly utilize TK within the project. Perspectives were shared at meetings, camp, and via answers to a series of interview questions. In general, elders were pleased with their involvement at camp and with the opportunities provided to pass on TK, for example through a gravesite visit, dryfish preparation, net repair, and teachings related to proper behaviours while at camp and on-the-land, and the history of the struggles people underwent to survive. However, elders were disappointed with youth leaving a day early (i.e. youth left for a handgames tournament, and camp participants were not informed of the departure until the day before), which had a noticeable impact on the transfer and integration of TK at the 2016 camp. Camp participants had agreed to concentrate on TK-related activities on the last day (additional gravesite visits, time for storytelling, further demonstrations and additional teaching on how to survive and show proper forms of respect) and all camp participants recognized the lost opportunity. Youth also responded to interview questions, and indicated that they had fun learning at fish camp, though they also understood that the loss of a day of activities prevented them from gaining additional knowledge from their elders. As a direct result of the lost opportunity, Alexis Arrowmaker School was visited the day after the results meeting. Two elders present at camp shared their perspectives with the students present at school (from kindergarten to grade 10), and spoke to activities at camp, and passed on knowledge and experience related to fish, water, and appropriate behaviors on-the-land. The elders spoke in their own language, with translation being provided to the students by translators who have been involved with the TAEMP since its inception.

Results

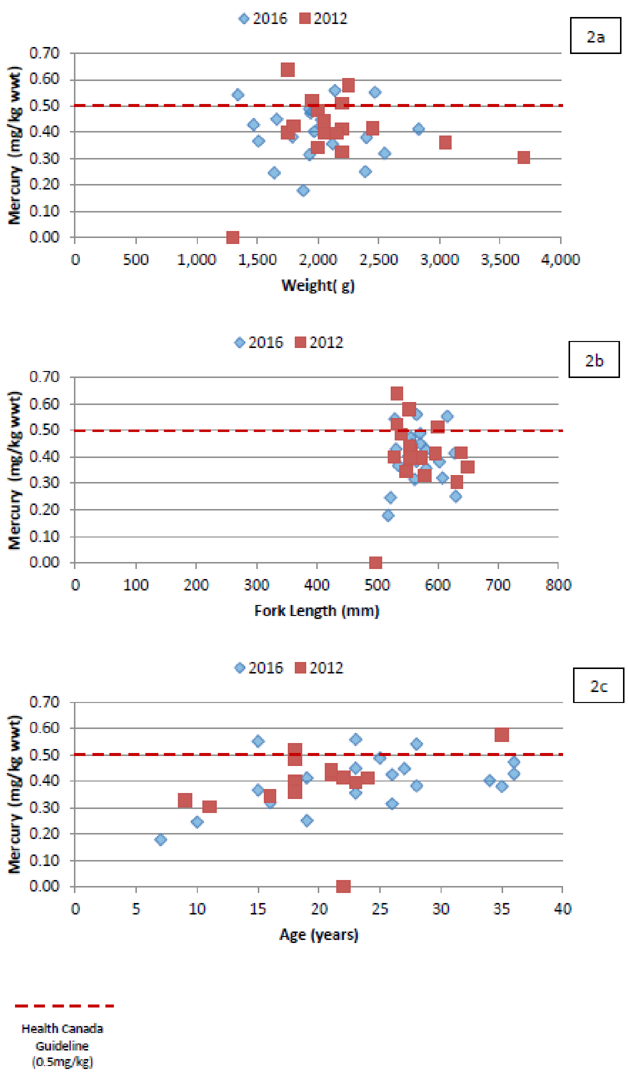
Fish

The two fish species which had tissues collected for contaminant analyses were Lake Trout and Lake Whitefish. These two species are regularly used for consumption in Wekweètì, and were the same species analyzed in 2012.

Lake Trout

The Lake Trout whose tissues were sampled for analyses in 2016 (n=20) were on average 569mm in fork length (95% CI= +/-14.95) with fork length measurements ranging from 518 to 630mm. They weighed on average 2001g (95% CI= +/-169.28) with weight measurements ranging from 1340 to 2830g. Via otolith aging, it was found that the Lake Trout were on average 24 years old (95% CI= +/-3.65) ranging from 7 to 36 years. Lab analyses indicated that mercury concentrations in tissues were on average 0.399mg•kg^{-1} wwt (wet weight; 95% CI= +/- 0.045, α=0.05) with data ranging from 0.18 to 0.56mg•kg^{-1} wwt. Three of the twenty fish sampled over the guideline for mercury of 0.5 mg•kg^{-1}, (wet weight, wwt; Health Canada 2016). Review of mercury concentrations in muscle tissue in relation to fork length and weight suggest positive relationships (Figures 2a, 2b), with the strongest positive relationship suggested with regards to age (Figure 2c).

Figure 2. Comparison of the relationships between mercury concentration in tissues (mg/kg; wet weight) and body weight (g) (2a), fork length (mm) (2b), and age (years; estimated via otolith aging) (2c) of Lake Trout collected during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Wekweètì, September 2016 and September 2012. Note: a Lake Trout collected in 2012 (718mm 7,500g, and 27 years of age) with a mercury concentration of 3.39 mg•kg^{-1} was not shown (see text in report for details). Health Canada Maximum Level for mercury concentration in commercial fish (0.5 mg•kg^{-1}) is provided.

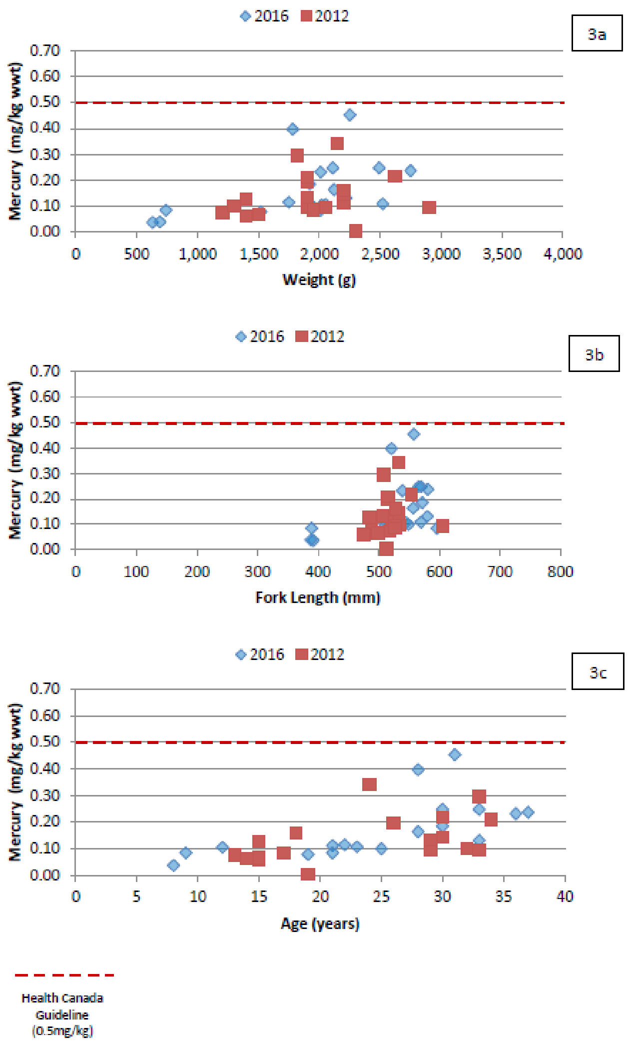


By comparison, Lake Trout sampled in 2012 (n=19) were on average 576mm in length (fork length; 95% CI= +/-14.95) ranging from 497 to 718mm. They weighed on average 2422g (total weight; 95% CI= +/-595.78) ranging from 1300 to 7500g, and were on average 20 years old (via otolith aging; 95% CI+/-2.96) ranging from 9 to 35 years (n=16; 3 of the 19 fish could not be aged due to damaged otoliths). Lab analyses indicated that mercury concentrations in tissues were on average 0.566mg•kg wwt (wet weight; 95% CI=+/-0.313) ranging from 0.001 to 3.39mg•kg wwt. However, the result of 3.39mg•kg^{-1} was from the longest (FL=718mm) and heaviest fish (7500g) sampled in 2012, and this individual is not included in the figures as it is approximately 7 times the guideline. By removing this individual (n=18), the average length becomes 568mm (95% CI= +/-19.04) ranging from 497 to 649mm, the average weight becomes 2161g (95% CI= +/-240.25), and the average mercury concentration becomes 0.41mg•kg^{-1} (95% CI= +/-0.06) ranging from 0.001 to 0.640. Comparison of 2012 results to 2016 results suggests no appreciable change in mercury concentration in tissue, as scatterplots and confidence intervals show a high degree of overlap between sampling years (Figures 2a, 2b and 2c). Of note, with the removal of the individual with the concentration of mercury at 3.39mg•kg^{-1} wwt, only 7 of the 38 Lake Trout sampled in 2016 and 2012 were above the guideline for mercury.

Lake Whitefish

Lake Whitefish sampled in 2016 (n=20) were on average 527mm in length (fork length; 95% CI+/-28.06) ranging from 388 to 596mm. They weighed on average 1870g (total weight; 95% CI+/-254.72) ranging from 630 to 2749g, and were on average 25 years old (via otolith aging; 95% CI+/-4.03) ranging from 8 to 37 years (n=18; 2 of the 20 fish could not be aged due to damaged otoliths). Lab analyses indicated that mercury concentrations in tissues were on average 0.163mg•kg^{-1} wwt (wet weight; 95% CI+/-0.049) ranging from 0.037 to 0.453mg•kg^{-1}wwt, and none of the fish sampled were over the guideline for mercury of 0.5 mg•kg^{-1}, (wet weight, wwt; Health Canada, 2016). Review of mercury concentrations in muscle tissue in relation to fork length, weight and age suggest positive relationships (Figures 3a, 3b and 3c).

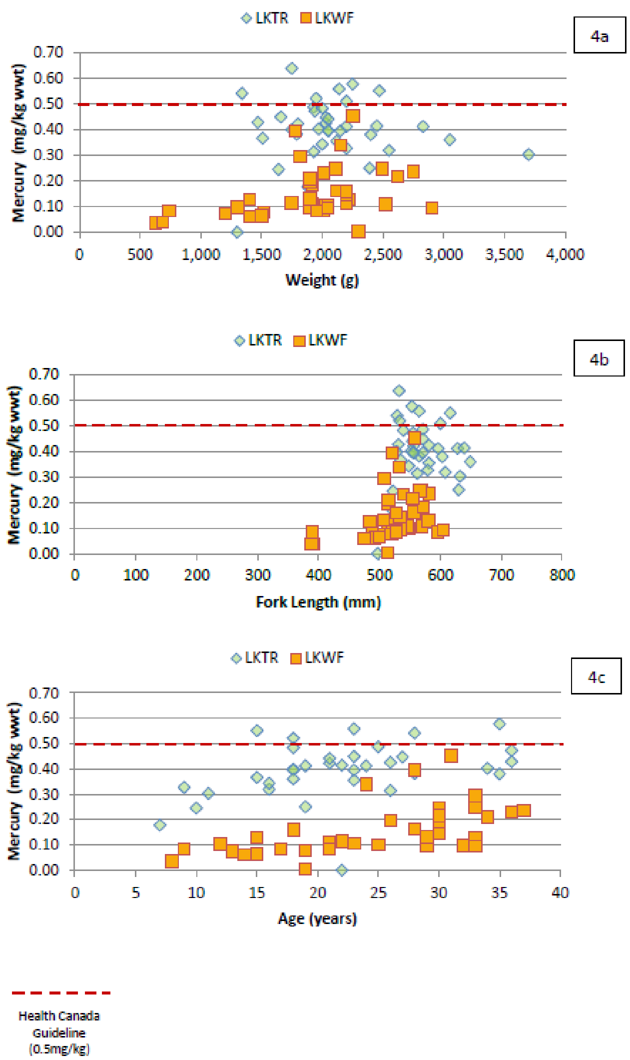
Figure 3. Comparison of the relationships between mercury concentration in tissues (mg/kg; wet weight) and body weight (g) (3a), fork length (mm) (3b), and age (years; estimated via otolith aging) (3c) of Lake Whitefish collected during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Wekweètì, September 2016 and September 2012. Health Canada Maximum Level for mercury concentration in commercial fish (0.5 mg•kg-1) is provided.



By comparison, Lake Whitefish sampled in 2012 (n=20) were on average 519mm in length (fork length; 95% CI+/-12.34, α=0.05) ranging from 475 to 605mm. They weighed on average 1910g (total weight; 95% CI+/-195.90) ranging from 1203 to 2900g, and were on average 24 years old (via otolith aging; 95% CI+/-3.38) ranging from 13 to 34 years. Lab analyses indicated that mercury concentrations in tissues were on average 0.134mg•kg^{-1} wwt (wet weight; 95% CI+/-0.036) ranging from 0.004 to 0.341mg•g^{-1} wwt. All of the Lake Whitefish sampled fell below the guideline for mercury. Comparison of 2012 results to 2016 results suggests no appreciable change in mercury concentration in tissue, as scatterplots and confidence intervals show a high degree of overlap between years (Figures 3a, 3b and 3c).

Comparison of the cumulative data sets (2016 and 2012) for Lake Trout and Lake Whitefish show positive relationships between mercury concentration in tissue and weight, length, and age (Figures 4a, 4b and 4c). Lake Whitefish consistently show lower concentration in their tissues than Lake Trout, with the clearest differentiation visible with regards to age (Figure 4c).

Figure 4. Comparison of the relationships between mercury concentration in tissues (mg•kg-1; wet weight) and body weight (g) (4a), fork length (mm) (4b), and age (years; estimated via otolith aging) (4c) for Lake Trout and Lake Whitefish using cumulative data for each species collected during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Wekweètì, September 2016 and September 2012. Note: a Lake Trout collected in 2012 (718mm 7,500g and 27 years of age) with a mercury concentration of 3.39 mg•kg-1 was not shown. Health Canada Maximum Level for mercury concentration in commercial fish 0.5 mg•kg-1) provided.



Northern Pike caught (n=11) were on average 668mm in length (95% CI+/-22.39) ranging from 611 to 741mm. They weighed on average 1924 g (total weight; 95% CI+/-204.92,) ranging from 1550 to 2570g. Neither cleithria (fish bone running from pectoral fin to the skull) for aging or tissue samples for contaminant analyses were collected (no tissue analyses were conducted on NRPK in 2012).

No deformities/abnormalities were noted in any of the fish sampled; parasites (e.g. worms and cysts) were found in majority of individuals, though not at levels considered to be abnormal. Lake Trout stomach contents included Ninespine Stickleback, cisco, and Lake Whitefish. Lake Whitefish stomach contents included invertebrates and Ninespine Stickleback.

Water

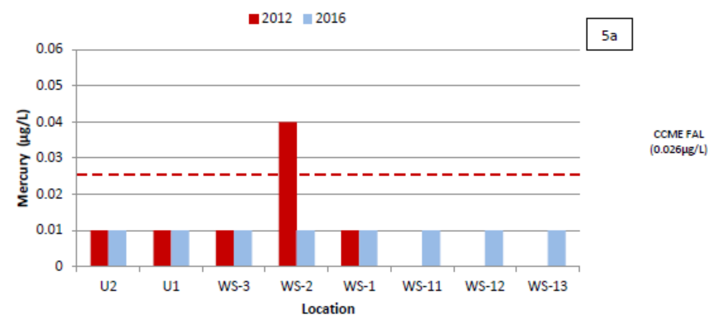
Analysis of water samples indicated no noticeable difference between 2016 and 2012 with regards to nutrient and physical parameters measured at all sample sites; all nutrients and physical parameters were found to be similar at all sites. For example, water samples in 2016 indicated pH ranged from 7.12 to 7.17, and results showed very little difference between sampling sites (n=8); results fell within Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL) (6.5-9.0) (CCME 2014). By comparison pH ranged from 7.04 to 7.17 in 2012 (n=5). Most metal concentrations in Snare Lake were very low (Figure 5) with many measuring below method detection limits (MDL). The 2016 water samples were all better than FAL guidelines, while 2012 water samples had a few metal concentrations greater than FAL guidelines (e.g. Mercury; Figure 5a). Overall, there was minimal difference between 2012 and 2016 (e.g. Arsenic; Figure 5b)

Sediment

The 2012 and 2016 sediment sample sites can be broken down into four different types: sand, silt, silt loam and sandy loam. The two sites upstream of Wekweètì are sandy (U1 and U2), the two sites downstream closest to the community are silty (W/S-3 and W/S-2), while (W/S-1), (W/S-12) and (W/S-13) are silty loam, and (W/S-11) is sandy loam (refer to Figure 1).

Sediment samples collected in 2016 from W/S-11 had an arsenic concentration of 11.58 µg•L^{-1}, which is above the CCME Sediment Quality Guidelines for the Protection of Aquatic Life interim Sediment quality guidelines (ISQG) of 5.9 µg•L^{-1} (CCME 2014); W/S-11 was not sampled in 2012. Location W/S-1 exceeded both ISQG and CCME probable effects levels (PEL; 17 µg•L^{-1}; CCME 2014) guidelines with a result of 48.87 µg•L^{-1} (Figure 6a). 2016 cadmium method detection limit was 1 µg•g^{-1} which is higher than the ISQG for cadmium of 0.6 µg•L-1. All of the 2016 sediment samples results for cadmium showed a "less than" detection result, but because "less than" values were treated as results equal to the detection limit, the results may represent a false exceedance. The 2012 sediment analysis method detection limit was 0.4 µg• L^{-1}, and none of the sediment samples collected in 2012 were above guidelines. Chromium concentrations slightly exceed the ISQG of 37.3 µg•L^{-1} at all sites downstream of Wekweètì in 2012 and 2016 (refer to Figure 1), with the exception of W/S-2 in 2012 and W/S-11 in 2016 (Figure 6b); concentrations ranged from 37.3 to 46 µg•L^{-1}. Copper concentrations exceeded ISQG of 35.7 µg•L^{-1} in 2012 at all sampling locations with results ranging from 37.5 µg•L^{-1} to 81.65 µg•L-1, and in 2016 all sediment samples were within guidelines ranging from 7 µg•L to 23 µg•L^{-1} (Figure 6c). This could be indicative of contamination occurring during sample preparation in the field such as the equipment that was being used for sampling, or of contamination occurring during sample preparation in the lab.

Figure 5. Comparison of the total concentrations of Mercury (5a) and Arsenic(5b) in surface water samples collected during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Wekweètì, September 2016 and September 2012. Sample locations are arranged from those more upstream located east of Wekweètì (U2), to downstream west of Wekweètì (W/S-13) (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 Mercury (0.026 µg•L^{-1}) and Arsenic (5 µg•L^{-1}).



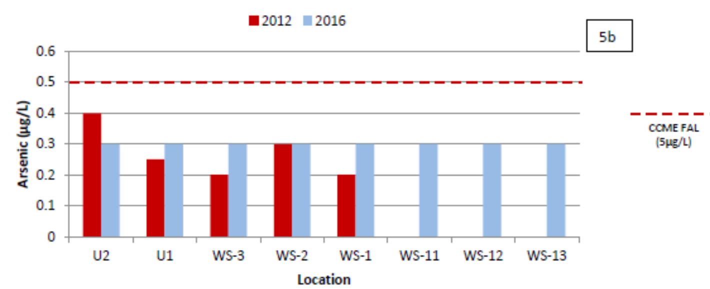
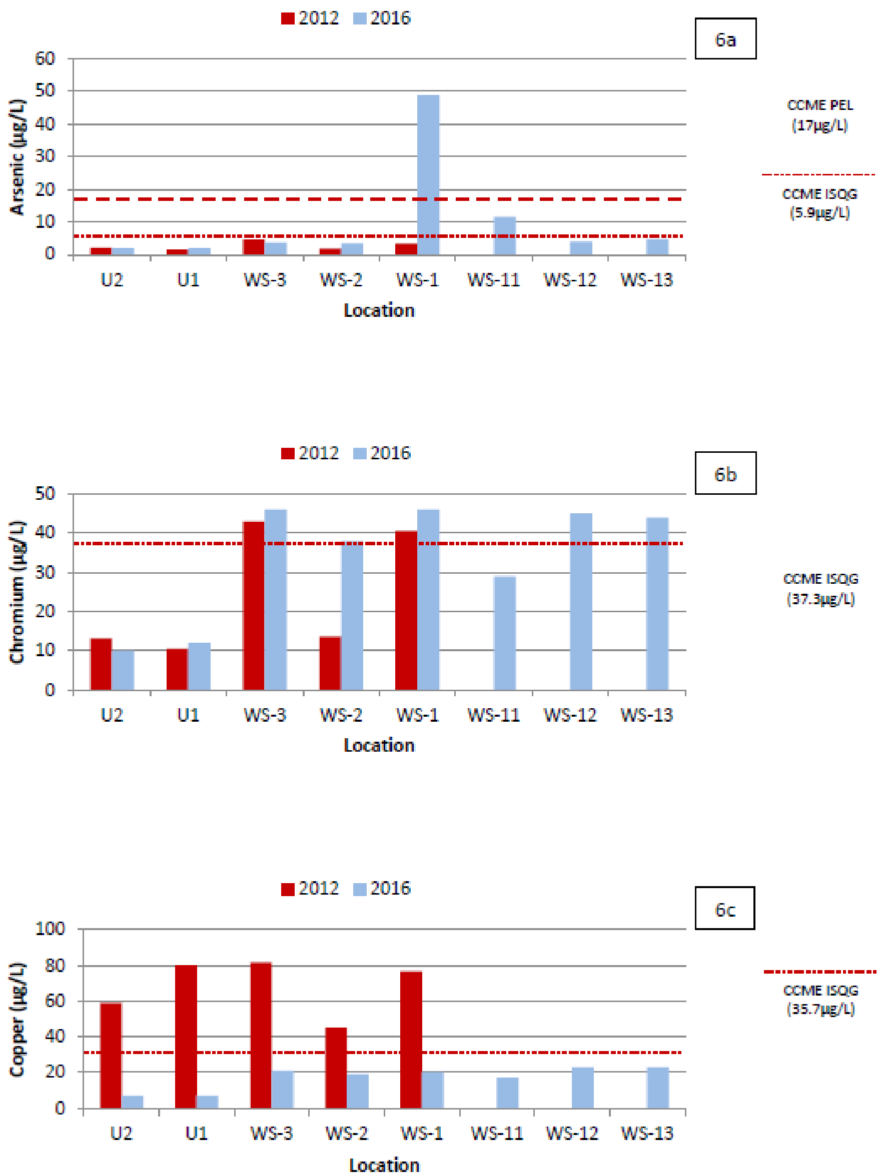
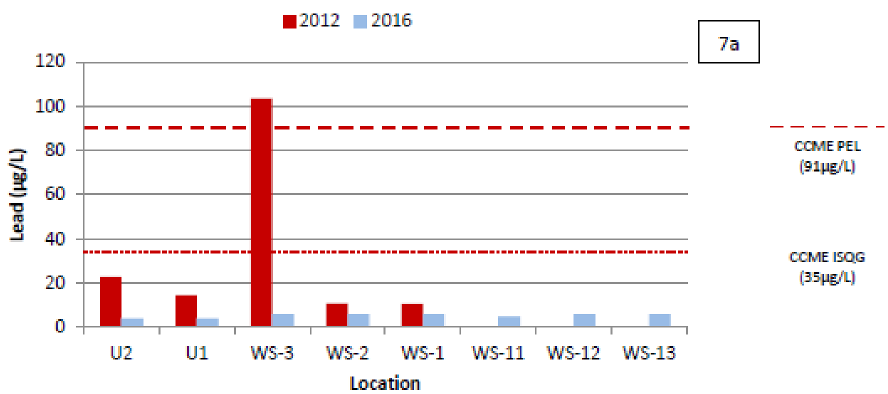


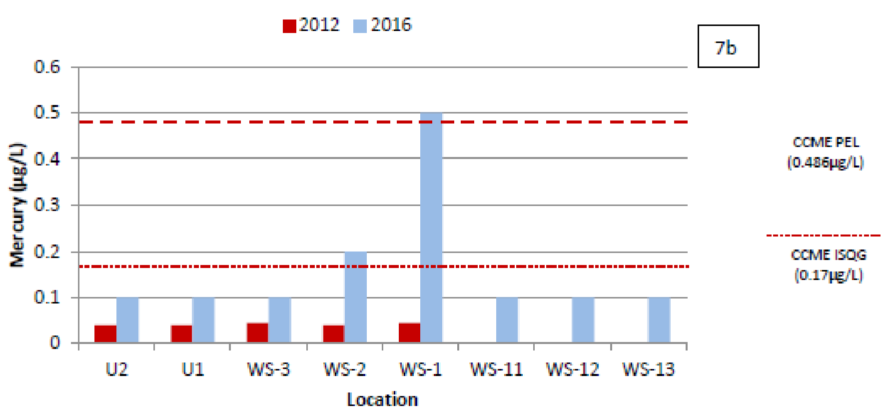
Figure 6. Comparison of the total concentrations of Arsenic (6a), Chromium (6b) and Copper (6c) for sediment samples collected during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Wekweètì, September 2016 and September 2012. Canadian Council of Ministers of the Environment (CCME) Sediment Quality Guidelines for the Protection of Aquatic Life Interim Sediment quality Guidelines (ISQG) were provided for Arsenic(5.9 µg•L^{-1}), Chromium (37.3 µg•L^{-1}) and Copper (35.7 µg•L^{-1}), and probable effects Levels (PEL) provided for Arsenic(17 µg•L^{-1}), but not for Chromium (90 µg•L^{-1}) or Copper (197 µg•L^{-1}). Sample locations are arranged from those more upstream located east of Wekweètì (U2), to downstream west of Wekweètì (W/S-13) (refer to Figure 1).



In 2012, the concentration of lead in sediment near the sewage lagoon exceeded the ISQG (35 μg•L^{-1}) and PEL guideline (91.3 μg•L^{-1}) with a concentration of 103.7μg•L^{-1}. This was not seen in 2016 where all lead concentrations from all sites ranged from 4 μg•L^{-1} to 6 μg•L^{-1} (Figure 7a). Mercury concentrations exceeded both ISQG and PEL guidelines at W/S-1, and exceeded the ISQG at WS-2 in 2016; all other 2016 locations were below guidelines (Figure 7b). By comparison, all locations sampled in 2012 were below both ISQG and PEL guidelines. However, it should be noted that minimum detection limits changed between 2012 (0.04 μg•L^{-1}) and 2016 (0.1 μg•L^{-1}), making direct comparison difficult.

Figure 7. Comparison of the total concentrations of Lead (7a), and Mercury (7b) for sediment samples collected during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Wekweètì, September 2016 and September 2012. Canadian Council of Ministers of the Environment (CCME) Sediment Quality Guidelines for the Protection of Aquatic Life Interim Sediment quality Guidelines for Lead (35 μg•L^{-1}), and Mercury (0.17 μg•L^{-1}), and probable effects Levels (PEL) for Lead (91 μg•L^{-1}), and Mercury (0.486 μg•L^{-1}) are provided. Sample locations are arranged from those more upstream located east of Wekweètì (U2), to downstream west of Wekweètì (W/S-13); refer to Figure 1.





Discussion and Conclusions

The main objective of the 2016 fish, water and sediment quality monitoring program was to repeat the sampling that was done in 2012 to see if any changes had occurred; this objective was achieved.

Fish tissue analysis indicated mercury levels were low in Lake Whitefish, with all tissue samples showing mercury concentrations below the Health Canada guideline. Lake Trout samples had higher concentrations overall, which was not unexpected given that they are predatory fish which commonly exhibit higher levels due to bioaccumulation and biomagnification. In contrast 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). On average the concentration of mercury in Lake Trout tissue was below the guideline and none of the tissue samples for either species showed levels of mercury that were considered abnormal for northern lakes. Further, when comparing fish tissue results from 2016 to 2012, no appreciable differences were noticed between years for either Lake Trout or Lake Whitefish. The one exception was the large old Lake Trout sampled in 2012, which had a mercury tissue concentration of 3.39 mg•kg-1; no results from 2016 were remotely close, which was viewed as positive by TAEMP staff and community members. 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 through 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 (please refer to the State of the Environment Report, 10.4 Status of Mercury in Fish; GNWT 2015). On a related data-use note, discussions with the Government of the Northwest Territories Environment and Natural Resources Water Resources Division and other water partners continue regarding the use of TAEMP data to help support the implementation of the Water Strategy and related initiatives such as the Mackenzie DataStream (officially launched in November 2016) (Mackenzie DataStream 2016). Recently, interest was expressed regarding the use of TAEMP fish data as a "pilot" to test the capacity of the DataStream. Use of TAEMP data in an open source format may help to address some of the data gaps in Wek'èezhìı, because, as mentioned in the World Wildlife Fund (WWF®) Freshwater Health Assessments for Watersheds in Canada (WWF® 2015, 2016), there is a general lack of information on the fish and water quality metrics used to help determine freshwater health in watersheds associated with Wek'èezhìı.

Analyses of water and sediment results supported the expectation that water and sediment quality is "good" (i.e. not abnormal) in Snare Lake. Overall, the sampling results indicate there was no appreciable change in the water quality and sediment quality between 2012 and 2016, with the understanding that some variation of parameters is to be expected with varying natural conditions and low frequency sampling. In short, Snare Lake water is typical of water originating on the Precambrian Shield and would be classified as an oligotrophic lake. The impacts of field conditions, field sampling methods, contamination, and lab methods were also noted as potential contributing factors to some of the results observed. For example, on the last day of sampling in 2016, sediment and water sampling was not possible by boat given wind conditions, and sample collection by wading out close to shore may have disturbed the sediment, affecting results (see location s U1, U2 and W/S-3 on Figure 1). This was similar to 2012, where samples were collected by wading into the water at three of the sites. This type of sampling can easily contaminate the water being collected due to capturing the suspended sediments which influence analysis and interpretation. Also, the composition of the sediment can reflect what is found in the water due to suspension and re-suspension of particles resulting from disturbance of the bottom; for example, chromium can be associated with silty sediment. The importance of repeat sampling, sufficient replicates per sample site, as well as incorporation of additional sampling methods (e.g. sediment cores vs. Ekman sediment samples) was acknowledged. Further, discussion regarding the use of sediment cores to supplement and further contextualize information gathered via grab samples has been discussed with Tłı̨chǫ Government and research staff involved with the Marian Lake Stewardship Program, along with elders from each of the four Tłı̨chǫ communities. Lastly, to determine if water bodies are being affected by industry and human activities, comparison of the study area water quality data to water quality data collected from a water body of roughly the same size in the same area of the study area would be appropriate. Though this was not done in 2012 or 2016, this practice would provide the best representation of natural, unaffected water quality data. The hope is, with collaboration with academic partners and GNWT Waters Division staff, that such comparisons will occur.

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 contains the Fortune Minerals NICO mine location and a proposed all-season road currently undergoing an Environmental Assessment (MVEIRB 2016) which may also have impacts (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 NT 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 also broadens the geographic coverage of sampling for mercury, as recommended in the Aboriginal and Northern Development Canada (now Crown-Indigenous Relations and Northern Affairs Canada) State of Knowledge Report (AANDC 2012).

With the conclusion of the TAEMP near Whatì in 2014, 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 comparative sampling phase (2015-2018) will continue to 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 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

Wekweètì portion of TAEMP completed April 30, 2017. The TAEMP aims to continue as a long-term community-based program in coming years.

Project website

Visit http://www.wrrb.ca/ for TAEMP updates (e.g. https://www.wrrb.ca/news/return-wekweeti-sharing-results-fish-camp-2016).

Acknowledgments

This project was guided by many elders from the community of Wekweètì, and we give thanks for their dedication to the project and their interest in sharing their knowledge and expertise. We thank all the participants and support staff who made the 2016 TAEMP on Snare Lake a success. The elders who participated: Joseph Judas, Madeline Judas, Charlie Football, Marie Adele Football, Jimmy Kodzin, and Noella Kodzin. The youth who participated from Alexis Arrowmaker School: Melvin Tom, Noah Kodzin, Simon Lamouelle, and Layden Judas. Wekweètì community member support at camp: William Quitte, Noel Quitte, Eric Laboline, Gilbert Boline, Beazoa Football, Betty Pea'a, and Virginia Lamouelle. Translators working at all meetings and at camp: Jonas Lafferty, and James Rabesca. Partner staff who participated at camp: Ryan Gregory (ENR), Cecilia Judas(TSCA), Roberta Judas (WLWB), Sean Richardson (TG), Boyan Tracz (WRRB), and Paul Vecsei (Golder Associates); and additional partner support provided by Susan Beaumont (WRRB), Nicole Dion (ENR), Jennifer Fresque-Baxter (GNWT), Linna O'Hara (HSS), Jody Pellissey (WRRB), and Sjoerd van der Wielen (TG). TG staff in Wekweètì: Adeline Football. TG staff in Behchokǫ̀: Michael Birlea, Jessica Hum. TCSA Staff at Alexis Arrowmaker school in Wekweètì: Kathy Dryneck, Hayley Frost, Rachel Ressor and Stephanie Staller. TCSA Staff: Linsey Hope (Behchokǫ̀) and Shannon Barnett-Aikman (Yellowknife).

Lab analyses were conducted by: ALS labs, BC (fish tissue), Taiga Environmental Lab, NT (water and sediment), and NorthSouth Consultants Inc., MB (otoliths/clethria). Golder Associates Ltd. provided QA/QC support.

Financial support was provided by: the Department of Fisheries and Oceans (DFO), the Northern Contaminants Program (NCP), Polar Knowledge Canada (POLAR), and the World Wildlife Fund/Loblaw Water Fund (WWF®/LWF). In-kind support was provided by ENR, TG, WLWB, and the WRRB.

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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 de la région désignée des Inuvialuits par la combinaison des connaissances scientifiques occidentales et des connaissances écologiques traditionnelles et locales

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Abstract

The Inuvialuit are leaders in beluga whale monitoring and research. This study was developed to ensure that local and traditional ecological knowledge (LEK and TEK) about beluga whales would be recorded to enhance existing programs in the Inuvialuit Settlement Region (ISR) in the Northwest Territories. The beluga monitoring programs in Darnley Bay and Kugmallit Bay provided ideal platforms for ensuring that the knowledge held by the Inuvialuit is recorded alongside or in addition to scientific measurements and samples. A comprehensive beluga-monitoring program in the ISR will provide key data on changes in the ecosystem through the use of biological, LEK, and TEK indicators.

The outcomes from this project were linked to the long-term beluga monitoring program. A suite of indicators for beluga health and habitat use were developed and are being piloted in the ISR beluga monitoring program. The indicators include observations made by the beluga harvest monitor about whale condition and observations made by harvesters while hunting and travelling. Beluga habitat use mapping indicated that opportunistic reporting of beluga observations inadequately reflected beluga presence/absence; therefore, beluga and fish monitors and field research camps could report marine observations during field-based activities to strengthen monitoring of the marine environment.

Community perspectives and knowledge on the characteristics of healthy belugas, general areas of beluga habitat use, and annual beluga sightings were synthesized and presented to the communities and renewable resource boards through oral presentations and the distribution of a brochure in March 2017. A community report is being prepared for distribution in Fall 2017. These materials were developed with the support from the Inuvialuit Game Council, Fisheries Joint Management Committee and Fisheries and Oceans Canada and in consultation with key knowledge holders in the three participating communities.

Résumé

Les Inuvialuit sont des chefs de file dans la surveillance et la recherche sur les bélugas. Cette étude vise à s'assurer que les connaissances écologiques locales (CEL) et les connaissances écologiques traditionnelles (CET) sur les bélugas soient consignées afin d'améliorer les programmes existants dans la région désignée des Inuvialuit (RDI), dans les Territoires du Nord-Ouest. Les programmes de surveillance des bélugas dans les baies Darnley et Kugmalit sont des plateformes idéales pour s'assurer que les connaissances des Inuivialuit soient consignées parallèlement ou en plus des mesures et des échantillons scientifiques. Un programme complet de surveillance des bélugas dans la région désignée des Inuvialuit fournira des données clés sur les changements dans l'écosystème grâce à l'utilisation d'indicateurs biologiques, des CEL et des CET.

Les résultats de ce projet étaient liés au programme de surveillance à long terme des bélugas. Une série d'indicateurs sur l'état de santé et l'utilisation de l'habitat des bélugas a été élaborée et fait l'objet d'un projet pilote dans le cadre du programme de surveillance des bélugas dans la RDI. Les indicateurs comprennent des observations faites par le surveillant de la chasse aux bélugas au sujet de l'état des baleines et des observations faites par des chasseurs pendant la chasse et les déplacements. La cartographie de l'utilisation de l'habitat des bélugas a montré que les rapports opportunistes sur les observations des bélugas ne reflétaient pas adéquatement la présence ou l'absence de bélugas; par conséquent, les surveillants de bélugas et de poissons et les camps de recherche sur le terrain pourraient signaler les observations marines pendant les activités sur le terrain afin de renforcer la surveillance du milieu marin.

Les points de vue et les connaissances des collectivités sur les caractéristiques des bélugas sains, ainsi que de l'utilisation des aires générales d'habitat du béluga et les observations annuelles de bélugas, ont été résumés et présentés aux collectivités et aux offices des ressources renouvelables par des exposés oraux

et la distribution d'une brochure en mars 2017. Un rapport communautaire sera distribué à l'automne 2017. Ce matériel a été élaboré avec l'aide du Conseil inuvialuit de gestion du gibier et du Comité mixte de gestion de la pêche et de Pêches et Océans Canada, et en concertation avec les principaux détenteurs du savoir dans les trois collectivités participantes.

Key Messages

- A suite of indicators for beluga health and habitat use were developed in the Inuvialuit Settlement Region and piloted in the regional beluga monitoring program.
- Local indicators of beluga health include observations about the condition of harvested beluga such as blubber thickness, protrusion of backbone, discolouration of internal organs/muktuk/skin, texture of muscle and blubber/uqsuq, and smell of the abdominal cavity.
- Beluga habitat use mapping indicated that opportunistic reporting of beluga observations inadequately reflected beluga presence/absence; therefore, beluga harvest and fish monitors, and science field teams are encouraged to report marine observations made during monitoring activities.
- A mobile app was successfully developed using Survey123 for ArcGIS to record beluga sightings and marine observations in the ISR.
- Local observations and Traditional Ecological Knowledge about beluga whales were synthesized and distributed in Spring 2017 through public meetings in Inuvik, Paulatuk, and Tuktoyaktuk, and presentations to the Hunters and Trappers Committees as well as the Inuvialuit Game Council.

Messages clés

- Une série d'indicateurs sur la santé des bélugas et l'utilisation de son habitat a été élaborée dans la RDI et mise à l'essai dans le cadre du programme régional de surveillance des bélugas.
- Les indicateurs locaux de la santé des bélugas comprennent des observations sur l'état des bélugas chassés, comme l'épaisseur de la graisse, la saillie de la colonne vertébrale, la décoloration des organes internes, du muktuk et de la peau, la texture des muscles et de la graisse/uqsuq, et l'odeur de la cavité abdominale.
- La cartographie de l'utilisation de l'habitat du béluga indique que les rapports opportunistes sur les observations de bélugas ne reflètent pas adéquatement la présence ou l'absence de bélugas; par conséquent, les surveillants de la chasse aux bélugas et des poissons, ainsi que les équipes scientifiques sur le terrain sont invités à signaler les observations marines faites pendant les activités de surveillance.
- Une application mobile a été créée à l'aide de Survey123 pour ArcGIS afin de consigner les observations de bélugas et les observations marines dans la RDI.
- Les observations locales et les CET sur les bélugas ont été résumées et distribuées au printemps 2017 dans le cadre de réunions publiques à Inuvik, Paulatuk et Tuktoyaktuk, et de présentations aux comités de chasseurs et de trappeurs et au Conseil Inuvialuit de gestion du gibier.

Objectives

Short term objectives

- Develop online tools to record and visualize scientific and community knowledge;
- Support the inclusion of Traditional and Local Ecological Knowledge (TEK/LEK) in beluga monitoring in the ISR; and,
- Communicate findings from the three year "Local Ecological Indicators" project to communities in the ISR.

Long term objectives

- Develop a comprehensive beluga monitoring program that includes biological and local indicators, and TEK of beluga health and habitat use; and,
- Promote capacity building in the ISR to support the inclusion of the Inuvialuit in all components of beluga research.

Introduction

Monitoring of the Eastern Beaufort Sea beluga population has taken place in the Mackenzie Delta since the 1970s. The beluga-monitoring program established in the Inuvialuit Settlement Region (ISR) was previously focused on traditional scientific indicators (e.g. general morphometrics, health indices, stable isotopes, fatty acids, diseases and contaminants). 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). This project was initiated in 2013 with the goal of recording local observations, and identifying local and traditional ecological knowledge indicators of beluga health and habitat use. The development and documentation of local ecological knowledge indicators complements the traditional scientific indicators currently monitored in beluga whales from the ISR.

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). 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).

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. Also, additional information about beluga habitat use may increase our analysis of temporal trends in harvested beluga in the ISR. In addition, the mobile App that we developed will support recording, managing and visualizing spatial data, which may increase the effectiveness of recording and presenting community held knowledge to multiple stakeholders, research partners and project participants.

Activities in 2016-2017

The 2016 summer field program included tracking beluga sightings and marine observations in Kugmallit and Darnley Bays, by field research teams, beluga whale monitors, youth, and Traditional Ecological Knowledge holders. Two community-based research assistants were employed in Tuktoyaktuk (Verna Pokiak) and Paulatuk (Dennis Illasiak) to support community-based monitoring of belugas and the marine environment. The Paulatuk-based work was led by Diane Ruben from the Paulatuk Hunters and Trappers Committee, with 42 beluga sightings recorded by community members, whale monitors and Dennis Illasiak. At Hendrickson Island, beluga sightings and marine observations were recorded by Lionel Kikoak and John Noksana Sr. with support from Sonja Ostertag and Shannon MacPhee. Observations for eight harvested beluga whales were recorded by Andrew Gordon Jr. at East Whitefish Station. In total, 77 separate beluga sightings were recorded by community members and these observations were inputted into a mobile application by the community-based research assistants and youth, and subsequently uploaded onto ArcGIS online. In Tuktoyaktuk, one new TEK projects that complemented this project was carried out by Devin Waugh in summer 2016.

In January 2017, Sonja Ostertag participated in the Beaufort Sea Beluga Assessment to provide input on the risk of contaminants for beluga in the Eastern Beaufort Sea and local perspectives on beluga health based on the outcome from surveys conducted with harvesters from 2013 to 2016.

In March 2017, Sonja Ostertag led a community tour to return results to Inuvik, Paulatuk, and Tuktoyaktuk, through public meetings, Hunters and Trappers Committee meetings, and a presentation to the Inuvialuit Game Council (IGC). Results were presented in a brochure that was prepared specifically for this tour and a final report is being drafted for release in the fall. Devin Waugh returned the results from his study to the community of Tuktoyaktuk during this tour. Elizabeth Worden joined the tour prior to travelling to Aklavik to initiate a community-based project to study changes in beluga harvesting activities.

Communications

Presentations: Ostertag and Worden presented their research proposal/results to the Fisheries Joint Management Committee in January 2017. Worden and Waugh presented their research results/proposals at the ArcticNet Scientific Meeting in December 2016.

Community Tour in the ISR: Public meetings were held in Inuvik, Paulatuk (14 participants), Tuktoyaktuk (29 participants) and Inuvik (10 participants) in March 2017. Representatives from HTCs attended the public meetings. Ostertag, Waugh and Worden presented to the Inuvialuit Game Council meeting in Aklavik in March 2017. Worden travelled to Aklavik in March 2017 to develop her research proposal with the Aklavik HTC and familiarize herself with the community before carrying out her research in summer 2017.

Communication materials: A brochure was prepared and distributed in March 2017 in the communities (500 copies printed). The brochure summarized observations from 2013 to 2016 on the location of beluga sightings, harvesters' observations of beluga health, and local indicators of beluga health. Sonja Ostertag provided a project summary in the 2016 Beluga Bulletin distributed in the ISR in spring 2016. A final community report is in preparation for distribution in fall 2017.

Capacity building

In 2016 and 2017, Dennis Illasiak in Paulatuk and Verna Pokiak in Tuktoyaktuk gained experience in the following: coordinating research logistics, using a mobile application, data entry, sampling beluga whales (only D. Illasiak), recording marine observations, assisting with meeting logistics (only D. Illasiak), supporting communication between researchers and community, and assisting with TEK research (only V. Pokiak). Lionel Kikoak and John Noksana Sr. gained more experience in sampling beluga whales for the health assessment. Kikoak received sufficient training in sampling and monitoring and as a result was selected as the Hendrickson Island beluga whale monitor-in-training for 2017.

Shannon MacPhee increased her capacity for community-based fieldwork at Hendrickson Island with a diverse team and the blending of local observations and scientific sampling. Noksana Sr continues to share his knowledge and experience with the field team at Hendrickson Island to support good communication between the research team and harvesters, and ensure that the field camp operates safely and in a culturally appropriate manner.

Two Masters students were mentored by Ostertag, Loseto and Pearce in the development and execution of community-based LEK/TEK research in the ISR.

Indigenous Knowledge Integration

Andrew Gordon Jr. led the sampling efforts at East Whitefish and gained experience in recording local observations about harvested beluga through the administration of the local indicators checklist. Brandon Green, Jody Illasiak Sr. and Dennis Illasiak monitored harvested beluga whales and recorded their marine observations using daily observation forms, which supported the linkage of LEK/TEK with beluga harvest monitoring.

A local indicator checklist was developed and piloted at East Whitefish in 2016 and was launched in the entire ISR beluga monitoring program in 2017. This checklist accompanies the standard beluga form that is used to record morphometrics (measurements) and sample collection. The checklist reflects the local indicators of beluga health based on the observations made by the Inuvialuit to characterize beluga health (Appendix 1). This checklist ensures that the harvest monitors record both scientific measurements and LEK/TEK indicators of beluga health, which greatly enhances the beluga monitoring program and allows for the integration of Inuvialuit knowledge and observations in beluga monitoring in the ISR.

Marine observations including beluga whale sightings were recorded from 2013 to 2016, and represent the documentation of local observations and TEK for beluga/marine monitoring. The development of a mobile application supports ongoing documentation of observations made by the Inuvialuit, for marine monitoring and management.

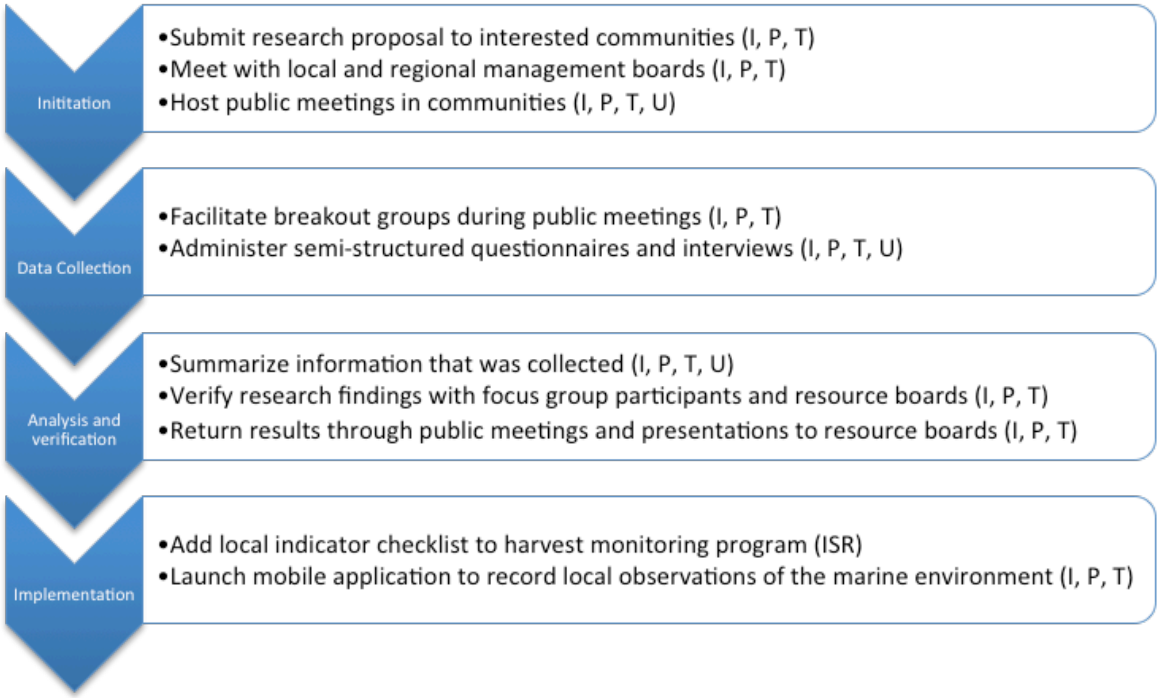
The results from this project provided valuable insight into factors that could affect blubber thickness for harvested whales, based on TEK and local observations. These results will be used to develop statistical models to analyse potential trends in the condition of harvested beluga whales, which represents the linkage of TEK and scientific analysis.

The Beaufort Sea Beluga Assessment began in Inuvik, NT, in January 2017. This meeting supported the integration of Inuvialuit knowledge and perspectives in a Fisheries and Oceans Canada (DFO) assessment of Beaufort Sea belugas. Inuvialuit TEK holders were present at the meeting and the observations made by harvesters about beluga health were presented in the research document and accompanying presentation.

Results

In this study, we successfully developed tools to record local observations about beluga whales based on local and traditional ecological knowledge, through frequent and ongoing participation from the communities of Inuvik, Paulatuk, Tuktoyaktuk, and Ulukhaktok (Figure 1).

Figure 1. The steps taken to develop local indicators of beluga health and habitat use in the Inuvialuit Settlement Region from 2013 to 2017. The initial of the participating communities are provided (Inuvialuit Settlement Region, ISR; Inuvik, I; Paulatuk, P; Tuktoyaktuk, T; Ulukhaktok, U).



Initiation

This project was proposed to the Fisheries Joint Management Committee in January 2013 and the HTCs in Inuvik, Paulatuk and Tukotyaktuk in spring 2013. More than 80 community members shared their local observations and Traditional Ecological Knowledge about beluga whales during community meetings held in Inuvik, Paulatuk and Tuktoyaktuk in June and November 2013. The information provided during these meetings was used to develop questionnaires to characterize beluga health. The community of Ulukhaktok was engaged in this project in 2014 during an unusually high harvest of beluga whales by the community.

Data Collection

In 2013, breakout groups were used in the three communities to identify the observations made about beluga whales during harvest and travel. Community mapping was used to record areas of beluga habitat use and travel routes. Questionnaires were completed by harvesters at Hendrickson Island, East Whitefish, and Paulatuk. In addition, nine harvesters in Ulukhaktok and two harvesters in Sachs Harbour responded to a subset of the questions in 2014. To strengthen the understanding of how the Inuvialuit characterize healthy and less healthy or sick whales, brief interviews were also conducted in Paulatuk (n = 11), Inuvik (n = 14), and Tuktoyaktuk (n = 20).

Traditional Ecological Knowledge was also collected in the communities of Tuktoyaktuk (June-August 2016), Paulatuk (Dec.- Feb. 2016), and Ulukhaktok (June- Aug 2016) using semi-structured interviews (n=17, 30, 32 respectively), along with participant observation (including time at the beluga hunting camp on Hendricks Island, hunting trips, participation in community life and events), and review of secondary sources.

Analysis and verification

Focus group meetings were held in summer 2015 with 8 to 10 youth, Elders, harvesters (men and women), and beluga monitors that were selected by the HTCs. These meetings were used to review the findings and fill in knowledge gaps. Ostertag and M. Wolki met with focus group participants individually or in pairs in February 2016 to verify findings. Indicators of beluga health were identified in the questionnaires and interviews and focus groups in each community were used to review and verify the indicators of beluga health (Table 1). The characterization of healthy and less healthy whales was based on interviews, harvester questionnaires and community meetings held between 2013 and 2016, and verified in 2016 and 2017. The communication materials developed were presented to the community members, HTCs and the IGC. The brochure that was developed with Simon Farla was very well received, as it communicated the research findings effectively and in an aesthetically pleasing format.

The maps generated from this component of the study were used to support the discussion with key knowledge holders about potential changes observed in beluga habitat use in the ISR, and methods for recording observations made about beluga whales. To adequately monitor beluga habitat use, the importance of harvesters' boat-based observations was highlighted in community meetings, as harvesters travel into the open water where more beluga activity occurs and is visible compared to shore-based observations. Comments made during the community presentations included the need to include more background information about beluga sightings, especially the locations of observers, to ensure that inter-annual differences in location/effort are not overlooked when presenting beluga sightings on maps. It was noted that shore-based observers view fewer whales than boat-based observers; therefore inter-annual differences in the number of sightings and the group composition of belugas could be due to differences in observation effort and location. Therefore, there is a need to present what viewing platform was used (boat or land) when showing aggregated data; concerns were highlighted about presenting sightings data if they suggest declines in calves or general abundance of whales, especially if these are an artefact of different viewing effort/platforms.

Table 1. Characterization of beluga health based on Inuvialuit knowledge and observations shared through harvester questionnaires, interviews, community meetings and focus groups in Inuvik, Paulatuk, Tuktoyaktuk and Ulukhaktok from 2013 to 2017. Muktuk refers to the outer skin and blubber layer and uqsuq refers to the blubber layer.

CHARACTERIZATION	HEALTHY	LESS HEALTHY
Body shape and condition	Spine not sticking out Wide back Love handles A lot of rolls on its body 3 to 4 inches blubber ¾ inch muktuk	If it's the right season and they are too skinny Very thin, barely any uqsuq
Behaviour	Coming up for air normally	If they are too tired
Signs of disease or infection	No unhealed wounds visible Lungs look good	A different smell when you open it up Abnormal lungs Heart has different marks on it Liver has white spots or is a different colour
Quality of meat and muktuk	Uqsuq and meat are firm	White part of the muktuk is soft and coming out of fresh whale

Implementation

A checklist (Appendix 1) was developed for beluga monitors to record their observations of harvested beluga whales based on Inuvialuit knowledge and perspectives on beluga health. This checklist built on the previous work conducted to ensure that LEK/TEK is collected alongside scientific measurements of harvested beluga whales. The response from participants during the public, HTC, and IGC meetings emphasized the need to separate the observations about beluga health by harvest camp rather than presenting the findings grouped together. The condition of harvested whales may differ by community, based on the harvesting strategy utilized. Each community has a unique harvesting strategy, which must therefore be taken into consideration when assessing the condition of harvested whales. Therefore, future communication materials and reports will separate beluga condition by year and camp, to provide clarification on the inter-camp differences in beluga condition, if and when they exist. In addition, data analysis of the condition of harvested whales using morphometrics (i.e. body measurements) will include the harvest camp as a variable that could explain variation in body condition.

Tools for recording community-based observations of beluga presence/absence, behavior, and group composition were developed, including a mobile application to support the documentation of marine observations. The communities recommended that harvesters participate more actively in recording beluga sightings, which could be achieved by having harvest monitors record harvesters' observations. Based on this feedback, the beluga monitors will record sightings made by harvesters as a component of the beluga harvest monitoring program. This would increase the number of sightings recorded and provide more consistent information about beluga calving numbers, which are an important element in understanding population health and dynamics. Although viewing platform was recorded for previous years, it was not included in the maps depicting beluga sightings. Based on the presentation of results in the communities, the effect of observer effort and location will be clearly identified in future communication materials.

Discussion and Conclusions

Initiation

This project was successfully initiated in 2013 in the communities of Inuvik, Paulatuk and Tuktoyaktuk. The HTCs, FJMC and IGC supported this project and public participation was excellent in the initial meetings. In 2014, following an unusually high beluga harvest in Ulukhaktok, two community meetings were held in Ulukhaktok to discuss the monitoring program, present results and discuss beluga preparation methods. One of the greatest challenges was running a pilot project and subsequent study in four communities concurrently. However, the collaboration with HTCs and the FJMC, and the employment of community research coordinators made this work possible. Including four diverse communities in this study allowed for a broader spectrum of perspectives, which strengthened this project. Engagement by HTC resource people was essential for all stages of this project and is strongly recommended for future community-based monitoring of renewable resources. In addition to HTC support, we suggest having teams that include a TEK advisor, harvester, youth, community technician/monitor and community-based research coordinator engaged in all aspects of the project.

Public meetings were poor formats for becoming familiar with communities, and were only successful if facilitated by researchers with prior community engagement. Therefore, we recommend that public meetings be used for project initiation and communication of results, but not for data collection; and, that facilitators be engaged if the researcher is unfamiliar with the community. If researchers are unfamiliar with the community, we recommend that he/she spends time in the community *prior* to commencing research, to learn about the people and place.

One of the strengths and challenges of this project was the linkage to the beluga science and monitoring program. This partnership created some confusion because Sonia Ostertag was associated with the science program and was therefore asked by the community and science teams to present the scientific results. Being the 'face' of the science program while initiating the local indicators project may have created confusion about what the local indicators project was focused on, and what Ostertag's role was in the program. Linking LEK/TEK projects to scientific research programs is important, but we recommend that the roles of the LEK/TEK coordinator are kept separate from the scientific team coordinator. Otherwise, the lack of clarity can undermine the success of the LEK/TEK project.

Data collection

Data collection in each community depended on the commitment of community-based research coordinators, field assistants, FJMC and DFO staff. Breakout groups during public meetings were useful for generating a broad understanding of local observations made about beluga whales during travel and harvesting activities. Public meetings were excellent routes for raising awareness about this project and returning results; however, this format for data collection was limited because of the unpredictability of turnout (number of participants and how they represented the community).

Semi-structured questionnaires were useful for characterizing the health of harvested animals; however, the good health of harvested animals limited the types of observations shared to those that characterized healthy beluga whales. The strength of the questionnaire was that beluga hunters usually participated at the site of beluga butchering; therefore, the carcass was available as a 'prop' or reminder of what the questionnaire was referring to. However, timing was a challenge with the questionnaires, either because the harvesters were concerned about the weather or simply tired after a long hunt, or the questionnaire felt out of place at the harvest site.

Interviews and focus groups were very important for delving deeper into the TEK about beluga whale health and habitat use. These methods provided the opportunity for TEK-holders (harvester and their families) to share observations from their whole lifetimes, which included rare occurrences of sick harvested whales.

Analysis and verification

Focus groups were an excellent mechanism for reviewing key findings and discussing data gaps; intensive one-on-one interviews with focus group participants provided an additional depth to the data collected. However, the public meetings provided an important opportunity for the final verification of results and community/board input on future direction and research needs. We recommend focus groups, individual interviews, and public meetings for the verification of results, prior to publication of LEK/TEK research.

Implementation

The final local indicator checklist for beluga health observations will be completed by the harvest monitor and the harvesters will only be asked two to five questions. This will reduce the effort required by the hunters to respond to questions and will hopefully increase the number of checklists completed. Adding a separate form for the local indicator checklist may cause confusion; therefore, beluga harvest monitors received training in how to complete the indicator checklist. Based on training in the ISR, we expect the checklist to be simple to complete by the whale monitors. To reduce confusion, we recommend that local indicators are recorded on the same form as the scientific measurements. A checklist provides a consistent mechanism to record local observations based on LEK/TEK. However, a checklist provides a limited mechanism to record LEK/TEK and future work is required to record LEK/TEK about beluga whales in the Beaufort Sea.

The mobile App provides a simpler format for recording local observations about the marine environment. This provides a mechanism for recording LEK/TEK; however, the mobile App or paper forms may not be the most suitable methods for recording LEK/TEK for all community members as it contrasts greatly from traditional forms of communicating local observations and TEK. Therefore, emphasizing the use of the App or daily observation forms by researchers and fish/whale monitors will strengthen the monitoring program by providing a consistent and comprehensive platform to record local observations and/or TEK. Using the App to upload observations in each community will strengthen the data collection and reduce errors by allowing follow-up with participants immediately if any confusion exists about the recorded information provided. Additional methods are required to record LEK/TEK about the marine environment for community members that are less comfortable with the observation forms/App.

Local observations and TEK about beluga habitat use reflect observations made during the everyday activities of community members in addition to specific beluga harvesting activities. In the Mackenzie Delta and Darnley Bay, the Inuvialuit residing in coastal communities or camping at coastal harvest camps observe beluga throughout the summer and fall (June to November) while travelling, fishing, spending time outside, and harvesting beluga. The observations made by Inuvialuit TEK holders in this area reflect a long history of observing beluga and inter-generational transmission of knowledge about beluga habitat use. Observations made by the Inuvialuit have the potential to expand the spatial and temporal scale of recorded beluga habitat use. In addition, TEK provides a historical context to present day beluga sightings and changes being observed in the ISR. Traditional Ecological Knowledge also supports the development of research questions and methods in response to environmental changes occurring in the ISR.

Conclusions

This study provided key information on how the Inuvialuit characterize beluga health and habitat use, and gives important details on processes and tools for developing and utilizing 'local indicators' for monitoring and research. Next steps include identifying how TEK can be documented in more depth and detail to support on-going input for monitoring the Eastern Beaufort Sea population of belugas, and continuing to improve the implementation of the collection and analysis of local indicators at a regional scale.

Expected Project Completion Date

March 31 2018

Acknowledgments

This project was supported by the Northern Contaminants Program, Fisheries and Oceans Canada, the Fisheries Joint Management Committee, Garfield Weston Foundation, Natural Sciences and Engineering Research Council, Aurora Research Institute and ArcticNet.

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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, and also about potential impacts of contaminants from long-range atmospheric transport and regional human activities. The Arctic Eider Society's Community-Driven Research Network (CDRN) has been established to measure and better understand large-scale cumulative environmental impacts in East Hudson Bay and James Bay. Building on CDRN collaborations and activities in five communities (Sanikiluaq, Kuujjuaraapik, Inukjuak, Umiujaq, Chisasibi), this NCP project is generating new information on contaminants (specifically metals) that

Résumé

Les collectivités de l'est de la baie d'Hudson sont préoccupées par rapport aux changements observés dans l'écosystème au cours des dernières décennies, particulièrement en ce qui concerne les conditions de la glace de mer et les conditions océanographiques, ainsi que les effets potentiels des contaminants engendrés par le transport atmosphérique à longue distance et les activités humaines dans la région. Le réseau de recherche communautaire de la Société des Eiders de l'Arctique (RRC) a été établi pour mesurer et pour mieux comprendre les effets environnementaux cumulatifs à grande échelle dans l'est de la baie d'Hudson et la baie James. En s'appuyant sur les collaborations du réseau et les activités réalisées dans cinq collectivités

provide a regionally-integrated perspective on metal exposure in the East Hudson Bay and James Bay marine environment. The five communities are sampling coastal bioindicator species (blue mussel, common eider) annually for three years. 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 the marine environment. 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.

(Sanikiluaq, Kuujjuarapik, Inukjuak, Umiujaq et Chisasibi), ce projet du PLCN produit de nouvelles données importantes sur les contaminants (particulièrement les métaux) qui fournissent une vue d'ensemble intégrée au plan régional sur la présence de métaux dans le milieu marin de l'est de la baie d'Hudson et la baie James. Les cinq collectivités recueillent des échantillons sur des espèces indicatrices en mer (moule bleue, eider à duvet) chaque année pendant trois ans. 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 le milieu marin. 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 second year of this project (2016), blue mussels, common eiders, Arctic cod, marine sculpin, and plankton 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 animal collections has been posted on a web-based platform called Interactive Knowledge Mapping Platform (IK-MAP; https://arcticeider.com/map#).

Messages clés

- Au cours de la deuxième année de ce projet (2016), des moules bleues, des eiders à duvet, des morues polaires, des chabots vivant en milieu marin et du plancton 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 les collections d'animaux a été publiée sur une plateforme Web nommée Interactive Knowledge Mapping Platform (carte interactive des connaissances; https://arcticeider.com/map#).

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 and James 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 CDRN 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 twenty communities that line its coasts. Mercury distribution in the Hudson Bay marine environment, especially in 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 and James 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 2016-2017

A list of the indicator species, tissue types and sample sizes collected in the first two years of the project (2015 and 2016) are provided in Table 1.

In the fall of 2016, collections by community participants resulted in 103 animal samples, specifically blue mussel, common eider, Arctic cod, marine sculpin, plankton (amphipods, copepods, shrimp), and small prey fish (in gut contents of cod and sculpin). Blue mussels were collected near Chisasibi in the fall of 2016 but the samples were damaged during shipping (stored unfrozen for several days while in transit). In addition, herring gull egg collection was not possible in June 2016 due to challenging ice conditions on Hudson Bay. Animal tissues collected in 2016 are currently being processed at the National Wildlife Research Centre for metals by ICP-MS. Total mercury and carbon and nitrogen stable isotope analyses have been completed. A new chemical analysis was conducted this year; methylmercury content was determined for primary consumer invertebrates (blue mussels, amphipods, copepods) as well as small prey fish. The proportion of total mercury as methylmercury is highly variable near the base of the food chain, and methylmercury data will allow us to better constrain the biomagnification of methylmercury in Hudson Bay.

Over the first two years of this NCP project, we have made excellent progress in collecting several bioindicators of metal bioaccumulation in the study area (Table 1). A total of 173 animal samples have been collected for measurement of metal concentrations, and a detailed breakdown of numbers by animal species and community is presented in Table 1. An additional 33 marine animals were collected at Kuujjuaraapik in 2014 as part of an earlier NCP project (CB-06), which will provide supplemental information for this project. Sampling efforts in the final year of this NCP project will focus on filling gaps in the dataset.

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 online (https://arcticeider.com/map/). This online tool provides near-real 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 and James Bay, engaging them in the process of research design and interpreting results using their own knowledge system. Project participants have 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 the wildlife sampling conducted in 2015 and 2016 is shown. 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.

Table 1. Tissue types, sample sizes, and locations of indicator species collected in 2015 and 2016 in East Hudson Bay and James Bay.

Year	Indicator species	Tissue type	Total sample size	Communities (sample size)
2015	Blue mussel *(Mytilus edulis)*	Whole (no shell)	20	Chisasibi (4 pools) Kuujjuaraapik (5 pools) Sanikiluaq (5 pools) Umiujaq (1 pool) Inukjuak (5 pools)
2015	Herring gull *(Larus argentatus)*	Egg	10	Sanikiluaq (10)
2015	Common eider *(Somateria mollissima)*	Liver, muscle	24	Kuujjuaraapik (8) Sanikiluaq (8) Umiujaq (8)
2015	Ringed seal *(Pusa hispida)*	Liver, muscle	16	Kuujjuaraapik (8) Sanikiluaq (8)
2016	Blue mussel *(Mytilus edulis)*	Whole (no shell)	15	Sanikiluaq (5 pools) Umiujaq (5 pool) Inukjuak (5 pools)
2016	Common eider *(Somateria mollissima)*	Liver, muscle	28	Kuujjuaraapik (8) Sanikiluaq (8) Umiujaq (8) Inukjuak (4)
2016	Amphipods, copepods, shrimp	Whole	5	Kuujjuaraapik (1 pool) Sanikiluaq (4 pools)
2016	Small prey fish *(gut contents)*	Whole	5	Kuujjuaraapik (1) Sanikiluaq (4)
2016	Arctic cod *(Boreogadus saida)*	Liver, muscle	30	Kuujjuaraapik (15) Sanikiluaq (15)
2016	Sculpin *(Myoxocephalus spp.)*	Liver, muscle	20	Kuujjuaraapik (10) Sanikiluaq (10)

The Arctic Eider Society hosted the first East Hudson Bay / James Bay Regional Roundtable meeting in Chisasibi in November 2016 as a part of the Hudson Bay Consortium initiative. This meeting brought together communities and stakeholders of East Hudson Bay and James Bay to consult on research and environmental stewardship priorities, as well as ways to coordinate research across jurisdictions. A brief overview of this NCP project was presented at the meeting.

A scientific poster was presented on this project at the ArcticNet Annual Meeting in Winnipeg in December 2016.

Results

Mercury concentrations in animals of East Hudson Bay and James Bay are presented in Table 2. Concentrations ranged three orders of magnitude, with more mercury in animals that feed at a higher position in the food chain (common eider, ringed seal, herring gull). This process, termed biomagnification, has been widely reported for mercury in the marine environment (Birgit et al. 2015). Methylmercury concentrations in animals near the base of the food chain were relatively low, ranging from 0.007-0.112 $\mu g \bullet g^{-1}$ dry weight (Table 2).

Total mercury concentrations in blue mussels and common eider were compared among communities to examine spatial variation in bioaccumulation within the study area. Average total mercury concentrations of blue mussels were highest near Chisasibi and also higher at Inukjuak and Kuujjuaraapik. Total mercury was lowest in blue mussels from Sanikiluaq. Although statistically significant differences were found among communities, overall the levels of total mercury were relatively low, ranging from 0.136–0.269 μg•g^{-1} dry weight (Figure 2).

Additional collections of blue mussels in 2017 will allow further refinement of the spatial trends and an examination of processes that may be driving that variation. There was little spatial variation in total mercury in liver of common eider for the four communities (Figure 3). Although the average concentration for eider livers at Kuujjuaraapik was higher, the difference was not statistically significant. Collections of common eider are planned for Chisasibi in 2017 to further expand the spatial comparison for that bioindicator.

Table 2. Total mercury and methylmercury concentrations in animals collected in East Hudson Bay and James Bay in 2015 and 2016. Concentrations are presented on a dry weight basis.

Biota (Tissue)	Sample Size[a] Average	Total Mercury (μg•g^{-1})		Methylmercury (μg•g^{-1})	
		Range	Average	Range	
Blue mussels (whole)	35 (25)	0.183	0.078-0.359	0.041	0.020-0.086
Amphipods/Shrimp (whole)	2 (4)	0.106	0.081-0.131	0.063	0.019-0.109
Copepods (whole)	1	---	---	0.007	---
Small prey fish (whole)	5	0.082	0.034-0.129	0.106	0.017-0.104
Arctic cod (liver)	30	0.037	0.010-0.127	---	---
Sculpin (liver)	20	0.183	0.055-0.413	---	---
Common eider (liver)	52	1.25	0.116-11.5	---	---
Common eider (muscle)	24	0.269	0.084-0.687	---	---
Herring gull (egg)	10	1.47	0.661-2.60	---	---
Ringed seal (liver)	16	13.0	2.81-54.9	---	---
Ringed seal (muscle)	8	0.842	0.633-1.06	---	---

[a] Sample sizes in parentheses are for methylmercury if different from total mercury

Figure 1. Total mercury concentrations in blue mussels collected in 2015 and 2016 from the five communities in the study area. The bars are means ± 1 standard error. There were statistically significant differences in mean total mercury concentration among the communities (one-way ANOVA, p = 0.001, n = 35). Bars with different letters were statistically different (Holm's p-value <0.05).

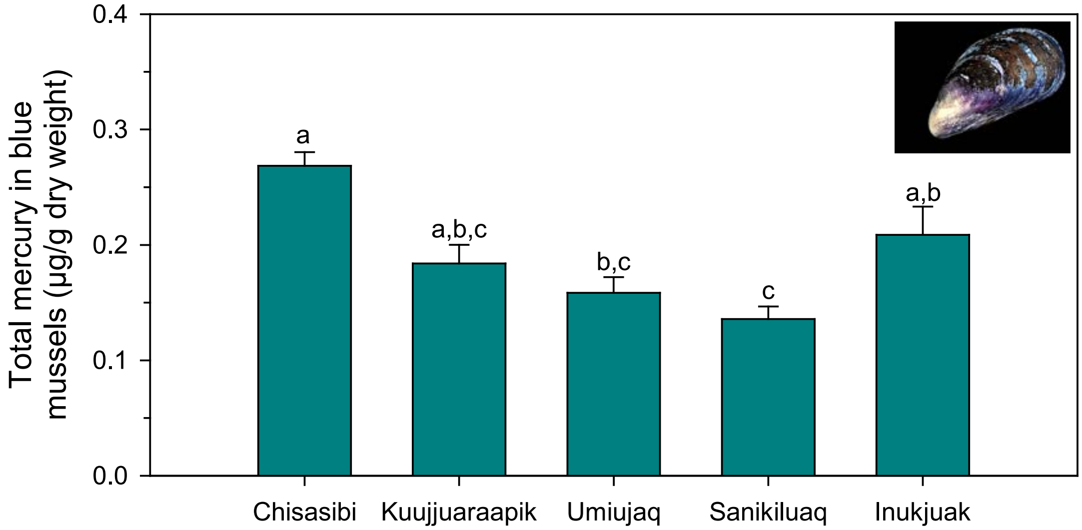
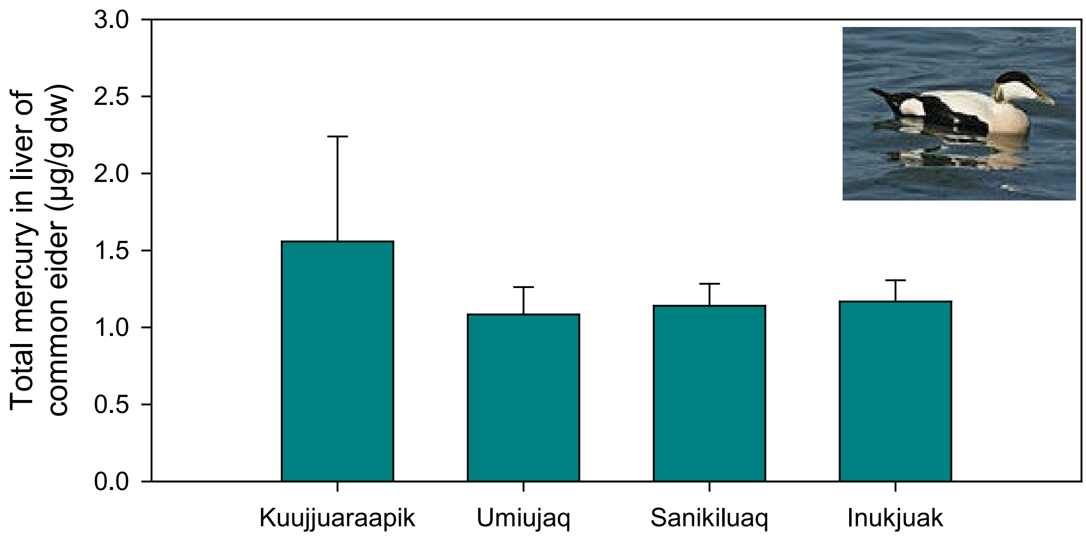


Figure 2. Total mercury concentrations in liver of common eider collected in 2015 and 2016 from four of the communities in the study area. The bars are means ± 1 standard error. The differences in mean total mercury concentration among the communities were not statistically significant (one-way ANOVA, p = 0.704, n = 52).



Discussion and Conclusions

The science generated from this NCP project will provide valuable information on: (i) metal levels in locally harvested marine animals, (ii) spatial variation in metal bioaccumulation within the study area, and (iii) environmental processes that control the accumulation and transfer of metals in the marine food web. This science will support environmental stewardship initiatives including tracking future impacts from environmental change, long-range atmospheric transport, and regional human activities.

The second year of the project was completed successfully, with twelve individuals from five communities participating in the collection of indicator species. In the third year of the project (2017), repeat sampling of some indicator species and the introduction of a new indicator species (sea urchin) will strengthen the characterization of metal levels in the marine food web of East Hudson Bay and James 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

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

Acknowledgments:

We wish to thank all the local team members who conducted the animal collections in 2015 and/or 2016 including John Lameboy (Chisasibi), Robert Lameboy (Chisasibi), Bobby Aculiak (Inukjuak), Allie Aculiak (Inukjuak), Billy Brian Kasudluak (Inukjuak), Davidee Mina (Inukjuak), Charlie Angatookalook (Kuujjuaraapik), Jordan Kronenburg (Kuujjuaraapik), George Tooktoo (Kuujjuaraapik), Vincent Tooktoo (Kuujjuraapik), Samson Tooktoo (Kuujjuaraapik), Eddy Tooktoo (Kuujjuaraapik), Johnny Kudluarok (Sanikiluaq), Stephan Kudluarok (Sanikiluaq), Simeonie Uppik (Sanikiluaq), Josie Amitook (Sanikiluaq), Salamonie Kowcharlie (Sanikiluaq), Johnny Kasudluak (Umiujaq), Peter Crow (Umiujaq), Charlie Kumarluk (Umiujaq), Suzanna Aragutak (Umiujaq), and Randy Aragutak (Umiujaq). We also wish to thank Christine McClelland, Emily Porter, Jianjun Yang and Yueting Shao who prepared and analyzed the tissues at the National Wildlife Research Centre in Ottawa.

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Mercury in seaweed and lichens from the home range of the Qamanirjuaq caribou

Mercure dans les algues et les lichens provenant du domaine vital des caribous de Qamanirjuaq

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Abstract

This is a project that was suggested and recommended by the Northern Contaminants Program Management Committee in 2015. Qamanirjuaq caribou have higher mercury concentrations than many other Arctic caribou herds. Usually caribou get most of their mercury from lichens, but local elders described the Qamanirjuaq caribou eating seaweed from the seashore. Since seaweed is known to accumulate some metals, the caribou may be getting additional mercury from this source. This project was designed to explore traditional knowledge held by hunters/elders from the Kivalliq region regarding caribou consuming seaweed, and then to use that knowledge in designing collection protocols for seaweed in the five communities in the region. Lichens and mushrooms were also collected, to determine how much mercury is coming from those dietary sources. Elder interviews and sample collections were carried out by two former students of the Environmental Technology Program at Nunavut

Résumé

Le projet a été proposé et recommandé par le Comité de gestion du Programme de lutte contre les contaminants dans le Nord en 2015. Les caribous de Qamanirjuaq présentent de plus fortes concentrations de mercure que bon nombre d'autres hardes de caribous de l'Arctique. Habituellement, la plus grande partie du mercure ingéré par les caribous provient des lichens, mais les aînés locaux ont indiqué que les caribous de Qamanirjuaq consomment des algues provenant du bord de mer. Comme les algues sont reconnues pour accumuler certains métaux, il est possible que le caribou ingère des quantités additionnelles de mercure à partir de cette source. Le projet a été conçu pour examiner les connaissances traditionnelles détenues par les chasseurs/les aînés de la région de Kivalliq sur la consommation des algues par le caribou. Il prévoit ensuite utiliser ces connaissances pour élaborer des protocoles de prélèvement d'algues dans les cinq collectivités de la région. Des lichens et des champignons ont aussi été prélevés afin de déterminer la

Arctic College, Iqaluit. Project results will be presented to each community in the fall of 2017.

quantité de mercure qui provient de ces sources alimentaires. Les entrevues avec les aînés et le prélèvement d'échantillons ont été effectués par deux anciens étudiants du Programme des technologies environnementales du Collège de l'Arctique du Nunavut (Iqaluit). Les résultats du projet seront présentés à chaque collectivité à l'automne 2017.

Key Messages

- Qamanirjuaq caribou could be getting high levels of mercury from eating seaweed.
- Elders have observed caribou eating seaweed and are concerned about the health of the caribou.
- Results from this study will be presented to participating communities in the fall of 2017.

Messages clés

- Le caribou de Qamanirjuaq peut ingérer des niveaux élevés de mercure en consommant des algues.
- Des aînés ont observé que des caribous consomment des algues et ils se préoccupent de leur santé.
- Les résultats de cette étude seront présentés aux collectivités participantes à l'automne 2017.

Objectives

- To determine if seaweed is a major contributor of mercury to the Qamanirjuaq caribou;
- To gather traditional knowledge about caribou foraging habits in the Kivalliq region;
- To measure mercury concentrations in two caribou forages from the Kivalliq region: lichen and seaweed; and
- To build capacity in the north in sample collection, mercury analysis, and communications.

Introduction

This is a project that was suggested and recommended by the Northern Contaminants Program Management Committee in 2015. The Qamanirjuaq caribou have higher mercury concentrations than many other Arctic caribou herds. Usually, caribou get most of their mercury from lichens, but at community meetings in Nunavut in the fall of 2014, elders described the Qamanirjuaq caribou eating seaweed from the seashore. Since seaweed is known to accumulate some metals (Chan *et al.* 1995), these caribou may be getting additional mercury from seaweed. This project was designed to explore the traditional knowledge held by hunters/elders from the Kivalliq region regarding caribou consuming seaweed, and then to use that knowledge in designing the collection protocols for seaweed in the five communities in the region. Samples were collected from four communities to determine variability in mercury concentrations among communities. In Arviat, seaweed is currently being used as compost for growing vegetables. Measuring Hg in the seaweed will also provide information for this activity, adding value for this project to the community.

Lichens were also collected, to determine how much mercury is coming from that dietary source. Although mushrooms were not initially included in the sampling protocol, they were added because they can be an important source of mercury for caribou at certain times of the year, and we had room in the budget since no samples were collected from Whale Cove and no seaweed samples were collected from Baker Lake.

An important aspect of this project is the building of capacity in the North. Interviews with hunters and elders, and sample collections were conducted by two recent students of the Environmental Technology Program (ETP) at Arctic College in Iqaluit. With help from the Department of Education, they identified an individual interested in the sciences in each community who assisted in the sample collections. These activities will increase capacity in these young researchers and hence the capacity of their communities (Arviat, NU).

Activities in 2016-2017

Emma Kreuger and Keenan Lindell travelled to Baker Lake, Rankin Inlet, and Chesterfield Inlet to interview elders and sample vegetation. Interviews and sampling were also done in their hometown of Arviat. Although they were scheduled to do the same thing in Whale Cove, the weather precluded air travel to that community, so it was not included in the project. This is not considered a problem for the overall project since Whale Cove is located geographically between Arviat and Rankin Inlet. Sample collections are summarized in Table 1.

Interviews are currently being transcribed by an interpreter in Arviat, NU. Vegetation samples are currently being analyzed for total mercury at NLET (Burlington) and a subset of the samples is being analyzed for methylmercury at the University of Western Ontario (Biotron Analytical Services).

Table 1. Vegetation samples taken from each community in the Kivalliq region.

	Baker Lake	Arviat	Chesterfield Inlet	Rankin Inlet	Total
Lichens	8	8	8	8	**32**
Seaweed	0	11	12	11	**34**
Mushrooms	8	8	6	3	**25**
Total	**16**	**27**	**26**	**22**	**91**

Capacity Building

This project has a very strong aspect of training and building capacity in Nunavut. Two students from the ETP program in Iqaluit (Emma Kreuger and Keenan Lindell) were involved in the project research, giving them invaluable experience in conducting interviews doing research (collecting samples), and communicating the results of that research. Vegetation samples were collected in each community with the assistance of a Nunavut beneficiary, recognized as an enthusiastic student who was experienced on the land and had an interest in science. This student was chosen by the researchers (Lindell and Kreuger) and trained in vegetation and data collection as well as GPS use. Presenting results to each of the communities with the help of an experienced researcher (Mary Gamberg) will also help to build capacity in these young researchers.

Communications

Community meeting and/or meetings with local HTOs will be held in each of the communities in this project to communicate results of the project when those results are available (anticipated for the fall of 2017). A synopsis report will be completed by April 2018 and distributed to all the stakeholders. Results will also be presented at the NCP results workshop in the fall of 2017 and a manuscript will be written and submitted for publication by April 2018.

Indigenous Knowledge Integration

This project hinges on the exploration of traditional knowledge about caribou foraging behavior, in particular with regard to the consumption of seaweed. Interviews with hunters/elders from each of the communities within the home range of the Qamanirjuaq caribou herd informed the collection protocols for this project.

Results

Results of the project are not yet available.

Expected Project Completion Date

April 2018.

Acknowledgements

Many thanks to the elders and hunters in Arviat, Rankin Inlet, Chesterfield Inlet and Baker Lake, who contributed their valuable knowledge to this project and to Anulik Kadjuk, Lars Qaqqaq, Megan Gavin and Qaumak Eccles for assisting with the vegetation collections. Thanks also to Heidi Swanson (University of Waterloo) and Brian Branfireun (University of Western Ontario) for contributing to the methylmercury analysis. We would like to acknowledge the Northern Contaminants Program which provided funding for this project.

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Environmental Monitoring and Research

Surveillance et recherche environnementales

Northern Contaminants Air Monitoring: Organic pollutant measurements

Surveillance atmosphérique des contaminants dans le 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 measures 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

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 de l'Arctique depuis 1992. La mesure de la quantité de polluants organiques présents 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. Les résultats de ce projet en

from sources in the South to the Arctic. Starting in 2006, we have extended the program to screen for emerging chemicals, such as current-use pesticides (CUPs), flame retardants and stain-repellent-related per and polyfluoroalkyl substances (PFASs), in Arctic air at Alert. Flame retardants (FRs) such as polybrominated diphenyl ethers (PBDEs) started to show declining trends in air after 2012 and non-BDE FRs are frequently detectable in air at Alert but concentrations are very low. As a follow-up study for the measured time trends of PFASs at Alert presented in last year's report, we tried to trace the sources of perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) in air at Alert. Results suggested that PFOS at Alert was influenced by air masses transported from land while PFOA was dominated by oceanic air masses. A passive flow-through 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.

cours servent à négocier et à évaluer l'efficacité des accords internationaux de lutte contre les contaminants, et à faire l'essai de modèles atmosphériques qui expliquent le déplacement des contaminants à partir de points d'origine situés au sud de l'Arctique. Dès 2006, nous avons élargi le programme pour étudier la présence dans l'atmosphère de l'Arctique canadien, à Alert, de nouveaux produits chimiques, tels que les pesticides d'usage courant, les produits ignifuges et les substances perfluoroalkyliques et polyfluoroalkyliques (PFAS) utilisées dans les produits antitaches. Des produits ignifuges comme les polybromodiphényléthers (PBDE) ont commencé à afficher des tendances à la baisse dans l'atmosphère après 2012, tandis que des produits ignifuges sans bromodiphényléther (BDE) sont fréquemment détectés dans l'atmosphère à Alert, mais dans des concentrations très faibles. À titre d'étude de suivi des tendances temporelles mesurées des PFAS à Alert présentées dans le rapport de l'an dernier, nous avons tenté de localiser les sources de perfluorooctanesulfonate (PFOS) et d'acide perfluorooctanoïque (APFO) détectés dans l'air à Alert. Selon les résultats obtenus, les PFOS mesurés à Alert y auraient été transportés par des masses d'air provenant des terres, tandis que les APFO y auraient été entraînés par des masses d'air océanique. Un échantillonneur passif à circulation continue (EPCC) spécialement conçu pour être utilisé dans un climat 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

- Air monitoring for organic pollutants continued at Alert, Nunavut, and Little Fox Lake, Yukon, and measurements are ongoing.
- Air concentrations of flame retardants (FRs) such as polybrominated diphenyl ethers (PBDEs) started to decline at Alert after 2012.
- Non-BDE FRs are frequently detectable in air at Alert but concentrations are very

Messages clés

- La surveillance atmosphérique et la mesure des polluants organiques se poursuivent à Alert, au Nunavut, ainsi qu'au lac Little Fox, au Yukon.
- Les concentrations atmosphériques de produits ignifuges comme les PBDE ont commencé à diminuer après 2012.
- Des produits ignifuges sans BDE sont fréquemment détectés dans l'atmosphère à Alert, mais dans des concentrations

low and high blank levels in some years prevented the determination of time trends.

- Source region analysis suggested that PFOS at Alert was influenced by air masses transported from land while PFOA was dominated by oceanic air masses.

très faibles, et les niveaux de blanc élevés pendant certaines années ont empêché la détermination de tendances temporelles.

- L'analyse des régions sources indique que la présence de PFOS à Alert serait due au transport par des masses d'air provenant de régions terrestres, tandis que les APFO y auraient été entraînés par des masses d'air océanique.

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:

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

  i. 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
  ii. 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
  iii. 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, to determine contaminant source regions, to evaluate global long-range transport models and for assessing 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. CUPs, PFASs used as stain-repellents, and new FRs were included in Arctic air measurements at Alert since 2006.

In this report, measured results for PBDEs and other halogenated flame retardants in air at

Alert are reported. Results for source region analysis of PFASs found in air at Alert are discussed.

Activities in 2016-2017

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. Results for PBDEs and other halogenated FRs are reported here.

A separate high volume air sampler (PS-1 sampler), sampling with 1 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 the source region analysis of PFASs in air at Alert are reported here.

Time trends for POPs have been updated to the end of 2012 and results are included in an article titled "Temporal Trends of Persistent Organic Pollutants (POPs) in Arctic Air: 20 Years of Monitoring under the Arctic Monitoring and Assessment Programme (AMAP)" (Hung et al. 2016) that was published in the special issue of "Ten Years of Global Monitoring under the Stockholm Convention on Persistent Organic Pollutants (POPs): Trends, Sources and Transport Modelling". PI Hayley Hung is one of the guest editors of this special issue.

Project leader Hayley Hung co-led the compilation of the air monitoring chapter in the Global report for the Global Monitoring Plan (GMP) of the UNEP Stockholm Convention on POPs (SC). The report was made available to the SC Effectiveness Evaluation Committee in 2016. The Global report will be released in the spring of 2017. Long-term trend results from Alert contributed to this report.

Some of the earlier screening results for OPs measured at Alert in 2008-2009 and 2012 were published together with results from Resolute Bay and ship-based measurements on the Amundsen Icebreaker in a scientific article titled "Organophosphate Esters (OPE) in Canadian Arctic Air: Occurrence, Levels and Trends" (Sühring et al. 2016). In this paper, it was found that concentrations of halogenated OPs seemed to be driven by river discharge from the Nelson and Churchill Rivers (Manitoba) and Churchill River and Lake Melville (Newfoundland and Labrador). Nonhalogenated OPE concentrations seem to have diffuse sources or local sources close to the land-based sampling stations (e.g. airports).

Time trends of CUPs, PFASs, emerging FRs, PCA, PAHs and other new chemicals measured at Alert and Little Fox Lake are included in the AMAP Emerging Chemicals Assessment.

A scientific paper including both neutral and polar PFASs measured in air at Alert and two Norwegian Arctic sites (namely Zeppelin and Andøya) from 2006 to 2014 has been prepared. Both PFOA and PFOS in air at Alert showed increasing trends over the studied period, but declining or non-changing trends were found at Zeppelin and Andøya. These differences in trends between the sites may reflect regional regulations and sources. Perfluorobutanoic acid (PFBA), a short-chain PFAS, was found in 100% of the samples. Its concentrations were relatively higher than other PFASs measured in this study. Furthermore, it exhibited an increasing trend over the studied period, suggesting a shift from long to short chain fluorochemical production. These are the first time trends ever published for these compounds in the Arctic. The paper is currently under review.

Results of short chain chlorinated paraffins (SCCPs) measured in air at Alert have been submitted to the POPs Review Committee of the Stockholm Convention through Katrin Vorkamp (AMAP) to be included in the Risk Profile of SCCPs.

An oral presentation titled "Emerging Flame Retardants in Canadian Arctic Air" including time trends of emerging FRs was presented at the Brominated Flame Retardants 2016 workshop in Toronto (May 5-6, 2016).

PI Hayley Hung, Jianmin Ma (retired ECCC; currently at Lanzhou University, China) and Robie Macdonald (retired Fisheries and Oceans Canada) were invited to compile a POPs and Climate Change review paper for the journal Global and Planetary Change. Studies performed under NCP were included in this review paper and NCP is acknowledged for supporting Hayley's work. The paper is now published (Ma, Hung, and Macdonald 2016).

Communications, Consultation and Capacity Building

Outreach and communication under this project "M-01 Northern Contaminants Air Monitoring: Organic Pollutant Measurements" is conducted in conjunction with that of the projects "M-02 Air Measurement of Mercury at Alert and Little Fox Lake" (P.I. Alexandra [Sandy] Steffen) and "M-03 Passive Air Sampling Network for Organic Pollutants and Mercury" (P.I.s Hayley Hung and Sandy Steffen).

The following is a description of the activities that occurred in 2016-2017:

A lot was accomplished in the past year on the communication and capacity building aspects of our programs which operate out of Alert, Nunavut; Little Fox Lake, Yukon; and, this year, at Cambridge Bay, Nunavut, as well as various locations across the Arctic. Alert is isolated, not near any community and access is restricted by the military, thus in previous years it has been challenging to meet our capacity building and training expectations. This year to address these challenges, we focused most of our efforts on working with the Nunavut Arctic College to teach and train students on contaminants in the atmosphere. For the Little Fox Lake part of the project, we are working more closely with the Council of First Yukon Nations (CYFN) and the Ta'än Kwach'än Council (TKC) in Whitehorse and we continue our collaboration with the Yukon College. The newly proposed subproject on Indigenous Knowledge (IK) under Project M-03 for Fiscal Year 2016/17 was funded at mid-year (see below). This year in Cambridge Bay, we worked with Polar Knowledge Canada on our outreach activities as part of Project M03 (see below).

In Fiscal Year 2016/17, consultation with the Nunavut Environmental Contaminants Committee (NECC) and Yukon Contaminants Committee (YCC) included a summary of the proposed work for the year and a plan for communication, training and capacity building.

In February 2016, Nunavut Arctic College instructors, Jason Carpenter and Daniel Martin, visited Sandy and Hayley's laboratories in Toronto. They gave a lunchtime seminar titled "An Overview of the Nunavut Arctic College's Environmental Technology Program" to the Air Quality Research Division of ECCC to inform scientists on how to employ students from the college's Environmental Technology Program for field studies. The talk was met with great interest and was eye-opening for scientists from ECCC. They have also provided useful information on Arctic field expeditions and how to engage and consult with local communities when conducting research in the North. During their visit, they discussed the potential for student exchange and training between the Toronto/Egbert laboratories and the College in the future with Hayley, Sandy and Liisa.

On January 26, 2016, Sandy, Hayley and Liisa conducted 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. We had great discussions with our partners at the school and with the NECC in an additional meeting.

In March 2016, Jamie Thomas, the potential student to be employed through CYFN to lead the IK subproject under Project M-03, also visited Hayley and Sandy's laboratories. During Jamie's visit, Jamie, Sandy, and Hayley had two intensive brain-storming meetings to discuss potential approaches on IK research in the Yukon region and how this information can be useful for the air monitoring projects.

Hayley Hung visited Cambridge Bay from Sep 13 to 15, 2016. Unfortunately, Sandy Steffen had to cancel her trip to Cambridge Bay as she had a medical emergency and was in the hospital. Hayley gave a seminar to the Environmental Technology Program students at the Nunavut Arctic College (with Instructor Erin Hamilton) and a seminar at the Kiilinik High School (School Principal Roman Mahnic). Both seminars were well-received. Hayley also met with Marla Limousin, Senior Adminstrative Officer of the Municipality of Cambridge Bay, and the Executives of the Ekaluktutiak Hunters & Trappers Organization (EHTO) to discuss about the project and our sampling and outreach activities in Cambridge Bay. Mia Otokiak, the local radio host, did an interview with Hayley on contaminants in Arctic air and NCP's passive air sampling activities in town (NCP M03 project). The interview was broadcasted live in the community on September 13th in the afternoon. Hayley met with Polar Knowledge Canada (POLAR) staff, including Angut Pedersen (passive sampling site operator), Dwayne Beattie (Manager, Technical Operations, CHARS) and Crystal Qaumariaq (Communication and Consultation Officer, CHARS), to discuss about passive sampling arrangements and our outreach activities at Cambridge Bay. Hayley's accommodation was kindly provided by POLAR for free at the CHARS Researcher Triplex.

In November 2016, Sandy visited Whitehorse and met with Derek Cooke (TKC) and the "IK student", Jamie Thomas, confirmed to be hired in January 2017 through CYFN with mid-year funding from NCP. Unfortunately, James MacDonald of CYFN and Mary Gamberg could not make the scheduled meetings due to last minute emergencies. Sandy updated Derek Cooke about our project plans both in terms of the research activities and the consultation, capacity building and IK work that accompanies these research programs (M01, M02 and M03). We discussed the work that Jamie will undertake for improving our knowledge and input from IK on the program. Her plan was to try and gain some initial IK information and interest from local elders on subjects such as air, weather, climate changes, forest fire changes, animal behaviours, history of wood and how wood is being used and other environmental factors that may relate to atmospheric contaminant monitoring in the Yukon.

On Feb 2, 2017, Hayley Hung gave a 1-hour lecture to Yukon college students in Instructor Larry Gray's course when she visited Whitehorse. Bob Van Dijken (CYFN) retired in October 2016 and we are currently in contact with James MacDonald (CYFN) who is temporarily taking over Bob's responsibilities. Hayley held teleconferences with James MacDonald (CYFN), Ellen Sedlek (CIRNAC, Yukon) and Derek Cooke (TKC) to discuss about the continued operation of the Little Fox Lake station and the ongoing IK project in collaboration with CYFN and TKC.

In February 2017, Sandy, Hayley, and Liisa Jantunen travelled to Iqaluit again 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 their communication, capacity building and IK plans. To follow-up with NECC's recommendation to consult with the City of Iqaluit regarding the passive air sampling activities in town under Project M-03, the team met with Matthew Hamp, Director of Public Works and Engineering, City of Iqaluit, to discuss about the passive air sampling work.

On Mar 1-2, 2017, Hayley Hung and Alexandra Steffen attended the Yukon Contaminants Workshop and gave presentations about the mercury and organic pollutant measurements in air in Little Fox Lake. The seminars were well-received by First Nations and other community members (about 50 people) that participated in this workshop.

- Data collected from Little Fox Lake (once interpreted) will be discussed and distributed to the CYFN and the Ta'än Kwach'än First Nation, in whose traditional territory the sampling 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.

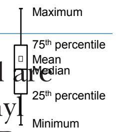
Indigenous Knowledge (IK) Integration

During the 2016-2017 Fiscal Year, in collaboration with Derek Cooke (Ta'än Kwach'än Council), Bob Van Dijken (Council of Yukon First Nations (CYFN), retired) and Pat Roach (CIRNAC, retired), we engaged a Yukon student (Jamie Thomas) to research on the IK information in the Yukon region in order to better understand how to use IK in the NCP air monitoring projects of POPs and mercury. We have discussed this plan with Derek Cooke (partner of projects M-01, M-02 and M-03) and have briefed James MacDonald (CYFN, taking over for Bob Van Dijken) and Ellen Sedlack (CIRNAC, taking over for Pat Roach) on this sub-project.

In consultation with the project leaders and the Ta'än Kwach'än Council, Jamie hosted a consultation session (March 2017) and invited local Yukon elders to attend and engage in a discussion on indigenous knowledge. The event was conducted at the Yukon Horse Packing retreat facility which is located between Whitehorse and Little Fox Lake, on Fox Lake. The plan was to conduct this session in the style of a "world café" where people can come and go, enjoy some food, enjoy the outdoor and indoor location and talk in an informal manner. Jamie made posters of the research activities from the area and invited elders to comment and discuss their views. Unfortunately, not many people attended the event. Therefore, to gather the IK information necessary to deliver results for this sub-project, Jamie conducted 3-4 interviews with elders and is in the process of transcribing the interviews and writing the final report.

Results

Halogenated Flame Retardants in Air at Alert



Air samples taken using the super-HiVol are screened for 14 polybrominated biphenyl ethers (PBDEs), 13 other brominated FRs and 2 highly chlorinated FRs. Figure 1 shows the time trends and seasonal cycles for BDE 47 and 99 in air at Alert developed using the Digital Filtration Techniques (Hung et al. 2016). Several BFRs, including bis(2-ethylhexyl)tetrabromophthalate (BEH-TEBP), 2-ethylhexyl-2,3,4,5-tetrabromobenzoate (EH-TBB), pentabromobenzene (PBBz), pentabromoethylbenzene (PBEB) and 2,3,5,6-tetrabromo-p-xylene (PTBX) are frequently detectable in air at Alert (Figure 2).

Figure 1. BDE 47 and 99 measured in air at Alert

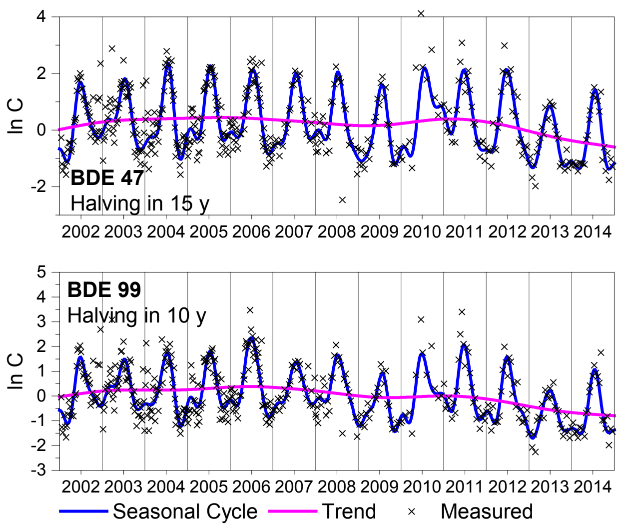
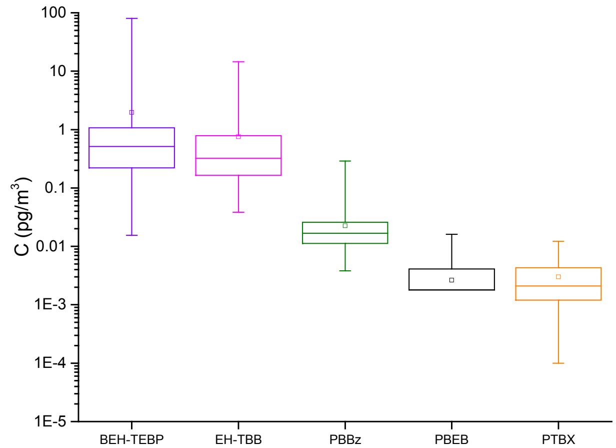


Figure 2. Box-and-whisker plots of 5 BFRs frequently detectable in air at Alert (2008-2014)



Source Region Analysis of Perfluorooctane Sulfonic acid (PFOS) and Perfluorooctanoic Acid (PFOA) in Air at Alert

We employed the Lagrangian particle dispersion model FLEXPART (Stohl et al., 2005) and a statistical analysis of the model output to identify the source regions of PFOS and PFOA at Alert. In brief, the analysis considers where air is coming from for the highest 20% of the measured data, compared to the average transport for all the data. A detailed description of the approach is described in Hirdman et al. (2010).

Discussions and Conclusions

Halogenated Flame Retardants in Air at Alert

Hung et al. (2016) previously reported that PBDEs in air at Alert did not decline which may be due to influence of local sources at Alert and the much higher historical usage of PBDEs in North America. With two more years of data, the air concentrations of PBDEs have started to show slow declining trends (Figure 1) with half-lives of 15 years and 10 years for BDE 47 and 99, respectively. Measurements will continue to confirm these declining trends.

Although several non-BDE FRs are detectable in air at Alert (Figure 2), the concentrations were generally very low and close to the detection limits. The blank levels were quite high in some years resulting in higher method detection limits (MDLs) which are defined as 3 times average blank concentrations plus 3 standard deviations. Therefore, it is not yet possible to derive time trends for these emerging FRs at Alert. Measurements must continue and efforts need to be made to ensure blank levels remain as low as possible in order to determine if their concentrations are increasing, decreasing or not changing in Arctic air.

Source Region Analysis of Perfluorooctane Sulfonic acid (PFOS) and Perfluorooctanoic Acid (PFOA) in Air at Alert

The relative emission sensitivity fields (R80) of the 20% of the measurements with the highest concentration (i.e. 80th percentile) were plotted in Figure 3. Data from 2013 were not included in the analysis due to the anomalous PFOS and PFOA measurements, which were analyzed separately and discussed later.

Figure 3a shows that the highest PFOS data are associated with continental air masses transported from North America, north-central and western regions of Russia. The highest PFOA data at Alert (Figure 3b) are associated with an oceanic transport signal with air mass transport over the Canadian Archipelago, Baffin Bay, Labrador Sea, and Greenland Sea. It has been hypothesized that PFOA is transported by oceanic currents (Wania, 2007), and subsequently the chemical is transferred from ocean to air via sea spray aerosols (McMurdo et al. 2008; Reth et al. 2011).

It is noted that episodes of high PFOS and PFOA measurements at Alert occurred in 2013. Indeed the maximum concentrations of the entire studied period were measured during these episodes. Figure 4 plots the average sensitivity fields (ST) for year 2013 relative to the average ST of the overall Alert data. The red region indicates the area where the air masses passed through more frequently in 2013 relative to the entire study period. Particularly, more air masses travelled across the Hudson Bay of Canada in 2013 than in other years, indicating that the Hudson Bay could be a source for these substances as it has a large watershed extending over five Canadian provinces, three territories and four US states with drainage from major streams (the Nelson, Saskatchewan and Churchill rivers) passing through cities (e.g. Edmonton and Winnipeg) (Zhang et al. 2016). It has been shown that river drainage could be major contributors of PFASs and the highest concentrations are found in surface water near urban areas (Filipovic et al. 2013; Zhang et al. 2016).

In conclusion, our source region analysis suggested that PFOS at Alert was influenced by air masses transported from land while PFOA was dominated by oceanic air masses. Continual atmospheric monitoring of these substances is needed to confirm this observation.

Figure 3. Fields of R80 for the highest 20% of all measured PFOS (A) and PFOA (B) concentrations at Alert.

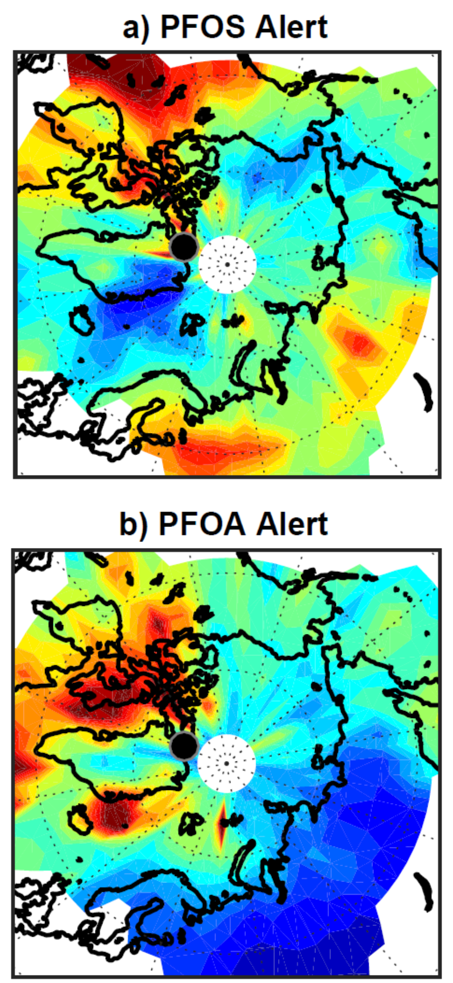
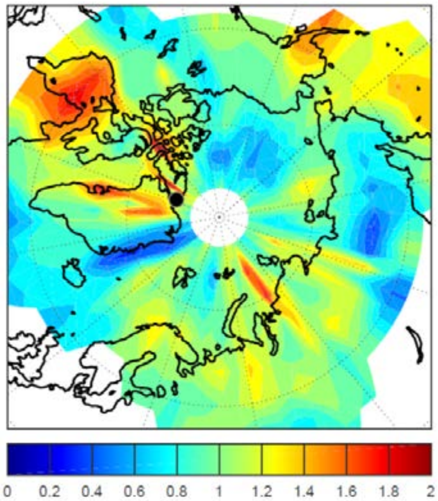


Figure 4. Relative fields of R80 for PFOS and PFOA for the 2013 Alert data to the average of the overall data (2006 to 2014).



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.

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Mercury Measurements at Alert and Little Fox Lake

Mesure du mercure à Alert et au lac Little Fox

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Abstract

Mercury (Hg) is a priority pollutant in Canada and of concern in Arctic regions. The Arctic receives Hg via long range transport from source regions, primarily from outside of Canada. Our results from atmospheric Hg concentration measurements at Alert, Nunavut show a median decreasing trend of (-0.821 ± 1.39 % per year for the past 21 years). In contrast, Hg concentrations at Little Fox Lake, Yukon show an increasing median trend (+1.47% ± 0.33% per year for 9 years). The pattern of the monthly trend has changed but the overall trend in concentration at this site remains on the increase. At Alert, Hg continues to show a distinct seasonal decrease in gaseous elemental Hg (GEM) in the spring. Concurrently, seasonal 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. Shorter-lived Hg show enhanced deposition of mercury to the snow at the same time.

Résumé

Le mercure (Hg) est un polluant prioritaire au Canada 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. Les résultats que nous avons obtenus grâce aux mesures des concentrations atmosphériques de mercure prises à Alert, au Nunavut, montrent une tendance médiane à la baisse (-0,821 ± 1,39 % par année depuis 21 ans). En revanche, les concentrations de mercure mesurées au lac Little Fox, au Yukon, suivent une tendance médiane à la hausse (+1,47 % ± 0,33 % par année, sur une période de neuf ans). Le profil de la tendance mensuelle a changé. Cependant, la tendance générale des concentrations à cet emplacement demeure à la hausse. 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

The project team worked with the Regional Contaminants Committees in both Nunavut and the Yukon to discuss project plans and ideas for this work.

courte durée de vie (mercure gazeux réactif, ou MGR, et mercure lié aux particules, ou PHg) ont continué de présenter un pic de PHg au début du printemps et un pic de MGR à la fin du printemps. Le mercure à plus courte durée de vie montre un dépôt plus important dans la neige à la même période. L'équipe de projet a travaillé de concert avec les comités régionaux des contaminants du Nunavut et du Yukon afin de discuter des plans et des idées de projet pour ces travaux.

Key Messages

- Atmospheric mercury concentration 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 the 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 scientific contribution to national policies and strategies. As well, it will be used in the assessment of effectiveness of national and international emission reduction strategies.

Messages clés

- On mesure les concentrations de 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 observe toujours une variabilité saisonnière du mercure atmosphérique à Alert et au lac Little Fox.
- Les données recueillies dans le cadre de ce programme représenteront la contribution scientifique du Canada aux politiques et stratégies nationales. De plus, elles serviront à évaluer l'efficacité des stratégies nationales et internationales de réduction des émissions de mercure.

Objectives

- Establish long-term concentrations, patterns and trends of Hg in the Canadian high Arctic air at the Alert site. This information has been and will continue to 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 effects 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.
- Engage with and train Northern students and community members on atmospheric mercury measurements and the impact of mercury in the ecosystem.

Introduction

The Canadian Mercury Science Assessment concluded that mercury (Hg) remains a risk to Canadian ecosystems and human health (Steffen 2016a). 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]…". As well, 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 (Steffen 2016b). 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 (Steffen 2016b; EC and HC 2010). 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 Hg to the atmosphere 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 Gaseous Elemental Mercury (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.

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 2016-2017

Research activities

Ground-based continuous atmospheric measurements of total gaseous mercury (TGM), gaseous elemental mercury (GEM), reactive gaseous mercury (RGM) and particulate mercury (PHg) continued at Alert. TGM at Alert is considered to be almost entirely GEM at Alert. Site visits for maintenance and calibration of all mercury instruments at Alert were made in April 2016 and November 2016 on top of regular weekly checks by the onsite operator and student. Continuous measurements of TGM/GEM at Little Fox Lake were also carried on through 2016-2017; a technical site visit was made in December 2016 on top of regular weekly checks by Laberge to check the instrument, download the data and perform minor repairs to the instrument on site. In this report we will use the term GEM for Alert and Little Fox Lake TGM/GEM.

Data from both sites for the years 2015 and 2016 are reviewed monthly and have been QCed. The final data are submitted to the Environment Canada Data Catalogue (ECDC) at the following links:

- http://donnees-data.intranet.ec.gc.ca/data/air/monitor/monitoring-of-atmospheric-gases/total-gaseous-mercury-tgm/?lang=en;
- http://donnees-data.intranet.ec.gc.ca/data/air/monitor/monitoring-of-combined-atmospheric-gases-and-particles/speciated-mercury/

The data up to 2011 has been transferred into the ECDC and the remaining data will be uploaded once approved by ECCC management. After discussion with Wenche Aas from NILU, it was decided that these links to the Canadian mercury data would suffice to house our data and meet our AMAP obligations. It was felt that there should be no need for duplicating the available data. Metadata from this program have also been updated in the Polar Data Catalogue (PDC); the existing link from the PDC record will be updated to the ECDC once all 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. The data from 2016 has not yet been analyzed.

Snow samples continued to be collected at Alert both weekly (from the ground) and on a per event basis (from the Teflon coated snow table). In addition, snow samples from over the sea ice to inland were also collected. All snow samples collected up to the end of 2016 have been analyzed at the Water Science and Technology Branch in Burlington, Ontario.

Communications and Capacity Building

As in previous years, the NCP atmospheric organic pollutants (Hayley Hung) 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 Jantunen visited Iqaluit in January 2017 to conduct a half-day lecture and half-day activity session to the students of the Environmental Technology Program at the Nunavut Arctic College. They also met with the Nunavut Environmental Contaminants Committee (NECC) to discuss the communication and capacity building plan of the projects. As well, the team met with Matthew Hamp, Director of Public Works and Engineering at the City of Iqaluit, to discuss about the passive air sampling and the general air quality work going on in the area. The Nunavut Research Institute (NRI) has now received their direct mercury analyser (DMA). Sandy hopes to work with the NRI to incorporate some mercury work for the students and the community using this instrument for future mercury passive sampling.

In November/December 2016, Sandy and Geoff Stupple visited Whitehorse and met with Derek Cooke (TKC) and the "IK student", Jamie Thomas. Unfortunately, James McDonald (CYFN) and Mary Gamberg could not make the scheduled meetings due to last minute emergencies. Sandy updated Derek about our project plans both in terms of the research activities and the consultation, capacity building and IK work that accompanies the research programs (M01, M02 and M03).

Hayley, Sandy and Liisa Jantunen visited Iqaluit in January 2017 to conduct a half-day lecture and half-day activity session to the students of the Environmental Technology Program at the Nunavut Arctic College. They also met with the Nunavut Environmental Contaminants Committee (NECC) to discuss the communication and capacity building plan of the projects. As well, the team met with Matthew Hamp, Director of Public Works and Engineering at the City of Iqaluit, to discuss about the passive air sampling and the general air quality work going on in the area. The Nunavut Research Institute (NRI) has now received their direct mercury analyser (DMA). Sandy hopes to work with the NRI to incorporate some mercury work for the students and the community using this instrument for future mercury passive sampling.

On March 1-2, 2017, Hayley and Sandy attended the Yukon Contaminants Workshop in Whitehorse and gave presentations about the mercury and organic pollutant measurements in air in Little Fox Lake. The seminars and ensuing discussions were well-received by First Nations and other community members (about 50 people) that participated in this workshop. Sandy would like to encourage the Yukon region to find the funds to purchase a DMA instrument (similar to that in Nunavut). It is hoped that if the college or region has this instrument, that we can collaborate on training students and local community scientists to develop a mercury passive sampling and analysis program based on the currently developing mercury passive sampler. This would enable a full science monitoring program to be run in and by the Yukon.

Indigenous Knowledge (IK) Integration

For Fiscal Year 2016/17, in collaboration with the Derek Cooke (Ta'än Kwach'än Council), Bob Van Dijken (Council of Yukon First Nations (CYFN), retired) and Pat Roach (CIRNAC, retired), we engaged a Yukon student (Jamie Thomas) to research potential IK information in the Yukon region in order to better understand how to use IK in the NCP air monitoring projects of POPs and mercury. We discussed this plan with Derek Cooke (partner of projects M-01, M-02 and M-03) and have briefed James MacDonald (CYFN, taking over for Bob Van Dijken) and Ellen Sedlack (CIRNAC, taking over for Pat Roach) on this subproject. In consultation with the project leaders and the Ta'än Kwach'än Council, Jamie hosted a consultation session (March 2017) and invited local Yukon elders to attend and participate in a discussion about Indigenous Knowledge. The event was conducted at the Yukon Horsepacking Adventures facility which is located between Whitehorse and Little Fox Lake, on Fox Lake. The plan was to conduct this session in the style of a "world café" where people can come and go, enjoy some food, enjoy the outdoor and indoor location, and talk in an informal manner. Jamie made posters of the research activities from the area and invited elders to comment and discuss their views. Unfortunately, not many people attended the event. Therefore, to gather the IK information necessary to deliver results for this sub-project, Jamie conducted 3-4 interviews with elders and is in the process of transcribing the interviews and writing the final report. We will review and discuss the findings in this report and present them in the next synopsis report.

Results

Figure 1 shows the gaseous elemental mercury (GEM) 6 hour averages for Alert (top) from 1995 to 2016 and for Little Fox Lake (bottom) from 2007 to 2016. We have 21 years of this fully quality controlled data from Alert and 9 years of data from Little Fox Lake. Figure 2 shows the monthly and annual trend analyses for GEM at Alert from 1995 to 2016 and for GEM at Little Fox Lake from 2007 to 2016. Boxes above zero represent an increasing trend and below zero represent a decreasing trend for a given month. Figure 3 shows the long term mercury speciation data from Alert including GEM, reactive gaseous mercury (RGM) and particulate mercury (PHg) from Alert from 2002 to 2016. Figure 4 shows the mercury levels at Alert in the snow (collected from the snow table) from spring 2015 and 2016. This figure also shows the atmospheric mercury speciation data (GEM, RGM, and PHg) during the same time period.

Figure 1: Time series of gaseous elemental mercury (GEM) from both Alert (bottom) and Little Fox Lake (top) up to the end of 2016. Data presented in 6 hour averages.

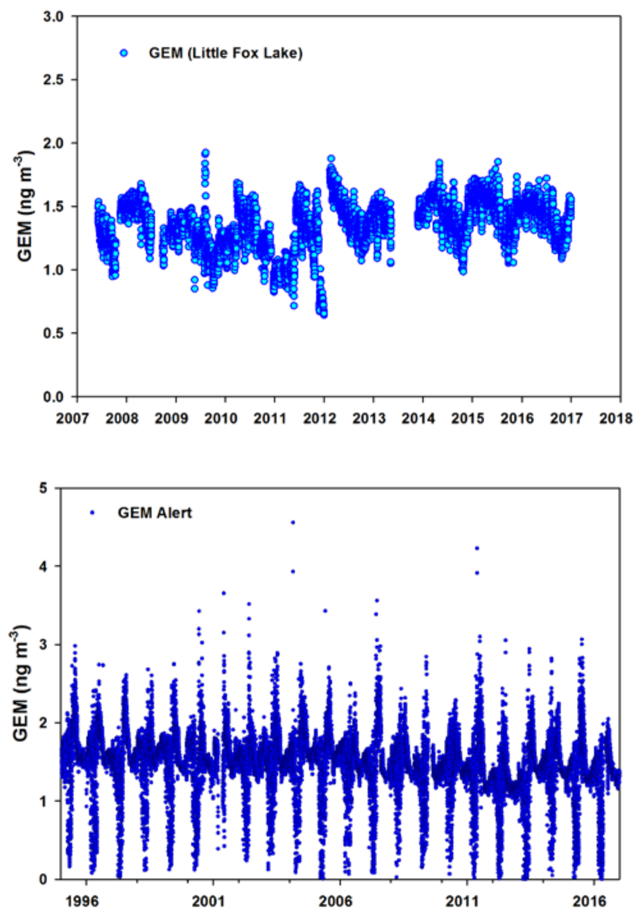


Figure 2. Monthly trends calculated as a percent of the median concentration from the TGM data collected at Alert (left) and Little Fox Lake (right). Boxes above zero represent an increasing trend and below zero represent a decreasing trend for a given month.

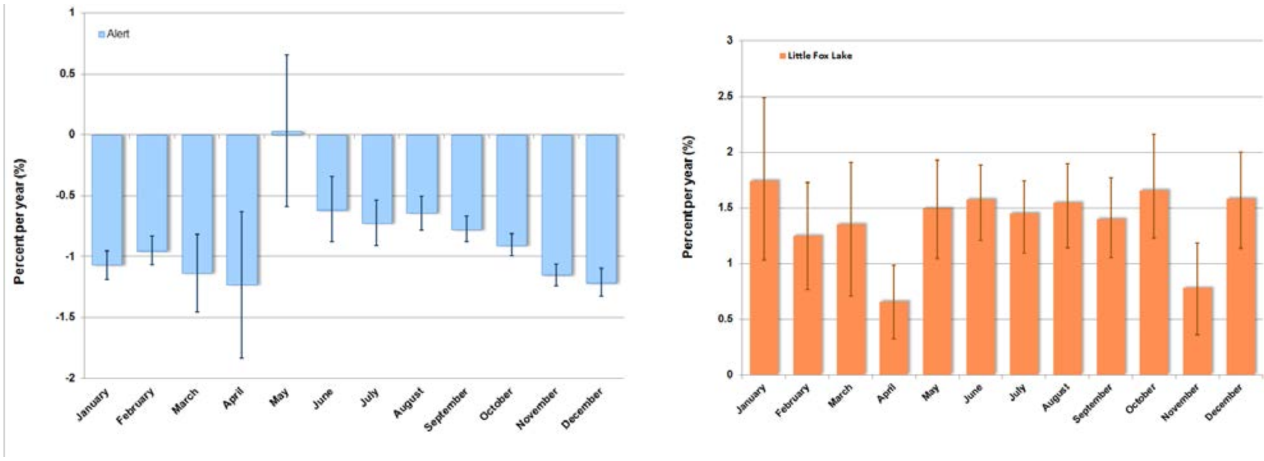


Figure 3. Atmospheric mercury speciation data from Alert up to the end of 2016. Data is presented in 6 hourly averages. Blue represents gaseous elemental mercury (GEM), pink represents reactive gaseous mercury (RGM) and green represents particulate mercury (PHg).

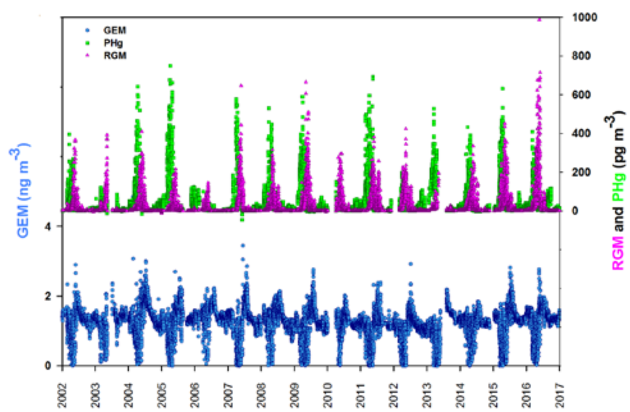
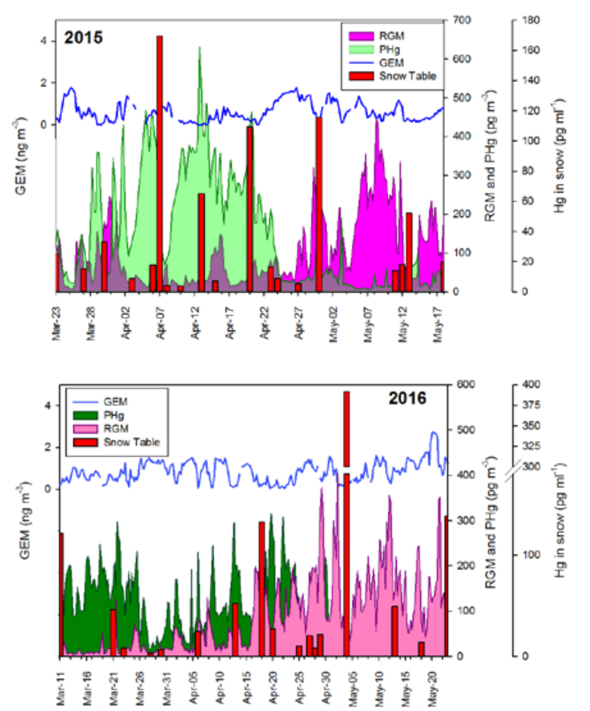


Figure 4. Mercury concentration in snow collected on a table at Alert in spring 2015 (top) and 2016 (bottom). Snow data are shown in red vertical bars, gaseous elemental mercury (GEM blue), reactive gaseous mercury (RGM pink) and particulate mercury (PHg green).



Discussion and Conclusions

Data collection, quality control and submission were the primary focuses of this year. Figure 1 shows the quality controlled data from both Alert (top) and Little Fox Lake (bottom) up to the end of 2016. The patterns from the GEM data at Alert continue to demonstrate the strong seasonal variability that repeats annually in the Hg levels at this site. The plot from Little Fox Lake shows annual variability in the data but a weaker seasonality than Alert. This is expected given that the variability is a result of the chemistry that is derived from ocean/atmosphere interactions and Little Fox Lake is inland with minimal exposure to such chemistry. Using the data from Figure 1, a seasonal Kendall trend analysis was performed for both Alert and Little Fox Lake (as described in (Cole *et al.* 2014)). In Figure 2, the bars show the monthly trend in percent as calculated from the median slope and the monthly median concentrations to determine percent per year. The trends shown are consistent with what has been reported in the past where the Alert concentrations are decreasing over most months and the Little Fox Lake concentrations are increasing in most months. Further analysis into the reason for the differences is in progress. Speciated atmospheric mercury data continued to be collected at Alert and the time series is shown in Figure 3.This figure shows that the distribution of atmospheric mercury species continues to be dominated by the springtime chemistry where GEM depletes from the atmosphere and is converted to RGM and PHg. RGM and PHg are more easily deposited to the snow (than GEM) which is collected on an event basis on the Teflon coated snow table at Alert. Figure 4 shows the concentration of mercury in the snow from the snow table from the spring of 2015 and 2016, as well as the associated GEM, RGM, and PHg over the same time period. This figure shows that the PHg concentrations are higher at the beginning of the spring and then the RGM concentrations are higher towards the end of the spring. The mercury levels in the snow in 2016 appear to increase as the season progresses while the 2015 samples show high levels throughout the spring period. While the concentration levels of mercury in the snow vary considerably due to the dependence on a coincidence of atmospheric chemistry and sampling opportunity, they are considerably higher than those reported in snow at other research sites in Canada. The Alert 2015 and 2016 spring sample concentration average was 49.6 ±73.8 pg•ml^{-1} and an example range of mercury levels reported in various Canadian snowpacks ranges from 0.3 to 4.1 ng·L-1 (ECCC, 2016). This demonstrates that there still remains a significant atmospheric input of mercury to the snow in Alert during this time period. Snow has also been collected over a transect from the land to the sea ice and on the surface next to the snow table at Alert. An in-depth analysis of these samples will be forthcoming.

Overall, this year focused on the continued collection of data. We anticipate a further analysis of the trends in the atmospheric data from Alert and Little Fox Lake and the snow data from Alert to be made in the coming fiscal year.

Expected Project Completion Date

Ongoing

Acknowledgements

The project team would like to thank the Global Atmospheric Watch program at Alert for supplying facilities, assistance and personnel. We would like to thank the Alert operators for collecting the mercury data at Alert. We would also like to thank Amanda Cole for her help and Ashu Dastoor for her continued input and support to the Hg measurement programs. As always, we thank the NCP for their continued support for this work.

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Passive Air Sampling Network for Organic Pollutants and Mercury

Réseau d'échantillonnage atmosphérique passif pour l'analyse 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

Résumé

Ce projet vise à mesurer les polluants atmosphériques, dont les polluants organiques persistants (POP) et le mercure, à différents emplacements dans le Nord canadien. Lorsqu'ils entrent dans l'écosystème, les POP et le mercure peuvent affecter l'état de santé des résidents du Nord. Actuellement, ces polluants sont mesurés à quelques endroits dans l'Arctique canadien. Ils y sont transportés par voie atmosphérique à partir

locations where they are measured will provide more information about where they come from and how they are changing over 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 is also suitable 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 ramp up over a few 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. At the onset of the project, some issues were encountered that resulted in delayed starts but most sites are currently in full operation and we continue to work on resolving the issues to get all sites up and running. Field tests for developing a passive mercury air sampler are progressing well. A northern student has been engaged to research on Indigenous Knowledge in the Yukon region which may be used in the air monitoring projects for POPs and mercury. Project Principal Investigators visited Iqaluit (Nunavut), Whitehorse (Yukon) and Cambridge Bay (Nunavut) 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 Yukon College (YK), Nunavut Arctic College (Iqaluit and Cambridge Bay) and the Kiilinik High School in Cambridge Bay.

de régions plus au sud. 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 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 (EAP) sont un moyen de surveillance des polluants atmosphériques peu coûteux, exigeant peu d'entretien et, par conséquent, bien adaptés au milieu arctique. Cette méthode favorise également la participation d'étudiants ou d'autres personnes intéressées à prélever des 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 s'échelonnera sur quelques années et permettra de compiler les concentrations atmosphériques de nombreux polluants au sein d'un réseau de sites disséminés dans le Nord. Des échantillonneurs atmosphériques passifs et du matériel d'échantillonnage ont été acheminés à sept sites du Nord afin d'entamer le processus d'échantillonnage atmosphérique en octobre 2014. Au début du projet, des problèmes ont entraîné des retards, mais la plupart des sites sont maintenant pleinement opérationnels, et nous continuons de travailler à la résolution des problèmes afin que tous les sites soient fonctionnels. Les essais sur le terrain visant à mettre au point un échantillonneur passif pour détecter les concentrations atmosphériques de mercure progressent bien. Un étudiant du Nord a été embauché pour mener une recherche sur les connaissances autochtones dans la région du Yukon qui pourraient être mises à profit dans les projets de surveillance atmosphérique des POP et du mercure. Les principaux chercheurs du projet se sont rendus à Iqaluit (Nunavut), à Whitehorse (Yukon) et à Cambridge Bay (Nunavut) afin de discuter avec les comités régionaux des contaminants et les dirigeants des collectivités respectifs des plans et 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 du

Yukon (Yukon), au Collège de l'Arctique du Nunavut (Iqaluit et Cambridge Bay) et à l'école secondaire de Kiilinik de Cambridge Bay.

Key Messages

- Passive air sampling equipment has been sent to 7 arctic sites and most stations were in operation since October 2014.
- Project Principal Investigators visited Iqaluit (Nunavut), Whitehorse (Yukon) and Cambridge Bay (Nunavut) 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, Yukon College and the Kiilinik High School in Cambridge Bay.
- Organochlorines (OCs) are frequently found in air samples collected in 2015. Hexachlorobutadiene (HCBD), hexachlorobenzene, (HCB), pentachloronitrobenzene (PCNB), pentachloroanisole (PCA), 2, 4-dibromoanisole (DBA), and 2, 4, 6-tribromoanisole (TBA) were found in all passive air samples collected and the concentrations are consistent with those found previously in other studies.

Messages clés

- De l'équipement d'échantillonnage atmosphérique passif a été acheminé à sept différents sites dans l'Arctique, et la plupart des stations étaient opérationnelles depuis octobre 2014.
- Les principaux chercheurs du projet se sont rendus à Iqaluit (Nunavut), à Whitehorse (Yukon) et à Cambridge Bay (Nunavut) 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 arctique du Nunavut, au Collège du Yukon et à l'école secondaire de Kiilinik de Cambridge Bay.
- Des organochlorés sont fréquemment décelés dans les échantillons atmosphériques prélevés en 2015. Des concentrations d'hexachlorobutadiène (HCBD), d'hexachlorobenzène (HCB), de pentachloronitrobenzène (PCNB), de pentachloroanisole (PCA), de 2, 4-dibromoanisole (DBA) et de 2, 4, 6-tribromoanisole (TBA) étaient présentes dans tous les échantillons d'air prélevés par des échantillonneurs passifs et concordent avec les concentrations observées précédemment dans d'autres études.

Objectives

Short-term objectives of this project are:

- 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.
- Determine latitudinal gradients in air concentrations from which empirical estimates of characteristic travel distances (CTDs) of pollutants can be made.
- 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.
- 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:

- 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.
- 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.
- Track long-term trends in pollutants to evaluate the effect of global and regional environmental changes at multiple Arctic locations.

Introduction

This project aims to measure 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 collaborates 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 2014-2015, 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 2015 air samples were sent back to Environment and Climate Change Canada (ECCC) where they were analyzed for priority chemicals. Results from these analyses 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 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 2016-2017

Activities at Passive Air Sampling Sites

Sampling at most of the 7 sites started in winter 2014/15. However, in FY2016/17, some sites have encountered problems and samples were not taken or lost, mostly due to changes in personnel.

At the Iqaluit station, former operator Karlene Napayok has left the program and supervisor Jamessee Moulton has taken on an assignment, this resulted in some confusion on when to change samples. Samples for the first and second quarters Q1 (Jan-Apr) and Q2 (Apr-Jul) of 2016 were not deployed. New operators, David Oberg and Chris Spencer, have now been identified and sampling has resumed.

At the Kuujjuaq station, PUF-disk-based samples were not taken during the first half of 2015 and mid-2016 (Q2 and Q3, i.e. Jul-Oct). These samples were not deployed due to personnel issues. That problem has been resolved and samples should be returning regularly now. In Dec 2016, we have received one sample from Kuujjuaq that was sent unpadded and the sample jar was broken. We have reminded the operator to pad all sample cartons securely before sending.

Hayley Hung was at Cambridge Bay September 13-15, 2016 and found that the PUF-disk based passive sampler has not been changed since October 2014 but now the site is next to an active quarry, so the sample cannot be used anymore as it is covered with dust. The XAD-based passive sampler has not been deployed. The current location is going to become the new center of town, thus there is intention to move the samplers to the North end of Greiner Lake where there are other measurements being planned under the Canadian High Arctic Research Station. POLAR staff will assist in finding a new location for the sampler and will move the samplers.

The Northwest River station has only been setup in Nov/Dec 2016; samples have not yet been received.

For the other stations, some delays were encountered due to staff changeover, poor weather conditions and/or damage to the samplers (someone shot at the samplers at Fort Resolution), but sampling is currently ongoing. We are in continuous communication with the various sampling sites to ensure that these problems are resolved in coming years. The training videos for operators continue to be available online.

Passive sampler analysis

Air samples collected in 2015 have been extracted and analyzed for organochlorine pesticides (OCs), non-brominated diphenylether flame retardants (non-BDE FRs), poly-BDEs (PBDEs), chlorinated-FRs (CFRs), brominated anisoles (BA), and neutral per- and polyfluoroalkyl substances (PFASs). Preliminary results are presented here in the Results section.

Communications and Capacity Building

Hayley Hung visited Cambridge Bay from September 13 to 15, 2016. Unfortunately, Sandy Steffen had to cancel her trip to Cambridge Bay as she had a medical emergency and was in the hospital. Hayley gave a seminar to the Environmental Technology Program students at the Nunavut Arctic College (with Instructor Erin Hamilton) and a seminar at the Kiilinik High School (School Principal Roman Mahnic). Both seminars were well-received. Hayley also met with Marla Limousin, Senior Adminstrative Officer of the Municipality of Cambridge Bay, and the Executives of the Ekaluktutiak Hunters & Trappers Organization (EHTO) to discuss about the project and our sampling and outreach activities in Cambridge Bay. Mia Otokiak, the local radio host, did an interview with Hayley on contaminants in Arctic air and the NCP's passive air sampling activities in town. The interview was broadcasted live in the community on Sept. 13 in the afternoon. Hayley met with Polar Knowledge Canada (POLAR) staff Angut Pedersen (passive sampling site operator), Dwayne Beattie (Manager, Technical Operations, CHARS) and Crystal Qaumariaq (Communication and Consultation Officer, CHARS) to discuss about passive sampling arrangements and our outreach activities at Cambridge Bay. Hayley's accommodation was kindly provided by POLAR for free at the CHARS Researcher Triplex.

Hayley Hung, Alexandra Steffen and Liisa Jantunen visited Iqaluit in January 2017 to conduct a half-day lecture and half-day activity session to the students of the Environmental Technology Program at the Nunavut Arctic College. They have also met with the Nunavut Environmental Contaminants Committee (NECC) to discuss about the communication and capacity building plan of the projects. When visiting Iqaluit again in February 2017, the team met with Matthew Hamp, Director of Public Works and Engineering, City of Iqaluit, to discuss about the passive air sampling work.

On March 1-2, 2017, Hayley Hung and Alexandra Steffen attended the Yukon Contaminants Workshop and gave presentations about the mercury and organic pollutant measurements in air in Little Fox Lake and the seminars were well-received by First Nations and other community members (about 50 people) that participated in this workshop.

Hayley has received an email from Annie Boucher (Executive Director of Akaitcho Territory Government (ATG)) indicating that Chief Wanderingspirit of Smith's Landing First Nation would like to enquire on how their First Nation can become involved in the passive air sampling program. Hayley placed several calls and left voice messages at the Chief's office over the summer but has not managed to make an appointment to discuss with the Chief. On Sept. 29, 2016, Hayley managed to speak to the operator at the Chief's office and has found out Chief Lorraine MacDonald is now the new Chief. Following the operator's instructions, Hayley sent an email to Chief MacDonald with a brief summary of the project to enquire if she would be interested to discuss about the project and whether we can make an appointment for this discussion. However, we have not yet received a response. Hayley will continue to follow-up with the ATG on this request.

Indigenous Knowledge (IK) Integration

For FY2016/17, in collaboration with the Derek Cooke (Ta'än Kwach'än Council), Bob Van Dijken (Council of Yukon First Nations (CYFN), retired) and Pat Roach (CIRNAC, retired), we have engaged Jamie Thomas, a Yukon student, to do research on the IK information in the Yukon region in order to better understand how to use IK in the NCP air monitoring projects of POPs and mercury. We have discussed this plan with Derek Cooke (partner of projects M-01, M-02 and M-03) and have briefed James MacDonald (CYFN, taking over for Bob Van Dijken) and Ellen Sedlack (CIRNAC, taking over for Pat Roach) on this subproject.

In consultation with the PIs and the Ta'än Kwach'än Council, Jamie hosted a consultation session (March 2017) and invited local Yukon elders to attend and engage in a discussion on Indigenous Knowledge. The event was conducted at the Yukon Horse Packing retreat facility which is located between Whitehorse and Little Fox Lake, on Fox Lake. The plan was to conduct this session in the style of a "world café" where people can come and go, enjoy some food, enjoy the outdoor and indoor location and talk in an informal manner. Jamie made posters of the research activities from the area and invited elders to comment and discuss their views. Unfortunately, not many people attended the event. Therefore, to gather the IK information necessary to deliver results for this sub-project, Jamie conducted 3-4 interviews with elders and is in the process of transcribing the interviews and writing the final report.

Results

Organic Pollutants in the PUF-disk and XAD-based Passive Samples in 2015

PUF-disk and XAD-based passive samples (refer to as PUF-PAS and XAD-PAS hereafter) collected in 2015 from 5 Arctic sites and one urban site were extracted. The name of the sites and number of PUF-PAS (n) analyzed were: Fort Resolution, FRE (n = 4), Inuvik, IN (n = 4), Iqaluit, IQ (n = 3), Kuujjuaq, KU (n = 2), and Nain, NA (n = 3), Downsview, DV (n = 4). DV is the urban site. Two XAD-PAS were extracted at each site, and the extracts were combined for analysis.

So far, we have analysed the samples for 25 organochlorine pesticides (OCs), 14 non-brominated diphenylether flame retardants (non-BDE FRs), 14 poly-BDEs (PBDEs), 3 chlorinated-FRs (CFRs), 2 brominated anisoles (BA), and 10 neutral per- and polyfluoroalkyl substances (PFASs). The non-BDE FRs, PBDEs, CFRs, PFASs were rarely found in the Arctic sites and the concentrations were close to the detection limit. OCs were frequently detected in the samples. Here, the OCs that were found in all PUF- and XAD-PAS are discussed. These OCs are: hexachlorobutadiene (HCBD), hexachlorobenzene, (HCB), pentachloroanisole (PCA), 2, 4-dibromoanisole (DBA), and 2, 4, 6-tribromoanisole (TBA).

We present the results in units of $pg \cdot m^{-3}$ by assuming linear uptake of chemicals by the PUF- and XAD-PAS. The sampling rate of PUF-PAS was assumed to be 4 $m^3 \bullet day^{-1}$ for all sites (Pozo et al., 2009), and XAD-PAS was 0.59 $m^3 \cdot day^{-1}$ for the Arctic sites and 1.85 $m^3 \bullet day^{-1}$ for the urban site (Hayward *et al.*, 2010). It is noted that the PUF-PAS are 3-months integrated sample, while the XAD-PAS are one-year integrated sample. Furthermore, the PUF-PAS captures both gas- and particle phase chemicals while the XAD-PAS only captures gas-phase chemicals. Our results are considered semi-quantitative.

The overall means and ranges ($pg \bullet m^{-3}$) of chemicals in the PUF-PAS from the 5 Arctic sites were: HCBD = 10 (4.3-21), HCB = 130 (30-280), PCA = 8.0 (1.7-13), DBA = 17 (8.1-28), TBA = 98 (20-205). For the urban site, DV, which is used as a reference here: HCBD = 2.4 (0.8-5.1), HCB = 26 (9.2-54), PCA = 8.0 (5.7-11), DBA = 3.5 (2.1-5.5), TBA = 14 (3.4-24).

The concentrations and ranges ($pg \bullet m^{-3}$) of chemicals in the XAD-PAS from the 5 Arctic sites were HCBD = 770 (280-1230), HCB = 110 (510-1230), PCA =6.7 (3.9-13), DBA =35 (17-70), TBA = 150 (71-300). For the urban site, DV: HCBD =67, HCB = 25, PCA = 10, DBA =4.1, TBA = 22.

Figure 1 shows the concentrations of chemicals in individual PUF- PAS, XAD-PAS, and mean PUF-PAS. Among the Arctic sites, Iqaluit (IQ) has the highest concentration in HCBD, HCB, PCA and DBA, and TBA, while Fort Resolution (FRE) has the lowest concentration in all of the above mentioned OCs. The levels of most OCs, except PCA, at the urban site, DV, were lower than the Arctic sites. There is no clear seasonality observed in the PUF-PAS which were deployed in different seasons. Concentration of HCBD in XAD-PAS was 80 times higher than PUF-PAS but concentrations of other chemicals in the XAD- and PUF-PAS agreed well, varying within a factor of two.

Discussions and Conclusions

HCBD is a by-product of the manufacturing of organochlorine solvents, as well as incineration processes. Class and Ballschmiter (1987) reported that HCBD at 18 background stations in Europe and North Atlantic Ocean ranged from 210 to 3200 pg•m^{-3}, with geometric mean of 1800 pg•m^{-3}. The literature value is higher than our mean PUF-PAS at the Arctic sites (i.e. 10 pg•m^{-3}). However, our HCBD in the XAD-PAS was 770 pg•m^{-3}, which is 80 times higher than the PUF-PAS, but within the range of those reported by Class and Ballschmiter (1987). HCBD has a relatively high vapour pressure (20 *Pa at 20°C*, Mackay et al., 1998). It is possible that the chemical has reached equilibrium during the 3-month deployment period of the PUF-PAS, thus sampling volume of the PUF-PAS was over-estimated, resulting in a lower concentration. The assumption of linear uptake for PUF-PAS may not be valid. XAD-PAS has a high uptake capacity and uptake of HCBD should be linear, thus providing a better estimation of air concentration (Hayward et al. 2010).

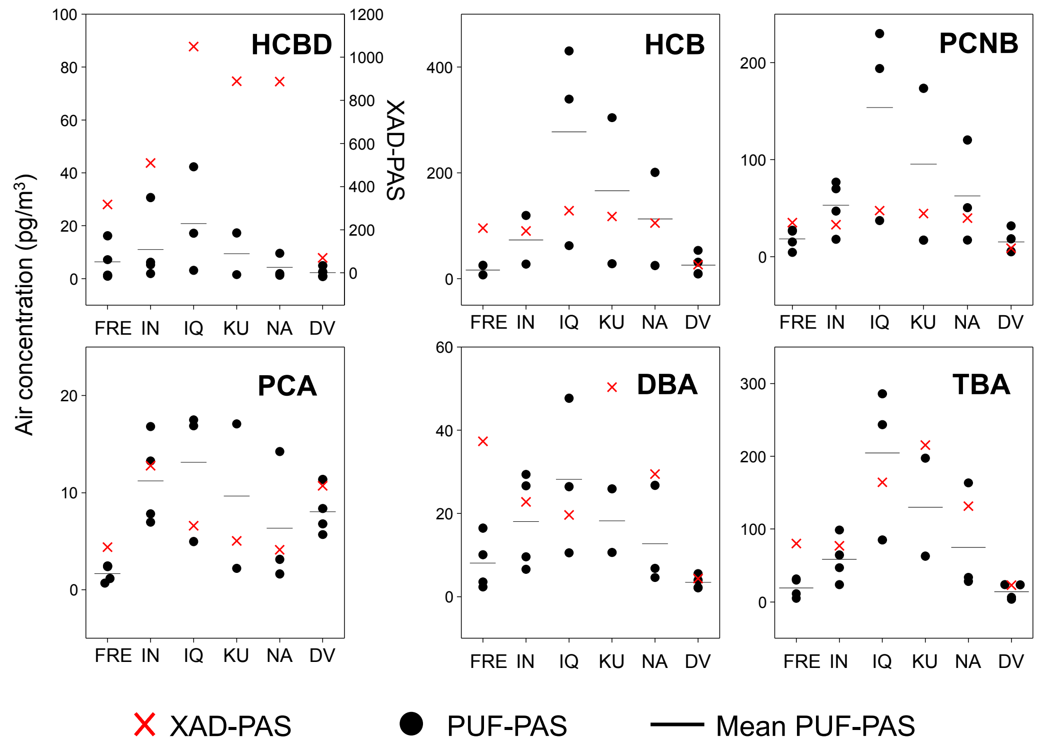
HCB is a by-product of the manufacturing of chlorinated chemicals, an impurity in pesticides, and a product of industrial/combustion sources. Su et al. (2006) reported that HCB was evenly distributed in the circumpolar atmosphere and uniform throughout the seasons. This is consistent with our observation that HCB concentrations in our 4 Arctic sites (i.e., Inuvik (IN), Iqaluit (IQ), Nain (NA), and Kuujjuaq, (KU)) are similar, varying within a factor of 3 (i.e. within the margin of error expected for passive sampling).

PCA is a biodegradation product of pentachlorophenol (PCP), which is used as a pesticide and a wood preservative. Su et al. (2008) reported that concentrations of PCA at 5 Arctic stations were comparable, varying within a factor of 2. Levels of PCA at IN, IQ, NA, and KU were similar, spanning a narrow range of 6.3 to 13 pg•m^{-3}. Our results are in line with Su et al. (2008), suggesting that emission of PCA and its precursor PCP in the Arctic is homogenous.

Bromoanisoles (BAs) are transformation products of bromophenols (BPs) by microorganisms. BPs are manufactured as fumigants, wood preservatives, and intermediates for the production of high-molecular weight flame retardants. They are also naturally produced by marine organisms. Wong et al. (2010) reported that levels of DBA and TBA in the Canadian Archipelago in 2008 were 16 and 23 pg•m^{-3} in marine air respectively. Recent measurements of DBA and TBA in the Baltic in 2012-2013 were 21 and 43 pg•m^{-3} respectively (Bidleman et al 2016). Our measurements of the BAs were within the range of the literature values.

In conclusion, our initial results indicate that the volatile OCs were commonly found in our Arctic sites. PUF- and XAD-PAS provided good means in capturing the volatile organic chemicals in Arctic air. Our results, in general, are consistent with the literature data. We will further investigate the sources and transport of these chemicals to the Arctic and performance of the PUF- and XAD-PAS.

Figure 1. Air concentrations (pg•m-3) of OCs in individual PUF-PAS (black dots), XAD-PAS (red cross) and mean PUF-PAS (black line). FRE = Fort Resolution, IN = Inuvik, IQ = Iqaluit, KU = Kuujjuaq, NA = Nain, DV = Downsview. Note that DV is an urban site.



Expected Project Completion Date

Ongoing

Acknowledgments

The team would like to acknowledge NCP (CIRNAC) for funding the passive air sampling network. The continued support of the five 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 (CIRNAC) 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.

We would also like to thank the following volunteers/agencies which continue to provide the sample change service as in-kind contribution to the project: Iqaluit (David Oberg and Chris Spencer, Nunavut Government); Nain and Northwest River – 2 sites (Rodd Laing and Liz Pijogge, Nunatsiavut Government); Inuvik (Erika Hille, Annika Trimble, Edwin Amos, Andrew Gordon, and Jolie Gareis, Aurora College); Cambridge Bay (Donald S. McLennan, Angulalik Pedersen, Dwayne Beattie and Johann Wagner, POLAR) and Kuujjuaq (Michael Barrett, Véronique Gilbert and Monica Nashak, Kativik Regional Government).

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

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

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Abstract

This project addresses the following major questions: (i) how are concentrations of legacy contaminants, such as polychlorinated biphenyls (PCBs) and other persistent organic pollutants (POPs) as well as mercury, changing over time in ringed seals and (ii) are trends similar across the Canadian Arctic. The presence and trends of new contaminants are also investigated. The project currently involves annual sampling at Sachs Harbour, Resolute Bay, Arviat, and Nain. All sampling is done by local harvesters and coordinated by Hunters and Trappers Associations in each community. The 2015-16 report focused on updates for

Résumé

Le présent projet traite des principales questions suivantes : i) de quelle façon les concentrations de contaminants hérités du passé comme les biphényles polychlorés (BPC) et d'autres POP ainsi que le mercure évoluent-elles au fil du temps chez le phoque annelé; ii) les tendances sont-elles semblables à la grandeur de l'Arctique canadien? La présence et les tendances des nouveaux contaminants sont aussi étudiées. Le projet consiste actuellement à faire des échantillonnages annuels à Sachs Harbour, Resolute Bay, Arviat et Nain. Toutes les activités d'échantillonnage sont menées par des chasseurs locaux et coordonnées par les

trends of polychlorinated naphthalenes (PCN), polybrominated diphenyl ethers (PBDEs) and other emerging flame retardants as well as for perfluoroalkyl substances (PFAS) in ringed seals. In this 2016-2017 report, updated trends of mercury and PCBs in ringed seal tissues are presented. The addition of a traditional knowledge component to this long-term monitoring project is also discussed.

Results of this core monitoring project indicated that concentrations of legacy PCBs continued to decline slowly. Mercury concentrations in liver and muscle varied from year to year but overall were not increasing. The annual measurements of contaminants in Arctic ringed seals have demonstrated that these pinnipeds are very good indicators of changing uses and production of chemicals widely incorporated in consumer and industrial products.

In 2016, a one-day educational workshop on ringed seal health was successfully organized at the Qarmartalik School in Resolute Bay. This project engaged youth, elders and scientific researchers in learning about ringed seals from both Inuit Qaujimajatuqangit and scientific perspectives. Collaboration between the current Environmental Monitoring project and an NCP Communications, Capacity and Outreach project provided the cost effective opportunity to create this educational workshop and enhance local capacity building, communications, and the integration of traditional knowledge in contaminants research on ringed seals.

associations de chasseurs et de trappeurs de chacune des collectivités. Le rapport 2015-2016 se concentrait sur la mise à jour des tendances des naphtalènes polychlorés (NPC), des polybromodiphényléthers (PBDE) et d'autres nouveaux produits ignifuges, de même que des substances perfluoroalkyliques (PFAS) chez le phoque annelé. Le rapport 2016-2017 présente les tendances mises à jour des concentrations de mercure et de BPC dans les tissus du phoque annelé. On y aborde également l'ajout d'une composante relative aux connaissances traditionnelles à ce projet de surveillance à long terme.

Les résultats de ce projet de surveillance de base indiquent que les concentrations de BPC hérités du passé continuent de diminuer lentement. Les concentrations de mercure dans le foie et les muscles varient d'une année à l'autre, mais, dans l'ensemble, n'augmentent pas. Les mesures annuelles des contaminants chez le phoque annelé de l'Arctique ont montré que cette espèce de pinnipèdes est un très bon indicateur de l'évolution de l'utilisation et de la production de substances chimiques largement intégrées dans les produits de consommation et les produits industriels.

En 2016, l'école Qarmartalik de Resolute Bay a organisé avec succès un atelier éducatif d'une journée sur le phoque annelé. Des jeunes, des aînés et des chercheurs scientifiques ont participé à cet atelier d'apprentissage de connaissances sur le phoque annelé, tant du point de vue scientifique que du point de vue des Inuits Qaujimajatuqangit. Les synergies entre le projet de surveillance environnementale actuel et le projet sur les communications, les capacités et la sensibilisation du Programme de lutte contre les contaminants dans le Nord (PLCN) ont permis de mettre sur pied, à faible coût, cet atelier éducatif et d'améliorer le développement des capacités à l'échelle locale, les communications et l'intégration des connaissances traditionnelles dans les études des contaminants chez le phoque annelé.

Key Messages

- Polychlorinated biphenyls continue to decline slowly in blubber of ringed seals.
- Mercury concentrations in liver and muscle vary from year to year but overall are not increasing in ringed seals.
- Synergies between NCP Environmental Monitoring and Communications, Capacity and Outreach programs provide a cost effective opportunity to enhance local capacity building, communications and the use of traditional knowledge in contaminants research on ringed seals.

Messages clés

- Les concentrations de BPC continuent de diminuer lentement dans le pannicule adipeux des phoques annelés.
- Les concentrations de mercure dans le foie et les muscles varient d'une année à l'autre, mais, dans l'ensemble, n'augmentent pas chez le phoque annelé.
- Les synergies entre le projet de surveillance environnementale actuel et le projet sur les communications, les capacités et la sensibilisation du PLCN ont permis d'améliorer, à faible coût, le développement des capacités à l'échelle locale, les communications et l'utilisation des connaissances traditionnelles dans les études des contaminants chez le phoque annelé.

Objectives

- 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 across the Canadian Arctic.
- 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 Northwest Territories Environmental Contaminants Committee, and the Nunatsiavut Health and Environment Research Committee.
- Present results and organize sessions on northern contaminants at national and international meetings.
- Contribute to a health in ringed seal workshop in Resolute Bay, NU that aims to engage youth, elders and scientific researchers in learning about ringed seal health from both *Inuit Qaujimajatuqangit* and scientific perspectives (in relation with a funded project by Henri, Houde and Provencher; Communications, Capacity and Outreach).

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, 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 of the communities in Nunavut, Nunavik, Nunatsiavut, and the Inuvialuit Settlement Region, this project provides an opportunity to involve the communities in the scientific program of the NCP. Participation of hunters in each community has been consistent and the quality of the hunter based collection has generally been high.

The 2015-16 report focused on updates for trends of polychlorinated naphthalenes (PCN), polybrominated diphenyl ethers (PBDEs) and other emerging flame retardants as well as for perfluoroalkyl substances (PFAS) in ringed seals. In this 2016-2017 report, updates on trends of mercury and polychlorinated biphenyls (PCBs) in ringed seal tissues are presented. The addition of a traditional knowledge component to this long-term monitoring project is also discussed.

Activities in 2016-2017

In 2016, ringed seal samples were successfully collected by hunters in the communities of Arviat (n=25), Sachs Harbour (n=22), Resolute Bay (n=13), and Nain (n=12). Reporting of biological data was very good with length and axial girth reported for all animals, and gender, blubber thickness, and maximum girth recorded for most animals.

As required under the NCP "Blueprint" for 2016-17, legacy POPs, i.e. chemicals currently on the Stockholm Convention list, were determined in ringed seals samples. New/emerging organic contaminants were also analyzed in 40 samples. Multi-element analyses were conducted on liver and provided concentrations of a range of toxic metals and essential elements. In addition to mercury, knowledge of the concentrations of two elements, selenium and cadmium, is particularly of interest. Selenium is important because of its protective role in reducing the toxic effects of methylmercury. Information on cadmium is also important because of its toxicity and relatively high levels in seal liver.

Chemical analyses

Analyses of organochlorine pesticides (OCPs) and PCBs in the 2015 and 2016 samples were contracted to ALSGlobal (Burlington, ON). Results for both years 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 $^{13}C_{12}$-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 brominated flame retardant/toxaphene determination (0.45mL). A suite of ^{13}C 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 analyzed by gas chromatography-low resolution mass spectrometry (GC-LRMS) for 94 PCB congeners or co-eluting congener groups. A suite of deuterated and ^{13}C-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 $^{13}C_{12}$ PCB-133 response. The suite of OCPs and PCBs analyzed was identical to the previous suite analyzed by the National Laboratory for Environmental Testing (NLET) organics lab. PBDEs and other brominated flame retardants as well as toxaphene and endosulfan isomers were analyzed on the remaining extract using GC-negative ion LRMS by the NLET organics lab.

Instrumental analysis was performed by liquid chromatography-tandem mass spectrometry (LC-MS/MS). 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). 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 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 the Canadian Standards Association and are participating annually in the NCP Interlab comparisons. The Muir lab at Environment Canada Burlington participated in the NCP Interlab 2016-17 comparisons for PFASs and for mercury. Quality assurance steps were included the analysis of reference materials for heavy metals and POPs and reagent blanks with each batch of samples. All results were blank subtracted.

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 that were <2 and geometric means (back transformed log data) were calculated. Significant model components for temporal trends were conducted using SAS 9.4 and SAS/STAT 13.1.

Communications

Regular communications were done with the Hunters and Trappers Committees of Arviat, Resolute, and Sachs Harbour, as well as the Environment Division of the Nunatsiavut Government. The main communications with the Hunters and Trappers Associations (HTAs) were done by phone and email. Short progress reports on the project in English and Inuktitut (for Nunavut) were sent in March 2017 to each participating HTA. Co-leaders of the project visited Resolute Bay in July and October 2016 and met with the Hunters and Trappers Organization (HTO) representative, the local school children, professionals, as well as elders. Results of this project were also presented at international meetings (e.g., ArcticNet, Society of Environmental Toxicology and Chemistry).

Indigenous Knowledge Integration

A traditional knowledge component was added to this project in 2016. The ultimate objectives of this work is to gather/document Inuit perspectives on various aspects of ringed seal ecology and to explore how information provided by community members could be linked with observed contaminant levels and trends. For this first year, a health in ringed seal workshop was held in Resolute Bay to engage youth, elders and scientific researchers in learning about ringed seals from both *Inuit Qaujimajatuqangit* and scientific perspectives. Interactions and discussions were very much appreciated by everyone. It is hoped to conduct this workshop every year in one of the four communities implicated in this core monitoring project.

Capacity Building

In October 2016, Houde participated in the health in ringed seal workshop held in Resolute Bay; Jennifer Provencher (replacing D. Henri who was on maternity leave) and a student from the Environmental Technology Program (ETP) at the Nunavut Arctic College were also present. Moreover, Muir visited Resolute Bay in July 2016 and met with the community members and the HTO. Houde and Muir have been invited to take part in a wildlife contaminants workshop at the Nunavut Arctic College in September 2017 in Iqaluit as part of training and capacity building. Houde and Muir will provide background on contaminants pathways and sources, and with the help of a local hunter, will co-lead the ringed seal dissections and discussions about wildlife sampling.

Results

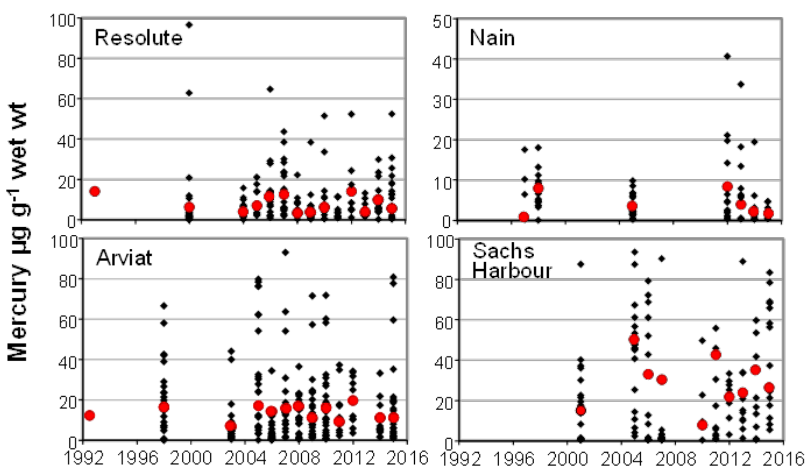
Sample collection and hunter observations

In 2016 the requested information on gender, girth, length, and blubber thickness was provided for all harvested animals except for three seals. The identification of the gender of the seals by hunters in the field was in agreement with DNA results. 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.

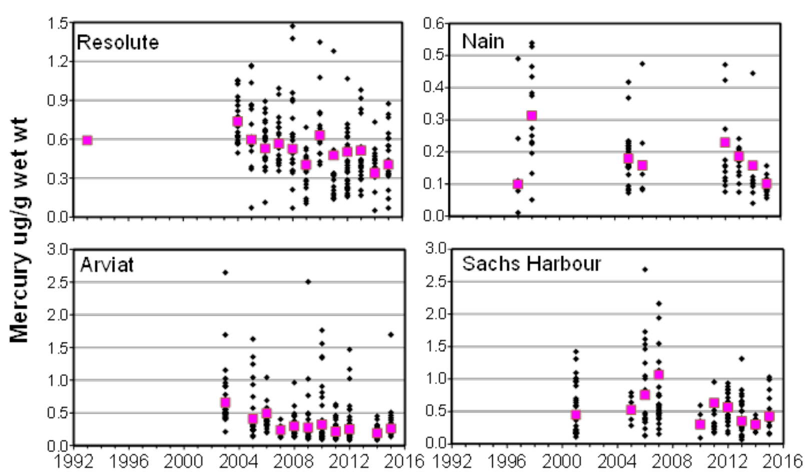
Mercury Trends in concentrations of mercury in ringed seal liver and muscle for the four communities were updated with samples from 2015 and results are shown in Figure 1. Results were for adults only (4+ years) because concentrations show little variation with age in mature seals. Average mercury concentrations in muscle were generally lower from 2010-2015 compared to the late 1990s and early 2000s; however, the differences were not statistically significant. Concentrations of mercury in liver were more variable than in muscle. Continued annual sampling and comparison with climate and food web related variables may help discern reasons for this variation.

Figure 1. Trends of mercury in A) liver and B) muscle of adult ringed seals (≥ 4years old) up to 2015. Red circles and pink squares are geometric mean concentrations in liver and muscle, respectively. Smaller dark symbols are individual results for each year of collection.

A) Liver

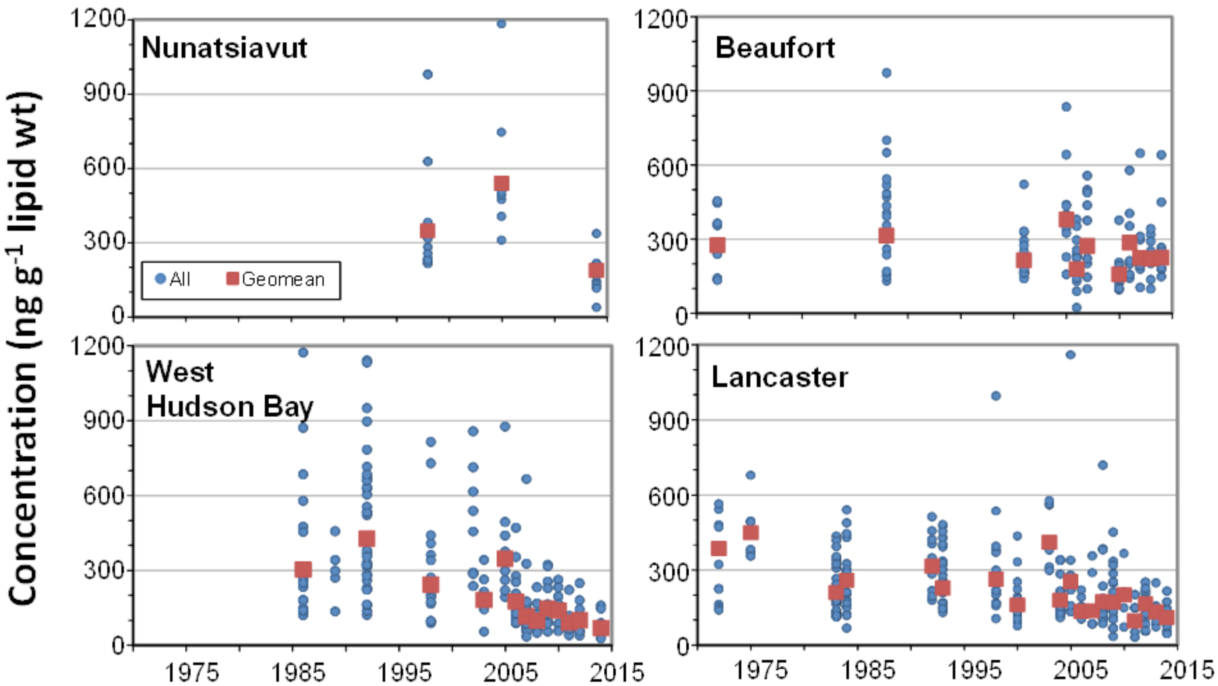


B) Muscle



Polychlorinated biphenyls (PCBs) - Results for PCBs (1970s-2014) in blubber of ringed seals from the four regions have been updated and are shown in Figure 2. Females and juvenile males have been analyzed for PCBs and other POPs because results were not influenced by age, whereas for adult males, age influenced PCB and POPs concentrations (Addison and Smith 1974). PCB concentrations were declining more rapidly in seals from the Western Hudson Bay (Arviat) and Lancaster (Resolute Bay) than in seals from the Beaufort Sea (Sachs Harbour/ Ulukhaktok). There were still too few sampling years from Nunatsiavut (Nain) to assess temporal trends.

Figure 2. Trends of PCBs (sum of 10 congeners) in ringed seal blubber (females and juvenile males) from the 1970s to 2014. Red squares were geometric mean concentrations and smaller dark symbols were results for individual seals from each year of collection. Nunatsiavut samples from Nain and Makkovik (1998 only); Beaufort included Sachs Harbour and Ulukhaktok (2006 and 2010); Lancaster included Resolute Bay, Arctic Bay and Grise Fiord; West Hudson Bay included Arviat and Rankin Inlet (1986 only).



Discussion and Conclusions

Results of this core monitoring project indicated that concentrations of legacy chemicals, such as PCBs, continued to decline slowly. Mercury concentrations in liver and muscle varied from year to year but overall were not increasing. The annual measurements have demonstrated that seals are very good indicators of changing uses and production of chemicals widely used in consumer and industrial products. The bans of PBDEs and PFOS for example, were followed by decreases in tissue concentrations in seals. In 2017-18, mercury and heavy metals will be analyzed at all four locations; new/emerging POPs will also be determined at two locations, Sachs Harbour and Arviat.

In 2016, a one-day educational workshop on ringed seal health was successfully organized at the Resolute Bay school. This project engaged youth, elders and scientific researchers in learning about ringed seals from both *Inuit Qaujimajatuqangit* and scientific perspectives. Collaboration between the current project and the Communications, Capacity and Outreach project (by Houde, Henri and Provencher) provided a cost effective opportunity to enhance local capacity building, communications and the use of traditional knowledge in contaminants research on ringed seals. The long term vision is to hold in the next years a similar workshop in the three other communities that contribute to the NCP core ringed seal monitoring project starting with Sachs Harbour in 2017-2018.

Expected project completion date

This is an on-going core monitoring project.

Acknowledgments

We are grateful to the hunters in each northern community for their long-term participation in this project. We also thank the Hunter and Trapper Associations of Qausuittuq, Sachs Harbour, Resolute Bay, and Arviat as well as the Nunavut Environmental Contaminants Committee, the NWT Regional Contaminants Committee and the Environment Division, Nunatsiavut Government in Nain, for their support throughout the years. We finally acknowledge the staff of the NLET inorganics as well as Ron MacLeod and Whitney Davis at ALS Global (Burlington) for conducting POPs analysis and providing detailed data reports.

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Temporal and spatial trends of legacy and emerging organic and metal/elemental contaminants in Canadian polar bears

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

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Abstract

The polar bear (Ursus maritimus) is the top predator of the arctic marine ecosystem and food web. Starting in 2007 ongoing in 2016-2017, this project samples on a biennial or annual basis, and continues to assess longer-term temporal trends and changes of NCP priority persistent (legacy and emerging) organic and elemental pollutants (POPs) in polar bears focusing on 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) and are NCP priority contaminants/POPs, for example tetra- to octa-brominated diphenyl ether (PBDE) flame

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 s'est poursuivi en 2016-2017, prélève des échantillons sur une base annuelle ou bisannuelle, et continue d'évaluer les tendances et les variations temporelles à plus long terme qui caractérisent les POP prioritaires (anciens et émergents) du PLCN et qu'on retrouve dans les tissus des ours blancs des sous-populations du sud et de l'ouest de la baie d'Hudson (Nunavut). Pour les nouveaux POP qui sont actuellement bannis ou réglementés (p. ex., en vertu du protocole de la Convention de Stockholm sur les POP) et qui sont les contaminants ou POP

retardants (FRs), both subpopulations continue to show a gradual decreasing trend from 2009 to 2016 for the sum (Σ) PBDE concentrations. Although quantifiable in the low ppb up until 2013, hexabromocyclododecane (HBCDD) has not been detectable in fat samples from 2014 to 2016 collections. Similarly and again in 2016, many non-PBDE and replacement or re-emerging FRs were not detectable as well. Since 2007 and including 2016, PFOS and sum (Σ) PFCA concentrations remained high (approaching or surpassing the ppm level) and have not temporally decreased in bear liver. A sub-set of 2016-2017 samples were analyzed for a suite of polychloronaphthalenes (PCNs) to complement data from 2013-2014 bear data, but concentrations were at the low ppb level. The present 2016-2017 monitoring year is an even year and thus legacy POPs (i.e., PCBs, chlordanes, DDTs and ClBzs) were also monitored (in fat) as well as total mercury (in liver). When compared to previous years, 2016-2017 legacy POP levels were basically unchanged. To more clearly reveal temporal trends, emerging POP concentration variance due to confounding factors is also being determined from collected data for 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). Northern peoples are integral partners as they carry out the annual harvest of polar bears and provide the collected tissue samples for this legacy and emerging POP/Hg monitoring.

prioritaires du PLCN, y compris les produits ignifuges tels que les tétrabromodiphényléthers ou les octabromodiphényléthers (PBDE), les deux sous-populations ont continué d'afficher des tendances graduelles à la baisse de la somme (S) des concentrations de PBDE de 2009 à 2016. Bien que quantifiable en quelques ppm (parties par milliard) jusqu'en 2013, l'hexabromocyclododécane (HBCDD) n'était pas détectable dans les échantillons de graisse d'ours prélevés de 2014 à 2016. De la même manière en 2016, bon nombre de produits ignifuges de remplacement ou réémergents et sans PDBE étaient également indétectables. Depuis 2007, et aussi pour 2016, les concentrations de PFOS et la somme (S) des concentrations de PFCA sont demeurées élevées (approchant ou dépassant le niveau de ppm) et n'ont pas diminué de façon temporaire dans le foie des ours. Un sous-ensemble des échantillons de 2016-2017 a été analysé pour détecter une série de naphtalènes polychlorés (NPC), afin de compléter les données des échantillons de 2013-2014 chez l'ours, mais les concentrations présentaient un faible niveau en ppm. L'année de surveillance actuelle (2016-2017) est une année paire, de sorte que les POP hérités du passé (c.-à-d., les BPC, les chlordanes [CHL], les dichlorodiphényltrichloréthanes [DDT]) et les chlorobenzènes [CIBz]) ont également été surveillés (dans les graisses), de même que le mercure total (dans le foie). Comparativement aux années précédentes, les concentrations de POP hérités du passé de 2016-2017 sont demeurées sensiblement les mêmes. Afin de déterminer plus clairement les tendances temporelles, on évalue également les variations des concentrations de POP qui sont attribuables à des facteurs de confusion, et ce, à l'aide des données recueillies sur l'âge, le sexe, l'état corporel, le moment de la collecte des données, la teneur en lipides, l'alimentation et le réseau trophique (p. ex., les ratios d'isotopes stables du carbone et de l'azote et le profil en acides gras). Les habitants du Nord sont des partenaires indispensables du projet puisqu'ils mènent une chasse aux ours blancs sur une base annuelle et qu'ils fournissent ainsi des échantillons tissulaires aux fins de la surveillance des contaminants (POP ou mercure) anciens et émergents.

Key Messages

- For western Hudson Bay bears as of 2016, the levels for ΣPCBs, ΣDDTs, ΣCHLs, α-HCH, β-HCH and ΣClBzs (in fat) were generally similar to those in samples going back to 2001. ΣPCBs and ΣCHLs continued to remain high in ppm (lipid weight corrected) concentrations.
- Trends for ΣPBDE concentrations (in fat) increased from 1991 to late 2000s for western Hudson Bay bears, but then decreased from 2010 to 2014, and appeared to be leveling off at about 50 ng•g^{-1} (lipid weight) between 2014 and 2016. Temporal trends were similar for southern Hudson Bay bears (2007-2008 to 2016 period); although for the southern subpopulation ΣPBDEs remained at about 80 ng•g^{-1} (lipid weight) between 2014 and 2016, and thus are at somewhat greater concentrations relative to the western subpopulation.
- HBCDD was consistently at low ppb levels in bear fat over the years 2001 to 2013, but was not detected in 2014, 2015 or 2016 samples for all bears. BB-153 concentrations were quite high in comparison to Σ_4PBDE concentrations in most years including 2016.
- Among the 22 PFASs analyzed (in liver) the concentrations were consistently greater for PFOS and ΣPFCAs (low levels of PFOA but mostly C_9, C_{10} and C_{11} PFCAs) in the Hudson Bay bears sampled over the period of 2007 to 2016.
- In the liver and in samples from 2010 through 2016, PFOS concentrations (800 to 2500 ng•g^{-1} (wet weight)) were consistently greater than for ΣPFCAs (500 to 1400 ng•g^{-1}) among all bears in 2016, and thus there were no obvious increasing or decreasing trends for ΣPFCAs and PFOS for both subpopulations of bears over the 2007-2016 period.
- From 2002 through 2016, THg concentrations in the liver ranged from 5 to 25 µg•g^{-1} (wet weight) and were generally unchanged and slightly greater in bears from western versus southern Hudson Bay.

Messages clés

- En 2016, chez les ours de l'ouest de la baie d'Hudson, les concentrations de SBPC, SDDT, SCHL, a-hexachlorure de benzène (HCH), b-HCH et SClBz (dans la graisse) étaient en général similaires à celles mesurées dans les échantillons datant de 2001. Les concentrations de SBPC et de SCHL sont demeurées élevées en ppm (poids lipidique corrigé).
- Les tendances des concentrations de SPBDE (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, et ont semblé se stabiliser à environ 50 ng•g^{-1} (poids lipidique) entre 2014 et 2016. Les tendances temporelles ont été semblables pour les ours du sud de la baie d'Hudson (période de 2007-2008 à 2016), bien que pour la sous-population du sud les concentrations de SPBDE soient demeurées à environ 80 ng•g^{-1} (poids lipidique) entre 2014 et 2016, et, par conséquent, elles sont légèrement supérieures à celles de la sous-population de l'ouest.
- Le HBCCD se retrouvait invariablement à de faibles concentrations en ppm dans la graisse des ours au cours des années 2001 à 2013, mais n'a pas été détecté dans les échantillons de tous les ours en 2014, 2015 ou 2016. Les concentrations de brominobiphényle-153 (BB-153) étaient assez élevées par rapport aux concentrations de S4PBDE pour la plupart des années, y compris 2016.
- Parmi les 22 PFAS analysés (dans le foie), les concentrations étaient invariablement supérieures pour le PFOS et le ΣPFCA (faibles concentrations d'APFO, mais surtout des PFCA en C9, C10 et C11) chez les ours de la baie d'Hudson échantillonnés au cours de la période de 2007 à 2016.
- Dans le foie et les échantillons prélevés de 2010 à 2016, les concentrations de PFOS (de 800 à 2 500 ng•g^{-1} [poids humide]) étaient invariablement supérieures à celles

des ΣPFCA (de 500 à 1 400 ng•g^{-1}) pour tous les ours en 2016. Par conséquent, il n'y avait aucune tendance à la hausse ou à la baisse évidente relativement aux ΣPFCA et au PFOS pour les deux sous-populations d'ours au cours de la période de 2007 à 2016.

- Entre 2002 et 2016, les concentrations de mercure total (HgT) dans le foie variaient de 5 à 25 mg•g^{-1} (poids humide), et étaient généralement inchangées et légèrement supérieures chez les ours de l'ouest par rapport à ceux du sud de la baie d'Hudson.

Objectives

- To continue to monitor with increased resolution in west Hudson Bay and south Hudson Bay polar bears the (retrospective) temporal trends and changes of legacy and emerging POPs that are NCP priorities, including those currently under review for regulatory action (e.g. Stockholm Convention on POPs).
- Use carbon and nitrogen stable isotopes and fatty acid profiles as ecological tracers, 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 participating in the study, as well as other northern communities, on the levels, changes and fate of POPs in polar bears.
- To archive the remaining polar bear tissue samples that were collected in Environment Canada's National Wildlife Specimen Bank (EC-NWSB), NWRC, Carleton University (Ottawa).

Introduction

Hg and a growing array of chlorinated, brominated and fluorinated POPs, have proven to be anthropogenic contaminants that are transported to the Canadian Arctic and accumulate in biota (Braune et al. 2015; Haider et al. 2015; Letcher et al. 2010; Morris et al. 2016; Muir et al. 2017, in press). These bioaccumulative POPs (and/or their precursors and degradation products) and Hg are transported via global atmospheric and/or oceanic pathways and processes that result in deposition in the Arctic, and are found in Arctic endothermic top predators, particularly in polar bears. Most known legacy and emerging POPs are lipophilic to some degree, and because lipids constitute an important energetic factor in polar biota, POPs are biomagnified in the long Arctic marine food chains. POP and Hg levels are generally very high in polar bears despite their relatively high ability to biotransform compounds via hepatic enzymatic processes and thus excrete these compounds (Braune et al. 2015; Letcher et al. 2010, 2015, 2016; McKinney al. 2011a, 2011b; Muir et al. 2017, In press; Rigét et al. 2016; Routti et al. 2011).

Polar bears are distributed throughout the circumpolar region, have unquestionable importance to Northerners both culturally and economically, and thus provide important sentinel or monitoring species for legacy and emerging POPs and Hg. The levels of POPs are generally the highest in the polar bear compared to other arctic wildlife (Letcher et al. 2010), and they 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. In Hudson Bay polar bears, levels of some legacy POPs such as PCBs decreased prior and up to 2000 but from 2000 up to 2016 have since remained relatively unchanged (Letcher et al. 2016). A number of (re)emerged environmental pollutants, such as short-chain chlorinated paraffins (SCCPs), polychlorinated naphthalenes (PCNs), PBDEs, other non-PBDE flame retardants, and perfluoroalkyl substances (PFASs; in particular the highly bioaccumulative perfluorooctane sulfonate (PFOS)), were reported, and in some cases for the first time, in the liver, fat and other tissues of polar bears (Boisvert et al., 2017; Letcher et al. 2016, 2017a, 2017b).

For 2016-2017 polar bear samples were analyzed for emerging POPs on a continued annual basis. This project provides important data on the presence, in polar bears, of priority chemicals to support the regulation of these chemicals as defined by international and national regulatory programmes and agreements. For example, negotiations on Hg that were initiated under the United Nations Environment Programme (UNEP) in 2009 produced a global legally binding treaty on Hg named the Minamata Convention, which was formally adopted in 2013. The present project also supports current agreements including the Stockholm Convention on POPs, the Basel Convention, and The Rotterdam Convention on Prior Informal Consent, SAICM, and the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP) Protocols on POPs and heavy metals. High priority POPs under consideration by or recommended for addition to the Stockholm Convention on POPs, and that have recently or are currently being reviewed by the POP Review Committee (POPRC) include DecaBDE (BDE-209) (recommended for addition), and SCCPs, perfluorooctane carboxylic acid (PFOA) and the pesticide dicofol.

This polar bear monitoring 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. For example, we have shown over the 1991-2007 period that changes in sea-ice in western Hudson Bay were linked to shifts in the diet of polar bears. These diet shifts have a varying influence on (mostly legacy) POP temporal trends (particularly PCBs, PBDEs) and on the more bioaccumulative legacy and new POPs present in arctic wildlife.

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 e.g. POPs (Bechshøft et al. 2013, 2017; Dietz et al. 2015, 2016; Ferguson et al. 2015; Letcher et al. 2010; McKinney et al. 2015; Muir et al. 2017, In press; Pavlova et al. 2016). More recently the warming of the Arctic has been signaled by the loss of multi-year sea ice, thawing of permafrost, and accelerated coastal erosion. This conversion of ice to water affects physical and biogeochemical pathways of POPs and other contaminants. This can result in alterations to animal behaviour such as habitat use and diet, as well as to ecosystem structure including the introduction of new species and loss of existing species. More recent research has shown that Arctic warming and changes in sea-ice can change exposure to POPs and Hg for Arctic biota, particularly for the polar bear (i.e. Canadian Hudson Bay and East Greenland subpopulations) (McKinney et al. 2011a, 2015).

Activities in 2016-2017

Field Sampling

Validated 2015 and 2016 Nunavut Wildlife Research Permits (NWRPs) were in place for polar bear sample collections during the harvests that occurred in late 2015 but mostly in early 2016 (during the 2016-2017 monitoring year) and carried out by communities in Hudson Bay and Baffin Bay. In September 2016, we also successfully applied for and received in December 2016, a 2017 NWRP. The NWRPs were prepared and evaluated in collaboration with communities via the Nunavut Department of Environment (Wildlife Management Research: M. Dyck and M. Harte). 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) were participants in this project in 2016-2017: Western Hudson Bay (Keewatin Region): Rob Harmer (CO) - Arviat; Johanne Coutu-Autut and Daniel Kaludjak - Rankin Inlet; Dan Mercer (CO; started in October 2016) - Whale Cove. Southern Hudson Bay (Qikiqtaaluk Region): Daniel Qavvik – Sanikiluaq; Baffin Bay (Qikiqtaaluk Region): Bruce Jerry Hainnu – Clyde River, George Koonoo – Pond Inlet.

As per the valid and approved 2015 and 2016 NWRPs, community hunters and COs collected polar bear fat, liver and/or muscle sample sets during harvests in the winter of 2015-2016, from n=21 western Hudson Bay: Arviat (n=8; 2 males and 6 females), Rankin Inlet (n=9; n=7 males and n=2 females), and Whale Cove (n=4; n=3 males and n=1 female); and from southern Hudson Bay: Sanikiluaq (n=20; n=14 males and n=6 females). Also, fat, liver and/or muscle sample sets were opportunistically collected from a total of n=25 bears from northern Baffin Island/Bay (Clyde River (n=8; n=7 males and n=1 female), Pond Inlet (n=12; n=8 males and n=4 females) and Qikiqtarjuaq (Broughton Island) (n=5; n=4 males and n=1 female) during the harvest period. 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. Sub-sample sets from these bears were shipped to the PI (Letcher) at NWRC in Ottawa in November 2016. All polar bear samples received by NWRC were processed, and portions of the Hudson Bay bear samples were taken for POP (fat, liver), element/metal (liver), FA (fat) and SI (muscle) analysis. Remaining sample portions were archived and are currently stored in ECCC's National Wildlife Specimen Bank (ECCC-NWSB) at the NWRC in Ottawa for future considerations (e.g. future retrospective monitoring of new/emerging POPs and possibly effects studies).

Sample Analysis

Since we only received and processed (including sub-sampling) the 2016 collected samples by the end of November 2016, it was only in December 2016 that we were able to perform all contaminant and other analyses on the samples. As of March 2017 the NWRC-OCRL completed all the POP analyses, and the NWRC-Lab Services completed the THg and FA (i.e., a suite of 37 saturated and polyunsaturated, C_6-C_{24} fatty acids) analyses. Age determinations (via bear teeth) for all harvested bears in 2014, 2015 and 2016 are currently being carried out via Matson's Laboratories (Matson's Laboratory LLC, 8140 Flagler Road Missoula MT 59802, U.S.A.; http://www.matsonslab/com) and will be available by June 2017. Analysis of SIs of nitrogen and carbon (i.e., ^{12}C, ^{13}C, ^{14}N and ^{15}N) in the 2016-collected muscle samples are being determined by 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 Government of Nunavut, Department of Environment, an Agreement of Cooperation and Contribution (ACC), which embodies this research and monitoring Environment and Climate Change Canada-Nunavut Department of Environment (ECCC-NDE) partnership. In the 2016-2017 fiscal year, this project assisted in building capacity and expertise in scientific sampling during the winter 2015-2016 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 2015 and 2016 NWRPs, and in cooperation with M. Dyck and M. Harte in 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 2016, electronic copies of the sampling instructions were also sent to the Nunavut Environmental Contaminants Committee (NECC; Co-Chairs Karla Letto (CIRNAC) and Andrew Dunford (Nunavut Tunngavik Incorporated (NTI))), and in direct response to the recommendations made in the NECC social-cultural review of the 2016-2017 project year. Two files were forwarded 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 and made available to hunters every year since 2008. As we noted in the 2016-2017 fiscal year, mid-year status report in September 2016 (report was then circulated to and reviewed by the NECC) all polar bear harvests completed in 2016 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 2016 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 samples collected.

In terms of other capacity building, a graduate student, Mr. Gabriel Boisvert (MSc student, Carleton U., Ottawa) successfully completed and defended his thesis in September 2016, on established and newly detected PFAS and precursor bioaccumulation and metabolism in ringed seals and polar bears. Ms. Adelle Strobel (MSc student, Carleton U., Ottawa) started her thesis work in January 2016) on the bioaccumulation and fate of organophosphate ester (OPE) contaminants in polar bears compared to ringed seal prey. Dr. Adam Morris started and completed a Postdoctoral Fellowship (via Carleton University and under the supervision of Dr. Letcher) from June to December 2016. Dr. Morris worked on and completed the compilation and analysis of a large metabolomics data set for Hudson Bay polar bears (Morris et al. 2017). Dr. Morris continues as a Post-Doctoral Fellow (PDF) on a NSERC Visiting Fellowship, which is jointly supported by ECCC-EWHD and the NCP, and where he is working on the relationship between temporal changes in major bioaccumulative POPs and any relevant climate change variable data for polar bears, arctic seabirds, caribou and fish (e.g. land-locked arctic char).

Communications

As detailed in the reference section and the NCP statistics and information table, as of March 2017, there were numerous publications in the form of papers and reviews in peer-reviewed journals (published, accepted or submitted) (e.g. Bechshøft et al. 2016, 2017; Boisvert et al. 2017; Dietz et al. 2016; Letcher et al. 2017a, 2017b; Morris et al. 2016, 2017; Pavlova et al. 2016; Pedersen et al. 2016), as well as reports (Letcher et al. 2016) and a book chapter (Dietz et al. 2016). There were also numerous oral and poster presentations at conferences or workshops. For example, presentations were made at the ArcticNet Annual Scientific Meeting (ASM2016) held on Dec. 5-9, 2016, in Winnipeg, MB. Another Arctic polar bear based presentation was also made at the 2016 DIOXIN symposium in Florence, Italy in August 2016, and in relation to a new AMAP Chemicals of Emerging Concern report due to be released in 2017 (Muir et al. 2017, In press).

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 requirements of the 2016 NWRP, and also to the NECC for editing and further distribution as deemed necessary. Whenever it was necessary, 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 2016-2017 proposal.

In early October 2016, Letcher travelled to Rankin Inlet and Arviat and interfaced and exchanged with COs and HTO members in those two communities. Letcher also travelled to Iqaluit to participate and instruct in the 3rd Wildlife Contaminants Workshop (WCW) 2016 held over five days from September 25-30, 2016 at the Nunavut Research Institute (NRI) at Nunavut Arctic College in Iqaluit. Along with Postdoctoral Fellow Dr. Adam Morris, Letcher lectured on contaminants and effects in polar bears as part of the WCW 2016 to students enrolled in the NRI-Environmental Technology Program (ETP). With hands-on instruction by Drs. Letcher and Morris, students participated and carried out a complete lab analysis exercise where PCBs were determined in actual polar bear fat samples and using NRI lab facilities. Overall, the WCW 2016 provided contaminants knowledge to the students in the context of ecosystem and wildlife health within the ETP. The WCW 2016 also (as in the previous year) provided an opportunity for Letcher 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 frontline workers closest to the field and in the communities (i.e. conservation officers, local research coordinators, etc.). It is crucial that the individuals in these positions are capable and confident when discussing contaminants and related subjects with experts and community members, as this will enhance communication and outreach as well as research in a codependent manner. Thus, the ETP is an ideal example of critical training programs for students who subsequently will go on to the above mentioned frontline research positions in Nunavut. Dr. Morris also delivered on September 29, 2016 at the Nunavut Research Institute, a community presentation that included data from Morris et al. (2016), and included discussions of current use pesticides in polar bear food chains and marine ecosystems.

In consultation with the NECC, in 2016 and in collaboration with M. Dyck at NDE, Letcher prepared a “polar bear - contaminant fact sheet and mini-report”. The final, NECC-approved version of this fact sheet was circulated to COs and HTO members in all participating communities in both English and Inuktitut. The fact sheet was written in very plain language for easy understanding, as per the recommendation of the NECC. As we responded to the NECC, the NDE requires that for all bears harvested a hunter kill return sheet be completed and submitted. On the kill sheets, the hunters have the opportunity to provide general observational comments. In the 2016-2017 period we were provided with available kill sheets for polar bears harvested in 2016, to optimize information exchange and communication, and consequently assist with capacity building and the utilization of Inuit knowledge. Since we only received and processed the 2016 bear samples in late November 2016, we intend to provide them to the NECC in 2017.

The Stockholm Convention’s POP Review Committee (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 (recommended for addition to Annex A). PCNs and pentachlorophenol/ pentachloroanisole (PCP/PCA) were added to the Convention at COP7 in May 2015. The last POPRC12 meeting was in October 2016 in Rome, Italy, where risk profiles of dicofol and PFOA were discussed and adopted. New Arctic information of high priority POPs, including for polar bears, is needed for this assessment and decision process. The PI (Letcher) continued to communicate and discuss POPRC data needs for these priority chemicals within EC, CIRNAC and with Dr. Eva Kruemmel (as she attends/participates in the POPRC committee meetings). New POP data and temporal trends for southern and western Hudson Bay polar bears was prepared and provided to the AMAP POPs Experts Group (led by Mr. Simon Wilson and Dr. Frank Rigét); the data has been converted to *.amp files to feed into a larger database to carry out Power Analysis using the PIA software application for statistical analysis of time-series data (Bignert 2013), of the data in an identical manner as for other NCP priority wildlife and fish monitoring sentinels/other Arctic compartments (e.g. air). This statistically analyzed data set was incorporated into a new AMAP POP temporal trend assessment report that was finalized and published in late 2016 (Rigét et al. 2016).

Indigenous Knowledge Integration

Indigenous knowledge (IK) integration needs to occur on an ongoing annual basis in the present contaminants monitoring program for polar bears, but can be improved by facilitating better communication and interaction with the participating hunters and communities. As in past sampling for this core monitoring project, the 2016 collection of samples was carried out exclusively by hunters in the participating Hudson Bay and Baffin Bay communities and in coordination with the PI and involved agencies in Nunavut. This project continued to seek any IK that could be provided in the information supplied 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 Conservation Officers (Cos) and biologists. The inclusion and integration of IK continues to be vitally important in the understanding of contaminant variations and changing trends (diet and habitat), despite the link to shared resources (e.g. contaminant exposure from seal). This supports a two-way integration of knowledge. As outlined in 2017-2018 activities, we are working with Northern partners, The Eider Society and Dr. Eva Kruemmel to increase the utilization of IK of polar bears and starting with Sanikiluaq. The full details of this initiative are described in the funded 2017-2018 NCP proposal being led by Dr. Joel Heath (The Eider Society).

Results

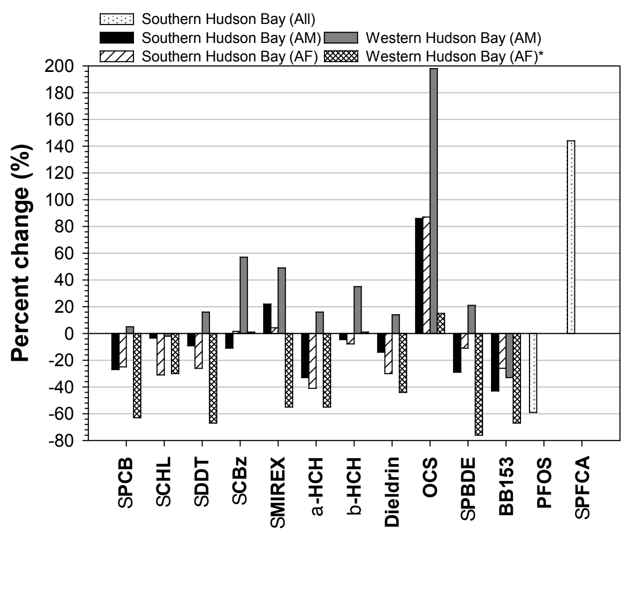
Polar bears are apex and pagophilic predators of the arctic marine food web, and are exposed to an array of stressors related to anthropogenic activities such as chemical contaminants. Quantifying the physiological changes and effects in arctic wildlife exposed to multiple stress factors, especially from an integrated perspective, is increasingly important for understanding health impacts. One such approach is the measurement and profiling of low molecular weight endogenous metabolites (metabolomics) that reflect the dynamic response of biological systems to stress factors. Such an approach has not yet been published for any arctic wildlife. In 2016 and early 2017, we completed a targeted, quantitative metabolomics platform (219 metabolites including amino acids, biogenic amines, acylcarnitines, phosphatidylcholines (PCs), sphingomyelins, hexoses (Hex) and fatty acids (FAs)) for muscle and liver collected from 2013-2014 harvested polar bears from SHB and WHB (Morris et al. 2017). Multivariate statistics were applied to the data in order to establish whether bears were discriminated by sex and/or location (subpopulation). Only five metabolites discriminated the hepatic profiles of SHB males and females (Hex, arginine, glutamine, one phosphatidylcholine (PC), one sphingomyelin), while the fifteen discriminatory metabolites contrasting the livers of males from SHB and WHB were primarily PCs, along with leucine. Metabolite profiles in the muscle of male and female bears could not be differentiated; however the muscle of SHB and WHB males were again discriminated primarily by membrane lipids.

Based on the same 2013-2014 bear tissue samples used in our metabolomics platform studies reported in Morris et al. (2017), we completed the data analysis and submitted a paper for publication on legacy and emerging POPs (Letcher et al. 2017a). A total of 296 individual, legacy and emerging POPs were analyzed, and the differences both within (between adult males, adult females and subadults) and between the two subpopulations (western Hudson Bay and southern Hudson Bay) were investigated, and where possible, time-point comparisons were made relative to POP levels determined in polar bears harvested in 2007–2008. The mean ΣPCB concentrations at both time points were the greatest among the POPs measured and were spatially uniform with little influence of sex or age of the bears. The second greatest POPs concentrations were ΣChlordanes (ΣCHL, 74–79 % oxychlordane) and the Sperfluoroalkyl substances (SPFASs, » 60 % PFOS) in the SHB and WHB respectively, with concentrations of SPFAS and SCHL significantly affected by age and/or sex. The SCHL concentrations were also spatially uniform; however SPFAS were significantly greater in the SHB bears, as were some FRs and SDDT, which could be a function of contamination from nearby communities or industry, and/or changes in behavior/diet in the bears. Several previously unknown POPs (endosulfans, hexabromocyclododecane) were detectable in samples from 2007–2008 but not in those from 2013–2014, which is consistent with the global regulations on these POPs. The mean SPCN concentrations were low relative to legacy POPs in the 2013-2014 bears. SCCPs in the 2013-2014 bears were a major group of contaminants found at concentrations comparable to other POPs such as DDT and HCH, though there was no significant variation between or within the subpopulations for PCNs or SCCPs. Most of the lipophilic POPs were lower in concentration in female bears from both subpopulations, and in SHB males relative to levels in 2007–2008 samples (Figure 1). However, concentrations in WHB males were greater in 2013-2014 relative to 2007-2008 for almost all investigated POPs.

In the 2016-collected samples, the major 4 congeners were BDE-47, -99, -100 and -153 consistently accounted for > 90 % of the SPBDE concentration in polar bear fat samples. With respect to temporal trends, and although uncorrected for e.g. age, sex and diet, from 1991 to 2016 the most concentrated BFRs, PBDEs, showed increasing S$_4$PBDE concentrations up until 2010, followed by a gradual decline progressing to 2014 in WHB bears (Figure 2). The same gradual downward trend occurred between 2007 and 2016 in SHB bears (Figure 2). However, between 2014 and 2016, mean SPBDE concentrations appeared to have leveled off for bears from the WHB subpopulation.

Starting in 2007 and until 2013, analysis of adipose samples from Hudson Bay bears showed that BDE-209 and 22 non-PBDE replacement FRs were not detectable at all or in any frequency, whereas HBCDD and brominated biphenyl-153(BB-153) were quantifiable in most years up to 2013 (Figure 2). However, in 2014, 2015 and again in 2016 samples, HBCDD was not detectable in any fat sample collected from WHB and SHB bears (Figure 2). In contrast, BB-153 concentrations were quite high in comparison to S$_4$PBDE concentrations in most years and including all years after 2013.

Figure 1. Percent change of analyte groups and POPs of interest relative to those measured in Hudson Bay polar bears from 2007–2008 (McKinney et al. 2011b) or 2002 (PFASs) (Martin et al. 2004). Geometric means were compared for lipophilic contaminants, and mean concentrations of all SHB bears alone were compared for the PFASs (no WHB data were available). The åPFCA was selected to match that in Martin et al. (2004) (åPFCA = PFOA, PFNA, PFDA, PFUdA, PFDoA, PFTrA, PFTeDA, and PFPeDA). PFPeDA was not measured, but it was below detection limits in 2002 and did not affect the present comparison. AM = adult males, AF = adult females.



Even though the concentrations were uncorrected for e.g. age, sex and diet for Hudson Bay bears, over the period of 2007-2016, among the 22 PFASs analyzed (in liver) the concentrations were consistently the greatest for PFOS and ΣPFCAs (low levels of PFOA but mostly longer chain length C_9, C_{10} and C_{11} PFCAs). In the liver samples from 2010 and including up to 2016, PFOS concentrations were consistently greater than for ΣPFCAs among all bears in 2016-2017, and there were no obvious increasing or decreasing trends for ΣPFCAs and PFOS for both subpopulations of bears over the 2007-2016 period (Figure 3).

THg concentrations in the liver collected in 2016 from bears from WHB and SHB were retrospectively comparable to concentrations in samples from years going back before 2000 (2000-2016 samples ranged from 5 to 25 μg•g^{-1} (wet weight)). Similar to previous years 2016 liver sample THg concentrations in WHB bears were slightly greater than for the SHB bears. However, the THg concentrations were variable from year to year, and so there is a need to continue annual monitoring of THg in Hudson Bay bears.

Figure 2. Temporal trends of the geometric mean concentrations (lipid weight corrected) of major brominated flame retardants (e.g. PBDEs) in the fat of WHB bears (top panel, 1991-2007, McKinney et al. 2010; 2008-2016, unpublished) and SHB bears (lower panel, 2008-2016, unpublished). Error bars are the standard deviations of the geometric mean concentrations. Data was not corrected for sex, age or diet.

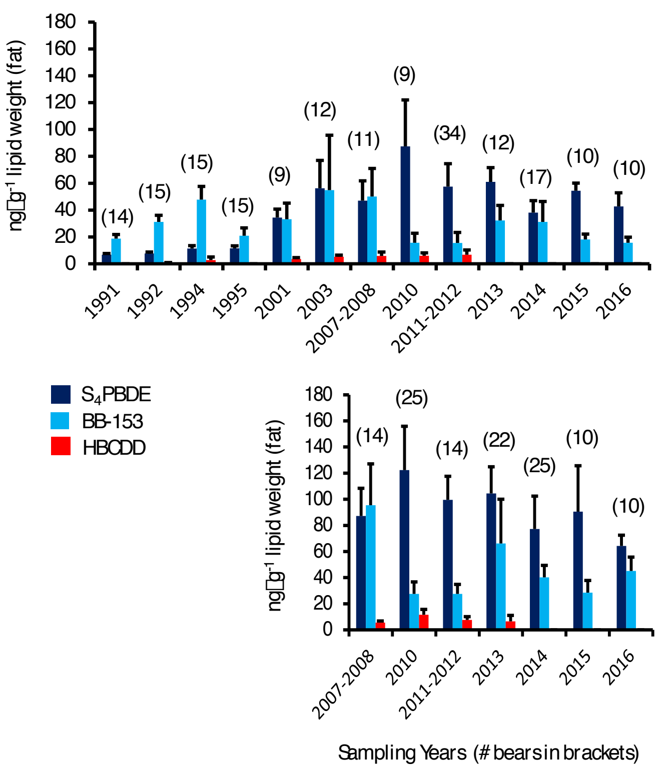
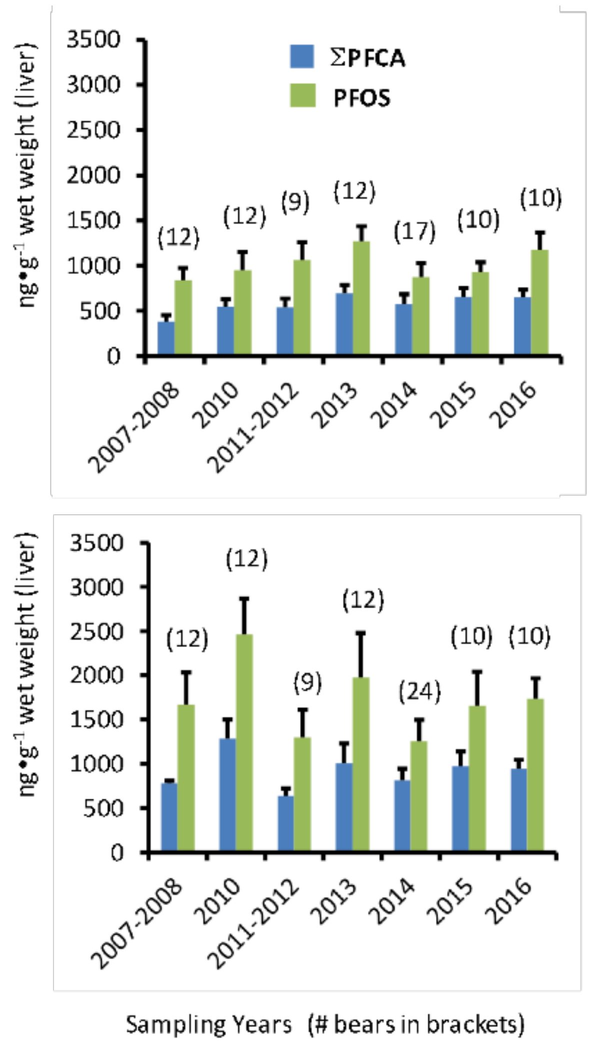


Figure 3. Temporal trends of the geometric mean concentrations (wet weight) of ΣPFCA and PFOS in the liver of WHB bears (2007-2016, top panel, Robert Letcher, unpublished) and SHB bears (2007 – 2016, lower panel, R. Letcher, unpublished). Error bars are the standard deviations of the geometric mean concentrations. Data was not corrected for sex, age or diet.



Discussion and Conclusions

Quantifying the physiological changes and effects in arctic wildlife exposed to multiple stress factors including POPs, through an integrated perspective is increasingly important for understanding health impacts. We completed a targeted, quantitative metabolomics platform (219 metabolites including amino acids, biogenic amines, acylcarnitines, PCs, sphingomyelins, Hex and FAs) for muscle and liver collected from 2013-2014 harvested polar bears from SHB and WHB (Morris et al. 2017). The unique metabolite profiles differentiating the sexes, and particularly those discriminating the subpopulations, may have utility for future assessments of the effects of stressors on the physiological state of Hudson Bay polar bears and those from other subpopulations.

For 2013-2014 bear tissue samples, 296 individual, legacy and emerging POPs were analyzed, and the differences both within (between adult males, adult females and subadults) and between the two subpopulations were investigated. Where possible, time-point comparisons were made relative to POP levels found in polar bears harvested in 2007–2008. Most of the lipophilic POPs were lower in concentration in female bears from both subpopulations, and in SHB males relative to levels in 2007–2008 samples (Figure 1). However, concentrations in WHB males were greater in 2013-2014 relative to 2007-2008 for almost all investigated POPs. Combined with information from previous investigations, differences in diet and feeding behavior as well as sources drive this difference.

The overall and recent status of the legacy and emerging POPs in both SHB and WHB bears shows that with the exception of the major PFASs (ΣPFCA and PFOS in liver), SSCCPs, SPCNs, SPBDEs and BB-153, all other recently screened POPs (e.g. SOPEs, a-endosulfan, HBCDD and SDP-like substances) were generally at much lower concentrations or non-detectable in fat tissue compared with the legacy POPs (SPCB, SCHL, SHCH, DDT and SClBz). Also, some priority POPs that were screened in the same fat samples collected as recently as 2014 were not detectable with any frequency (e.g. b-endosulfan, endosulfan sulfate, HCBD, PCP, PCA and dicofol isomers) (Letcher et al. 2017a).

In the 2016 collected samples, 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 in any Arctic sample. PFEtCHxS, FBSA and PFBA are representative of new and replacement PFASs currently being produced and used and continued monitoring of polar bears is warranted.

With respect to temporal trends, and although uncorrected for e.g. age, sex and diet, from 1991 to 2014 in WHB bears the most concentrated BFRs were SPBDEs and concentrations increased up until 2009. After 2009 concentrations of BFR's general declined until 2015 and appeared to level off in 2016 in WHB bears (Figure 2). The same downward trend was also true between 2007 and 2016 in SHB bears (Figure 2). This is consistent with the PentaBDE and OctaBDE production phase out in the early 2000s (about 2002) 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 PBDE 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 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).

PFOS and ΣPFCA levels appeared to be neither increasing nor decreasing and there was no clear trend for the period of 2007-2016 (Figure 3), and despite C8 (eight carbon chain length) chemistry phase-out around 2002 by the major worldwide producer at the time, the 3M Company, PFOS and its C8 chemistry to Annex B of the Stockholm Convention in 2009. 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.

In the liver of bears from both subpopulations, THg concentrations (ww) from 2002 to 2016 were essentially unchanged and ranged between 5 and 25 mg•g^{-1} ww, and slightly greater in bears from WHB versus SHB. As we reported in Rush et al. (2008), in liver of SHB or WHB bears collected in 2002 and as far back as 1984, mean THg concentrations were less than 10 mg•g^{-1} ww. Thus, increases occurred after 2002 and have remained constant up to 2016. 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 (e.g. bears from East Greenland). Several high priority POPs under consideration for addition to the POPs 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. These high priority POPs include SCCPs, and PFASs, as well as 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.

Acknowledgments

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

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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 2016 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 14 liver samples of beluga from Hendrickson Island in 2016 was 38.35 ± 28.50 $\mu g \bullet g^{-1}$ while that of muktuk from the same animals was 0.34 ± 0.17 $\mu g \alpha g^{-1}$. 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 1401 arctic beluga from several locations over the period of 1977 to 2016. Mercury content varies among species, among individual animals, and among organs within an animal. This variation makes rigorous detection of

Résumé

On a analysé les concentrations de mercure total et de sélénium dans des échantillons de foie, de reins, de muscles et de muktuk de béluga prélevés en 2016. Les concentrations de mercure étaient similaires à celles enregistrées au cours d'années antérieures. Parmi les organes et tissus analysés dans cette étude, c'est habituellement le foie qui renfermait les plus fortes concentrations de mercure; venaient ensuite les reins, les muscles et le muktuk. Par exemple, la concentration moyenne de mercure total dans 14 échantillons de foie prélevés en 2016 chez des bélugas de l'île Hendrickson s'élevait à 38,35 ± 28,50 $\mu g \bullet g^{-1}$ alors que celle dans le muktuk des mêmes animaux s'élevait à 0,34 ± 0,17 $\mu g \bullet g^{-1}$. 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. À présent, la base de données contient des renseignements sur plus de 1 401 bélugas échantillonnés à

differences among animals, places, and times statistically difficult. Detection of differences among samples is further complicated by the fact that mercury accumulates with age so that older animals usually have higher levels than younger ones from the same location. Consequently comparison of mercury levels among different groups of beluga requires adjustment for differing ages, thus 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.

plusieurs endroits en Arctique au cours de la période de 1977 à 2016. La teneur en mercure varie selon les espèces, selon les sujets et selon les organes dans un animal donné. Ces fluctuations rendent difficile la détection rigoureuse, d'un point de vue statistique, des différences entre les animaux échantillonnés, les lieux de prélèvement et les moments d'échantillonnage. La détection des différences entre les échantillons est en outre compliquée par le fait que le mercure s'accumule avec l'âge; la concentration de mercure est donc habituellement plus élevée chez les animaux âgés que chez les jeunes animaux provenant du même endroit. Par conséquent, la comparaison des niveaux de mercure chez les différents groupes de bélugas demande un rajustement du fait des différences d'âge, et des données précises sur l'âge sont essentielles. Les échantillons supplémentaires recueillis chaque année accroissent les probabilités de détecter les différences réelles et réduisent celles de signaler des différences apparentes, mais non réelles. Habituellement, on effectue les analyses chimiques avant de déterminer l'âge des sujets; il y a donc un délai dans l'interprétation des données.

Key Messages

- New data were obtained on total mercury in organs of beluga from Hendrickson Island (HI) and Sanikiluaq (SK).
- The mean level of mercury in 2016 liver samples from the HI animals was 38.35 ± 28.50 $\mu g \bullet g^{-1}$. The mean age of these same whales was 15.3 ± 7.3 years. Mercury in muscle was lower than that in liver with a mean concentration of 1.65 ± 1.07 $\mu g \bullet g^{-1}$.
- In spite of the lower values in HI muscle, all of them still exceeded 0.5 $\mu g \bullet g^{-1}$, the concentration long used to regulate the sale of commercial fish in Canada.
- Of the 3 organs analyzed in the HI animals, muktuk contained the lowest levels of total mercury with a mean 0.34 ± 0.17 $\mu g \bullet g^{-1}$. 21 percent of the samples (3 of 14) were at or exceeded 0.5 $\mu g \bullet g^{-1}$.

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 (Saskatchewan).
- La concentration moyenne de mercure mesurée dans les échantillons de foie prélevés en 2016 chez des animaux de l'île Hendrickson était de 38,35 ± 28,50 $\mu g \bullet g^{-1}$. L'âge moyen des bélugas échantillonnés était de 15,3 ± 7,3 ans. La concentration moyenne de mercure était plus faible dans les muscles (1,65 ± 1,07 $\mu g \bullet g^{-1}$).
- Même si les valeurs étaient plus faibles dans les muscles des bélugas de l'île Hendrickson, elles demeuraient toutes supérieures à 0,5 $\mu g \bullet g^{-1}$, soit la concentration de référence utilisée depuis longtemps pour réglementer la vente d'espèces commerciales de poissons au Canada.

- 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.

- The mean mercury concentration in Sanikiluaq liver samples was 15.07 ± 10.83 $\mu g \cdot g^{-1}$, Muscle levels were lower, with a mean of 1.03 ± 0.52 $\mu g \bullet g^{-1}$ and mercury in muktuk were even lower with a mean concentration of 0.32 ± 0.20 $\mu g \bullet g^{-1}$.

- 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 0,34 ± 0,17 $\mu g \bullet g^{-1}$. Vingt-et-un pour cent des échantillons (3 sur 14) atteignaient ou dépassaient 0,5 $\mu g \bullet g^{-1}$.

- 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 15,07 ± 10,83 $\mu g \bullet g^{-1}$. Les concentrations dans les muscles étaient plus faibles, la moyenne étant de 1,03 ± 0,52 $\mu g \bullet g^{-1}$ et les concentrations dans le muktuk étaient plus faibles encore, la moyenne étant de 0,32 ± 0,20 $\mu g \bullet g^{-1}$.

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 (i) mercury in these unique animals as examples of mercury as a global pollutant and; (ii) dietary intakes of mercury by northern people who consume these animals and the possible health implications for northern people. Recently a new factor has been discovered, namely a linkage between exposure to mercury in young adulthood and the development of diabetes later in life (He et al. 2013); this will likely foster additional interest in the intakes of mercury by northern people.

The levels of mercury in several organs of marine mammals from the Canadian Arctic have been relatively high (Wagemann et al. 1996; Lockhart et al. 2005; Loseto et al. 2015), exceeding levels in commercial fish analyzed by the Canadian Food Inspection Agency. Health Canada (2007) published an updated evaluation of the risks of mercury in fish for human health 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 µgg^{-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 µgg^{-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 data 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 8 years) 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 2016-2017

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 2016 animal tissues, total Hg (THg) was analyzed 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 of Hg (absolute; most beluga tissues have several thousand ng of Hg per 0.01 g of sample). Quality assurance/quality control 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% relative standard deviation (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 the Freshwater Institute (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 2016

- Muscle, liver and muktuk samples and ages of 14 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 of 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 2016

Collections from Hendrickson Island are one of the most extensive with 468 samples from 20 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 2016 was 38.35 ± 28.50 $\mu g \cdot g^{-1}$ (Table 1). The mean age of these same whales is 15.3 ± 7.6 years. Mercury in muscle was lower than that in liver with a mean concentration of 1.65 ± 1.07 $\mu g \cdot g^{-1}$. In spite of the lower values in 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 3 organs analyzed, muktuk contained the lowest levels of total mercury with a mean 0.34 ± 0.17 $\mu g \cdot g^{-1}$. Twenty one percent of the samples (3 of 14) were at or exceeded 0.5 $\mu g \cdot g^{-1}$. 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 2016

Ten samples were analyzed from Sanikiluaq in 2016. Total mercury levels found in the 3 organs analyzed are listed in Table 1. The mean mercury concentration in liver was 15.07 ± 10.83 $\mu g \cdot g^{-1}$; Muscle levels were lower, with a mean of 1.03 ± 0.52 $\mu g \cdot g^{-1}$ and mercury

Table 1. Age data and concentrations of total mercury in organs of beluga (M+F) from HI and SK. Concentrations are shown in µg·g-1 wet weight followed by standard deviations.

Location	Year	Age	Liver	Muscle	Muktuk
Hendrickson	2016	15.3 (7.3)	38.35 (28.50)	1.65 (1.07)	0.34 (0.17)
Sanikiluaq	2016	9.8 (8.6)	15.07 (10.83)	1.03 (0.52)	0.32 (0.20)

in muktuk were even lower with a mean of 0.32 ± 0.20 $\mu g \bullet g^{-1}$. As previously reported, mercury concentrations in Sanikiluaq animal tissues (actually all eastern Arctic beluga) are significantly lower than concentrations 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 $\mu g \bullet g^{-1}$, the concentration long used to regulate the sale of fish for human consumption. These results 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).

Expected Project Completion Date

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

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Temporal trends of contaminants in Arctic seabird eggs

Tendances temporelles des contaminants dans les œufs des oiseaux de mer de l'Arctique

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Abstract

Contaminants are monitored in arctic seabird eggs as an index of contamination of arctic marine ecosystems. Eggs of 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. Concentrations of polychlorinated dibenzo-p-dioxins, furans, and non-ortho PCBs declined between 1975 and 2014 in eggs of thick-billed murres and northern fulmars from Prince Leopold Island. Concentrations of polychlorinated naphthalenes also declined between 1975 and 2014 in eggs of thick-billed murres from Prince Leopold Island. Polychlorinated naphthalenes accounted for only a relatively small amount of the total toxicity calculated for dioxin-like compounds measured in the murre eggs.

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 on assure une surveillance des œufs de guillemots de Brünnich à l'île Coats, dans le nord de la baie d'Hudson, depuis 1993. Les concentrations de polychlorodibenzoparadioxines (PCDD), de furanes et de BPC non substitués en ortho (nBPC) ont diminué entre 1975 et 2014 dans les oeufs des guillemots de Brünnich et des fulmars boréaux de l'île Prince Leopold. Les concentrations de naphtalènes polychlorés (NPC) ont également diminué entre 1975 et 2014 dans les œufs des guillemots de Brünnich de l'île Prince Leopold. Les concentrations de NPC ne représentaient qu'une quantité relativement faible de la toxicité totale des composés de type dioxine mesurés dans les œufs de guillemots de Brünnich.

Key Messages

- Concentrations of polychlorinated dibenzo-p-dioxins, furans, and non-ortho PCBs, as well as their associated toxic equivalents (TEQs), declined between 1975 and 2014 in eggs of thick-billed murres and northern fulmars from Prince Leopold Island.
- Concentrations of polychlorinated naphthalenes (PCNs) and their associated TEQs also declined between 1975 and 2014 in eggs of thick-billed murres from Prince Leopold Island.
- The total TEQ-PCN accounted for only a small amount of the total toxicity calculated for dioxin-like compounds measured in the murre eggs.

Messages clés

- Les concentrations de PCDD, de furanes et de BPC non substitués en ortho (nBPC), de même que leurs équivalents toxiques connexes, ont diminué entre 1975 et 2014 dans les œufs des guillemots de Brünnich et des fulmars boréaux de l'île Prince Leopold.
- Les concentrations de NPC et leurs équivalents toxiques connexes ont également diminué entre 1975 et 2014 dans les œufs des guillemots de Brünnich de l'île Prince Leopold.
- Les concentrations totales de NPC et d'équivalents toxiques ne représentaient qu'une quantité relativement faible de la toxicité totale des composés de type dioxine mesurés dans les œufs de guillemots de Brünnich.

Objectives

- To monitor legacy and new contaminants in eggs of northern fulmars and thick-billed murres from Prince Leopold Island in Lancaster Sound, and from thick-billed murres from Coats Island in northern Hudson Bay.

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 and eggs of thick-billed murres from Coats Island in northern Hudson Bay have been monitored since 1993 (Braune et al. 2015a). Eggs are analyzed for legacy persistent organic pollutants or POPs (biennially as of 2014), and total mercury (Hg) (annually). 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 and Letcher 2014).

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) Convention on 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.

Activities in 2016-2017

Sample Collection/Analysis

Despite six daily attempts over two time periods, poor weather conditions prevented us from landing on Prince Leopold Island (74°02'N, 90°05'W) to collect the thick-billed murre and fulmar eggs from that location. However, we successfully collected eggs of thick-billed murres (n=15) from Coats Island (62°30'N, 83°00'W) in northern Hudson Bay.

As legacy POPs are now analyzed on a biennial basis in even years (e.g. 2016) for this project, eggs from Coats Island were analyzed for the normal suite of legacy POPs (e.g. PCBs, DDT, chlordanes, chlorobenzenes, etc.), PBDEs and HBCD in pools of 3 eggs each (15 eggs per collection = 5 pools of 3 eggs each). 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 legacy POPs (including PCBs), PBDEs, HBCD, and total Hg were carried out at the National Wildlife Research Centre (NWRC) laboratories at Carleton University in Ottawa, Ontario. Analysis of the legacy organochlorines (OCs) was carried out by gas chromatography using a mass selective detector (GC/MSD) operated in the electron impact (EI) mode, and analysis of 22 PBDE congeners and total-α-HBCD was carried out using GC/MSD run in negative chemical ionization (NCI) mode according to NWRC Method No. MET-CHEM-OC-06D. 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 Quality Assurance/Quality Control Program. Stable isotope (C, N) analyses were carried out at the G.G. Hatch Stable Isotope Laboratory, University of Ottawa in Ottawa, ON. All samples are archived in the National Wildlife Specimen Bank at the NWRC in Ottawa.

Capacity Building

The contaminants monitoring program at Prince Leopold Island in the Canadian high Arctic is part of a long-term, integrated seabird monitoring program which has been investigating seabird population trends and relationships with climate change and contaminants for over 35 years. As there was no field camp at Prince Leopold Island in 2016, 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. Josiah also helped with the construction of some new cabins at Coats as did Juipie Angootealuk of Coral Harbour. We tried to recruit four other individuals from Coral Harbour to help with the cabin construction, but all four declined for various reasons. Building on earlier successful collaborations between NWRC and the Nunavut Arctic College (NAC) in Iqaluit, Jennifer Provencher (postdoctoral fellow) went to Iqaluit again in Fall of 2016 with NCP support to work with NAC Environmental Technology Program students. Although there was not a separate module for marine birds in 2016, students attended a lecture that highlighted seabird contaminant monitoring work in Nunavut. In October 2016, Jennifer also talked about seabirds in the context of food webs and contaminants research during a seal workshop held at the Qarmartalik School in Resolute Bay.

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 and again in January 2017 to present a plain-language field report (English-Inuktitut) summarizing our 2016 field activities (or lack thereof) on Prince Leopold Island and discuss future sampling requests. Amie also went to the Qarmartalik School in Resolute Bay to help with their breakfast program and to speak with the grades 4-6 classes as part of a scientist profile project. She then met with the senior class to co-present information along with Julia Prokopik (CWS, Iqaluit) on ECCC's Inuit Field Assistant Program and describe field projects and camp life at field sites. Amie also met with the school principal and science teacher.

Paul Smith (ECCC, Ottawa), who also has a field camp on Coats Island, met with the Aiviit HTO and the Irniurviit ACMC in Coral Harbour in March 2016 to present information on the monitoring and research activities on migratory birds in the region, including our monitoring of contaminants in eggs of thick-billed murres on Coats Island. Paul attempted to meet with the Aiviit HTO and the Irniurviit ACMC again in March 2017, but poor weather prevented the plane from landing in Coral Harbour. Consultation was, therefore, limited to phone and e-mail. 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 project.

Indigenous 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 2016, we again respected the concerns of the Sulukvait ACMC and did not plan to open a field camp at Prince Leopold Island, hoping to collect eggs during a one-day trip instead.

Results

The results for the thick-billed murre eggs from Coats Island for 2016 are presented in Table 1. There is no update on the temporal trend data for Prince Leopold Island as no egg collections were made in 2016. However, concentrations of polychlorinated dibenzo-*p*-dioxins (PCDDs) and furans (PCDFs) as well as non-*ortho* PCBs (nPCBs) declined between 1975 and 2014 in both murre and fulmar eggs from Prince Leopold Island (Figure 1), as did their associated toxic equivalents (TEQs) (Figure 2). In both species, the dominant PCDD congeners were 1,2,3,7,8-PnCDD, 2,3,7,8-TCDD, and 1,2,3,6,7,8-HxCDD; the dominant PCDF congener was 2,3,4,7,8-PnCDF, and the nPCB profile was dominated by PCB-126 (Braune and Mallory 2017). The TEQ profile in the murre eggs was dominated by nPCB-TEQ, whereas in the fulmar eggs, the PCDF-TEQ contribution to ΣTEQ was slightly greater than that of nPCB-TEQ (Braune and Mallory 2017).

Table 1. Mean concentrations (± standard deviation) of % lipid, $\delta^{15}N$ (‰), total Hg (mg·g^{-1} dry weight), and organochlorines (Σ_{37}PCB, *p,p'*-DDE, hexachlorobenzene (HCB), oxychlordane, heptachlor epoxide (HE), dieldrin, mirex), polybrominated diphenyl ethers (BDE-47, BDE-99, BDE-100) and HBCD (ng•g^{-1} wet weight) in eggs (*n*=15) of thick-billed murres collected from Coats Island in 2016.

	Mean ± SD
% lipid	11.9 ± 0.88
$\delta^{15}N$	14.6 ± 0.45
Hg	0.64 ± 0.186
Σ_{37}PCB	120 ± 40.0
DDE	118 ± 41.1
HCB	78.5 ± 33.6
Oxychlordane	2.44 ± 0.518
HE	4.68 ± 2.49
Dieldrin	7.94 ± 3.57
Mirex	2.30 ± 0.925
BDE-47	0.76 ± 0.484
BDE-99	0.16 ± 0.156
BDE-100	0.44 ± 0.246
HBCD	0.66 ± 0.362

Figure 1. Mean annual ln-transformed concentrations of ΣPCDD, ΣPCDF and ΣnPCB (pg•g^{-1} lipid weight ± standard error) in eggs of northern fulmars and thick-billed murres collected from Prince Leopold Island, Nunavut, 1975-2014. Source: Braune and Mallory (2017).

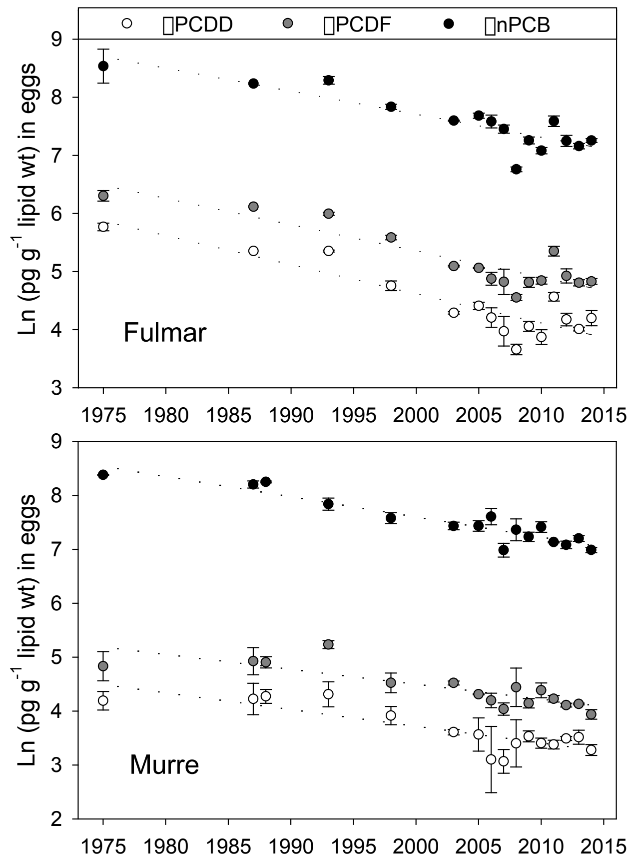


Figure 2. Mean annual ln-transformed concentrations of ΣTEQ (pg•g^{-1} lipid weight ± standard error) for PCDDs, PCDFs and nPCBs in eggs of northern fulmars and thick-billed murres collected from Prince Leopold Island, Nunavut, 1975-2014. Source: Braune and Mallory (2017).

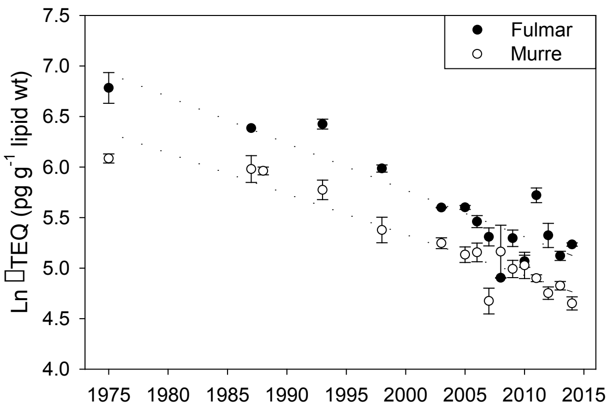
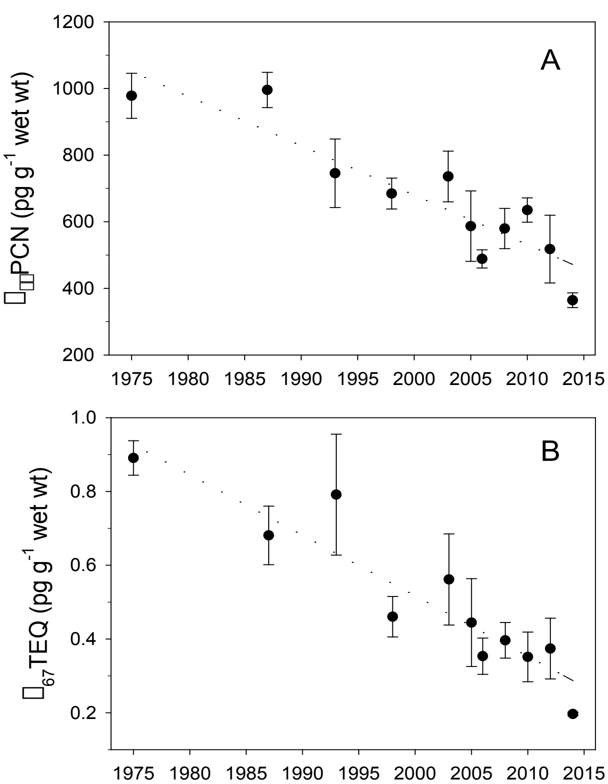


Figure 3. Mean annual concentrations (pg•g^{-1} wet weight ± standard error) of (A) Σ_{67}PCN and (B) Σ_{67}TEQ-PCN in eggs of thick-billed murres from Prince Leopold Island, Nunavut, 1975-2014. Modified from Braune and Muir (2017).



Concentrations of polychlorinated naphthalenes (PCNs) and their associated TEQs also declined between 1975 and 2014 in thick-billed murre eggs from Prince Leopold Island (Figure 3). Although the penta- and tetra-CNs (predominantly CN-52/60 and CN-42) dominated the PCN profile, the hexa-CNs (mainly CN-66/67) accounted for the majority of the ΣTEQ-PCN (Braune and Muir 2017). The total TEQ-PCN accounted for only 1.9% of the total toxicity calculated for dioxin-like compounds measured in the murre eggs (Braune and Muir 2017).

Discussion and Conclusions

The declines in concentrations of ΣPCDD, ΣPCDF, ΣnPCB and their associated ΣTEQ in murre and fulmar eggs from Prince Leopold Island reflect trends reported for other avian species and regions (Braune et al. 2007; Elliott et al. 2001; Harris et al. 2003; Hebert et al. 1994; Miller et al. 2014). However, Addison et al. (2005) found no significant changes in concentrations of PCDD/Fs in blubber of ringed seals (*Phoca hispida*) sampled at Holman Island in the Canadian Arctic between 1981 and 2000. Changes in the pulp and paper industry were enforced with Canada-wide legislation in 1993 (Government of Canada 1992) which may have also had some bearing on the pronounced decline of ΣPCDD, ΣPCDF, and ΣnPCB concentrations observed in the murre and fulmar eggs from Prince Leopold Island between 1988/93 and 2007/08. The global ban of PCBs, PCDDs and PCDFs under the Stockholm Convention on Persistent Organic Pollutants in 2004 (http://www.pops.int) may account for the apparent plateauing of concentrations in the murre and fulmar eggs in recent years (Figure 1).

The declines in concentrations of ΣPCN in the murre eggs from Prince Leopold Island are also consistent with the trends found in other studies (Gewurtz et al. 2009, Houde et al. 2016, Järnberg et al. 1993, Ross et al. 2013, Sinkkonen and Paasivirta 2000), although a study which included several species of marine mammals from the Arctic and sub-Arctic showed no consistent temporal trends between 1986 and 2007 (Rotander et al.

2012). Although the manufacturing of PCNs has been discontinued (Bidleman et al. 2010, Falandysz et al. 2008, Kilanowicz et al. 2011), emissions to the environment continue from combustion sources (Falandysz 1998).

Despite being regulated, PCDDs, PCDFs, nPCBs, and PCNs continue to persist in the environment, and the presence of these chemicals in the Arctic illustrates the vulnerability of polar regions to contamination by persistent, semi-volatile organic chemicals.

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 in Ottawa. Funding over the years has been provided by Environment and Climate Change Canada and the Northern Contaminants Program of Crown-Indigenous Relations and Northern Affairs Canada. Logistical support out of Resolute Bay is provided by the Polar Continental Shelf Program, Natural Resources Canada.

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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

This study is investigating trends in mercury concentrations (and metals) in sea-run (anadromous) Arctic char from the domestic fishery at Ekaluktutiak (Cambridge Bay). Although mercury concentrations are low in these Arctic char, we are continuing to monitor them as part of our investigations as to how mercury concentrations are influenced by changes in climate, air circulation patterns, and Asian and other mercury emissions. Mercury concentrations remain low although they appear to be slightly higher in cooler years when fish have lower body weights relative to their length. Continued monitoring will provide us with a stronger data set to assess trends. As in previous years, 20 Arctic char were harvested from the sea by local fishermen from the Hunters and

Résumé

Cette étude permet d'analyser les tendances des concentrations de mercure (et de métaux) chez l'omble chevalier anadrome provenant de la pêche locale à Ekaluktutiak, à Cambridge Bay. Bien que les concentrations de mercure soient faibles chez l'omble chevalier, nous continuons la surveillance dans le cadre de notre étude afin de déterminer de quelle façon les tendances relatives aux concentrations de mercure réagissent aux changements du climat, aux régimes de circulation de l'air et aux émissions en Asie et autres émissions de mercure. Les concentrations de mercure demeurent faibles, bien qu'elles semblent être légèrement plus élevées au cours d'années plus froides lorsque le poids corporel des poissons est plus faible par rapport à leur longueur. Une surveillance continue nous

Trappers Organization (HTO) and provided to us for analyses. As part of these studies, we continued our lake trout and Arctic char collections from Grenier Lake, again involving Ekaluktutiak HTO and utilizing ECCC funds. We continued to collaborate with others investigating features of Arctic char biology and their environment, including working with Les Harris who is conducting stock assessments on the major river/lake systems supporting the commercial fishery; Donald McLennan with the Canadian High Arctic Research Station who is working to develop a monitoring program on Grenier Lake; and Milla Rautio, Université du Québec à Chicoutimi, who is conducting biodiversity and productivity studies (including fatty acid studies) in Grenier and other nearby lakes. We also are contributing to mercury monitoring in char at Nain.

permettra d'obtenir un ensemble de données plus solide afin d'évaluer les tendances. Comme dans les années précédentes, 20 ombles chevaliers ont été récoltés par des pêcheurs locaux de l'organisation de chasseurs et de trappeurs et nous ont été remis à des fins d'analyse. Dans le cadre de ces études, nous avons continué de récolter le touladi et l'omble chevalier dans le lac Grenier, de nouveau en collaboration avec les chasseurs et les trappeurs d'Ekaluktutiak et à l'aide des fonds d'Environnement et Changement climatique Canada (ECCC). Nous avons continué de collaborer avec d'autres projets qui étudient certaines caractéristiques biologiques de l'omble chevalier et son environnement, y compris avec Les Harris qui procède à des évaluations des populations dans les principales rivières et les principaux lacs qui servent à la pêche commerciale, Donald McLennan de la Station de recherche du Canada dans l'Extrême-Arctique qui travaille à l'élaboration d'un programme de surveillance au lac Grenier et Milla Rautio, Université du Québec à Chicoutimi, qui mène des études sur la biodiversité et la productivité au lac Grenier et dans d'autres lacs à proximité (y compris des études sur les acides gras). Nous contribuons également à la surveillance des concentrations de mercure chez les ombles chevaliers à Nain.

Key Messages

- Mercury concentrations remain low in sea-run char harvested from the domestic fishery at Cambridge Bay.
- Char inhabiting Grenier Lake in summer have somewhat lower condition factor and slightly higher mercury concentrations than fish caught from the sea. Some char caught in the lake are feeding suggesting that they are resident fish.
- Mercury concentrations are moderately high in lake trout from Grenier Lake, possibly because these fish are very old.
- Temporal variability in mercury concentrations appear to be related to temporal variability in condition factor and climate.

Messages clés

- Les concentrations de mercure demeurent faibles chez l'omble chevalier anadrome provenant de la pêche locale à Cambridge Bay.
- L'omble chevalier vivant dans le lac Grenier durant l'été a, dans une certaine mesure, un facteur de condition plus faible, de même que des concentrations de mercure légèrement plus élevées que d'autres poissons capturés dans la mer. Certains ombles chevaliers pêchés dans le lac s'y alimentent, ce qui laisse à penser qu'ils y résident.
- Les concentrations de mercure sont modérément élevées chez le touladi du lac Grenier, probablement parce que ces poissons sont très vieux.

- La variabilité temporelle des concentrations de mercure semble liée à la variabilité temporelle du coefficient de condition et du climat.

Objectives

- Continue our mercury trend monitoring of sea-run (anadromous) Arctic char from the domestic fishery at Ekaluktutiak with a focus on the role of climatic variability in affecting trends.
- Obtain fish from the stock assessment studies being conducted by Fisheries and Oceans Canada (Les Harris) to investigate differences in mercury concentrations in Arctic char between various river/lake systems used by the commercial fisheries to extend our mercury temporal trend assessments.
- In collaboration with the Canadian High Arctic Research Station (CHARS; Donald McLennan) and the Ekaluktutiak Hunters & Trappers Organization (HTO), continue our mercury investigations of Arctic char and lake trout in Grenier Lake using other sources of funding than the NCP.
- Continue to collaborate with Milla Rautio in ecosystem studies in Grenier Lake including essential fatty acids and their differences between marine and freshwater environments.
- Visit Ekaluktutiak to discuss the findings of the sea-run Arctic char project and conduct limited training and sampling while on site.
- Contribute to the sea-run Arctic char monitoring being conducted at Nain by Rodd Laing with the Nunatsiavut Government and sea-run Arctic char studies out of Pond Inlet.
- Continue to provide contributions to the Arctic Monitoring and Assessment Program (AMAP) on mercury trends.

Introduction

This sea-run Arctic char study is part of NCP's Marine Ecosystems Trend Monitoring Program and was first established in 2004 to obtain spatially comprehensive data on contaminant concentrations in sea-run Arctic char across the Canadian north. Over the course of our studies, we demonstrated that mercury and persistent organic contaminant (POC) concentrations were low in these fish (Evans 2011, Evans and Muir 2014, Evans et al. 2015) supporting the recommendation they are an excellent food choice for communities wishing to consume a traditional diet while minimizing their contaminant intake. Therefore in 2014, NCP reduced the sea-run Arctic char biomonitoring program to a single location, Cambridge Bay, and only for mercury (and metals) analyses. The rationale for continued sampling at this location was:

i) It is the site of a long-term commercial fishery for sea-run Arctic char with large local economic value (Day and Harris 2013).

ii) There is a domestic fishery at Cambridge Bay with harvested fish migrating inland to several lakes with Grenier Lake being the largest (Johnson 1964).

iii) A relatively extensive record exists for mercury concentrations in sea-run Arctic char from a number of fish populations commercially-harvested from the mouths of several river/lake systems located within 100 -150 km of the community (Lockhart et al. 2005, Evans et al. 2015).

iv) With the Canadian High Arctic Research Station (CHARS) being built at this location, the community is becoming a research center investigating many aspects of the freshwater and marine environment, including responses to climate change. There is now an extensive marine char program investigating char movement and resource use. A watershed program, centered on Grenier Lake, is also being developed.

v) Mercury investigations in Arctic char contribute to ECCC's CARA mercury trend assessment program and open the door to broader research studies on these lake ecosystems.

vi) This sea-run Arctic char study is NCP's only biomonitoring study at Cambridge Bay. Hayley Hung and Alexandra Steffen have established a passive air sampling station here for mercury and organic pollutants.

The Arctic char we are investigating are from the domestic fishery with most believed to live in Grenier Lake except during their brief migration to the sea every second year. Lake trout also live in this lake along with glacial relicts including the predaceous *Mysis relicta* (Johnson 1962, Johnson 1964). As Grenier Lake is regularly fished by the community and is the site of expanding limnological studies as part of the growing CHARS program, we have arranged for lake trout and Arctic char to be collected annually from this lake since 2014. These data add to the past research conducted on sea-run and landlocked Arctic char and lake trout populations in northern Canada (Gantner et al. 2010; Swanson et al. 2010; Swanson et al. 2011; Evans et al. 2013; van der Velden et al. 2013a; van der Velden et al. 2013b). Little is known of the ecology of char inhabiting Grenier Lake including whether there are resident in addition to anadromous forms. In addition there are several landlocked char populations in the area. Thus, our studies at Cambridge Bay are an excellent complement to the char studies at Resolute where the populations being investigated are landlocked, inhabit small lakes, and where there are no substantial fisheries as a consequence.

In 2014 CHARS supported baseline studies of the biodiversity and productivity of Grenier and nearby lakes which led to the successful submission of a Polar Knowledge proposal by Milla Rautio. During 2015-2018 she and her team (including Evans) will be investigating water chemistry, phytoplankton, zooplankton, benthos, and fish communities including lipid content and fatty acid composition. Essential fatty acids such as omega-3 and omega-6 cannot be manufactured by animals but must be taken up in the diet from phytoplankton or terrestrial plant producers and are a focus of this research. Changes in marine and lake productivity have the potential to impact fatty acid concentrations and composition in animals, including fish. There is recent interest in emphasizing the health benefits of consuming fish based on omega-3 and omega-6 concentrations that, in some situations, can mitigate concerns with mercury uptake (Dellinger et al. 2014; Paterson et al. 2014; Dellinger and Ripley 2016; Reyes et al. 2017).

Activities in 2016-2017

Fish collections

Local fishermen caught Arctic char from the sea in August 2016. In addition, lake trout and Arctic char (non-migratory) were collected by these fishermen from Grenier Lake. Fish were shipped to Saskatoon for processing. Arctic char submitted to the commercial fish plant from various river systems were processed by Les Harris with samples shipped to us for analyses. Arctic char from Nain and Saglek Fjord were collected by Rodd Laing and sent to us for analyses.

Fish analyses

Fish were weighed, length (total and fork) and sex 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 were noted. Liver and gonad weight were determined. Condition factor, gonad somatic index, and liver somatic index were calculated based on these weight determinations.

Condition factor = Weight*1000/Length^3
Where weight is in grams (g) and
fork length millimeters (mm)

Gonad somatic index = (Gonad weight/
Body weight)*100
Liver somatic index = Liver weight/
Body weight)*100

Approximately 100 g of skin on fillet were removed from the dorsal region for mercury, stable isotope (carbon and nitrogen) analyses; unused tissue was archived for possible future analyses. The liver also was archived.

Total mercury analyses were performed on skinless and boneless fillet using a Hydra C mercury analyzer and following EPA method 7473 (USEPA 2007). We participated in the Northern Contaminants Program and Arctic Monitoring and Assessment Programme Interlaboratory Study

(NCP/AMAP – Phase 10) and received an "excellent" score (Myers and Reiner 2017). Stable isotope carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) analyses were performed at the Environmental Isotope laboratory in Saskatoon using isotope ratio mass spectrometry.

Thirty-two elements were determined by Inductively Coupled Plasma-Mass spectrometry and performed at NLET Burlington. This laboratory also participates in the NCP Quality Assurance Program.

Sample and data exchanges

In 2014 CHARS began supporting baseline studies of the biodiversity and productivity of Grenier and nearby lakes with one study lead by Milla Rautio. Since 2015, she has been investigating water chemistry, phytoplankton and zooplankton communities by determining lipid content and fatty acid composition, (including omega-3 and omega-6 fatty acids). Omega-3 and Omega-6 cannot be manufactured by animals but must be taken up in the diet from phytoplankton or terrestrial plant producers. In 2016, we exchanged samples with Dr. Rautio who is the Principal Investigator on a Polar Knowledge study (Ecosystem Health of Arctic Freshwaters) with a special interest in fatty acids. We provided her with subsamples of the sea-run char which we collected over the years at Cambridge Bay in addition to our more recent char collections from Grenier Lake which had been caught in summer and fall. The fall caught fish may have been a mixture of sea-run and resident char as both types live in Grenier Lake. Dr. Rautio provided us freeze-dried plankton for mercury and stable isotope analyses so that we can develop a mercury food web for Grenier Lake char.

Data were provided to the NCP for PIA trend analyses of mercury and POPs and other chemicals of concern. Analyses on POPs and other chemicals of concern ended in 2012 (Cambridge Bay and Pond Inlet) and 2010 (Nain).

Communications

Marlene had extensive discussions with the Beverly Maksagak (Ekaluktutiak Hunters and Trappers Organization) through the calendar year, first with the collection of fish under this core NCP study and then in developing Dr. Rautio's Polar Knowledge proposal ("Ecosystem Health of Arctic Freshwaters"). Marlene did not visit Ekaluktutiak in summer because the HTO was unavailable when she was able to travel; flight cancellations because of weather prevented her meeting with the HTO in March for another meeting. Marlene also held discussions with the Department of Health of the Government of Nunavut about developing posters on her mercury findings. Finally, there have been communications with Rodd Laing regarding the sea-run Arctic char monitoring at Nain.

Results and Discussion

Mercury trends in anadromous char

Mercury concentrations remained low in anadromous char over 2004-2016 with variations in concentration related to fork length (FL) and condition factor (CF); homogenized air temperature data for 2015 and 2016 are unavailable (Equation 1). Additional mercury data are available for 1977-1993 to extend the trend analyses. However, fish caught from Cambridge Bay in 1977 were small (538 ± 17.9 mm) as were 1978 fish (595 ± 82 g, length not determined) and were excluded from trend analyses. Variations in mercury concentrations over 1993-2016 were best explained by a negative relationship with condition factor and a positive relationship with fork length; year was not a significant term (Equation 2). Other relationships based on climate and air circulation were explored with annual air temperature (1993-2014) and North Atlantic Oscillation (NAO) index also providing good statistical explanation (Equation 3). Analyses of char provided by Les Harris are ongoing.

Equation 1

Log Hg = 17.209 -0.009*Yr + 0.000*FL-0.335*CF
(n = 119; R^2 =0.28, F = 15.2, p<0.001)

Equation 2

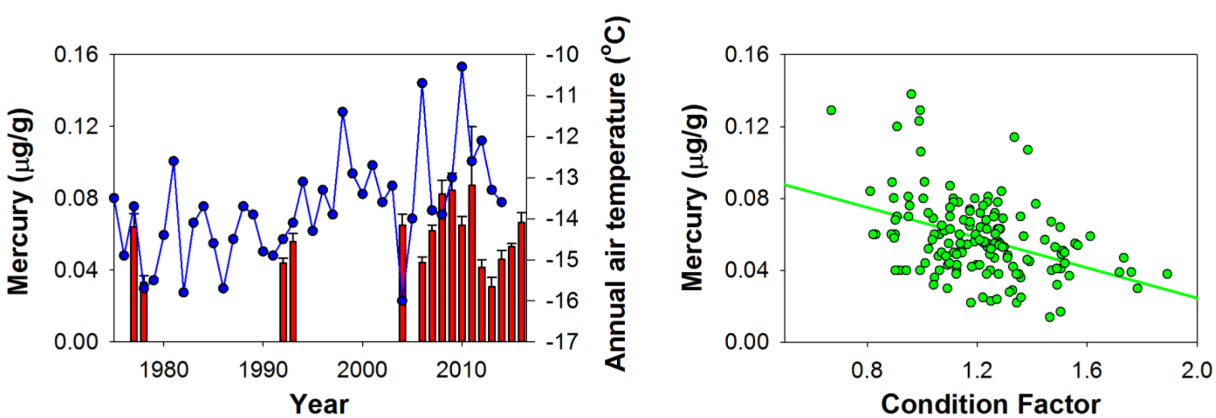
Log Hg = -1.233 + 0.000*FL -0.265*CF (n=134, R^2=0.19, F=15.484, p<0.001)

Equation 3

Log Hg = -2.260 – 0.050*AT – 0.22*NAO (n=114, R^2=0.27, F = 21.60. p<0.001)

Overall, there continues to be evidence of higher mercury concentrations in sea-run char when their condition factors are lower; this seems to occur during cooler years. Higher condition factors during warmer years may result in increased productivity, enhanced fish growth, and lower mercury concentrations. However, with only 12 years (2004, 2005, 2007-2016) of monitoring, the power to detect trends is not strong. This could be improved with additional years of monitoring and measuring mercury in archived fish not yet run (10 or 20 fish are analyzed each year for mercury).

Figure 1. Left panel: Temporal variations in mercury concentrations (fillet, wet weight) of Arctic char collected from the Cambridge Bay area over 1975-2016 and mean air temperatures. Right panel: Relationship between condition factor and mercury concentration.



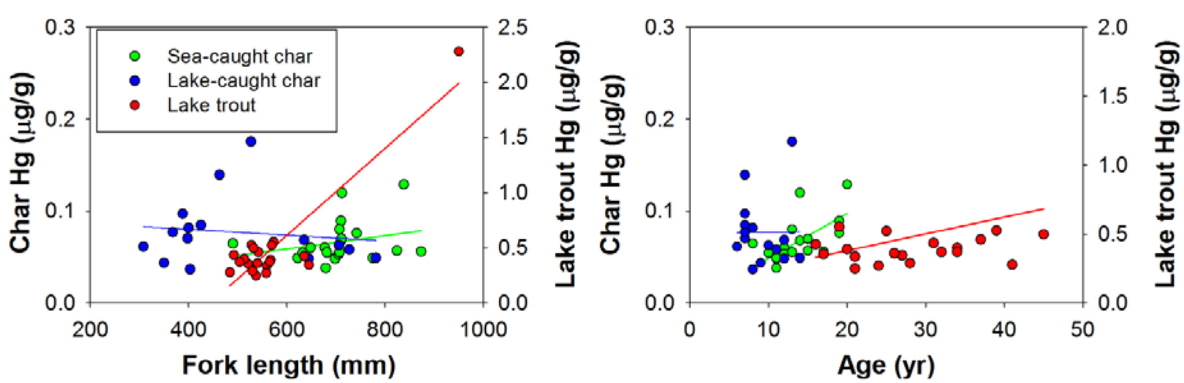
Grenier Lake fish

We continue to explore the relationship between anadromous char and char inhabiting Grenier Lake. Sea-run arctic char tended to be larger and older than arctic char harvested from Grenier Lake; in 2015 char were provided only from Grenier Lake and in the fall after sea-run fish would have returned inland (Table 1; Figure 2). Mercury concentrations, while low, were higher in Grenier Lake arctic char than sea-run char. These slight differences may have been related to (i) the lower condition of Grenier Lake char than sea-caught char and/or (ii) resident char inhabiting Grenier Lake in addition to anadromous char (Swanson et al. 2010; van der Velden et al. 2013a). More than half the Grenier Lake char caught in August 2016 had food in their stomachs; their diet consisted mainly of unidentified invertebrates with some amphipods being recognizable. Lake trout were small and old but with higher condition factors than Arctic char. Their high mercury concentrations were probably related to their increased age with many fish older than 30 years. The average mercury concentration, 0.5 $\mu g \bullet g^{-1}$ is greater than the mean concentration of 0.23 $\mu g \bullet g^{-1}$ observed by Swanson et al. (2011) for lakes in the Kent Peninsula.

Table 1. Biological features and mercury concentrations of Arctic char caught in Cambridge Bay (sea-run) in 2014 and 2015 and Grenier Lake in 2014, 2015 and 2016. Also shown are lake trout data for fish caught from Grenier Lake in 2014, 2015, and 2016.

Species/location		N	Fork Length (cm)	Condition Factor	Age (yr)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Hg ($\mu g \bullet g^{-1}$)
Arctic Char								
Cambridge Bay	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
Cambridge Bay	2016	20	707 ± 83	1.1 ± 0.2	13.6 ± 3.2			0.07 ± 0.02
Grenier Lake	2016	15	510 ± 158	1.1 ± 0.1	9.2 ± 2.6			0.08 ± 0.04
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
Grenier Lake	2016	20	567 ± 99	1.5 ± 0.1	28.7 ± 9.4			0.49 ± 0.43

Figure 2. Length-mercury and age-mercury relationships for sea-caught and Grenier Lake-caught char in 2016. Also shown are lake trout (right axis) from Grenier Lake.



Conclusions

Our study is continuing to investigate trends in mercury concentrations in Arctic char harvested from the domestic fishery at Cambridge Bay on their return inland. Char condition factor and climate appear to be the primary influencing factors in the inter-annual variability in mercury concentrations. Our research continues at Grenier Lake, where our sea-run char are believed to spend most of their lives and where the community regularly fishes. Very old lake trout, moderately high in mercury concentrations, inhabit this lake in addition to resident char. Our study is contributing to ecosystem studies at Grenier Lake, including fatty acid investigations, and will continue with expanded research in 2017. The ability for us to detect trends in mercury concentration will improve with additional years of monitoring; inclusion of data from other char harvesting locations, including the historic record, will also improve trend assessment.

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Temporal trends of persistent organic pollutants and mercury in Landlocked Char in high Arctic lakes

Tendances temporelles des polluants organiques persistants et du mercure chez l'omble chevalier dulcicole de l'Extrême-Arctique

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Abstract

This long term study examines 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 (Amituk, North, Small, and Resolute) near the community of Resolute Bay on Cornwallis Island and in Lake Hazen in Quttinirpaaq National Park on Ellesmere Island. In 2016, arctic char samples were successfully

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 POP, anciens et émergents, qui sont présents chez les ombles chevaliers dulcicoles recueillis annuellement dans des lacs (Amituk, North, Small et Resolute) près de la collectivité de Resolute Bay, sur l'île Cornwallis, et dans le lac Hazen, dans le parc national Quttinirpaaq, sur l'île d'Ellesmere. En

collected from all lakes except Lake Hazen. With the addition of our 2016 results, we've found that declining mercury trends observed in char over the period of 2005 to 2013 in Amituk, Hazen, North, and Resolute lakes have stopped and concentrations have levelled off or increased slightly from 2014 to 2016. Concentrations of fluorinated substances in char have generally declined since 2008-09 but the trends vary among lakes and specific chemicals. The year to year variation in concentrations of both mercury and fluorinated substances in Arctic char may be influenced by factors such as earlier ice out, increased catchment runoff, and changes in benthic invertebrate abundance.

2016, on a réussi à prélever des échantillons d'ombles chevaliers dans tous les lacs, sauf le lac Hazen. L'ajout de nos résultats de 2016 nous a permis de constater que les tendances à la baisse du mercure dans les ombles chevaliers des lacs Amituk, Hazen, North et Resolute, au cours de la période de 2005 à 2013, ont cessé et que les concentrations se sont stabilisées ou ont légèrement augmenté de 2014 à 2016. Les concentrations de substances fluorées chez l'omble chevalier ont généralement diminué depuis 2008-2009, mais les tendances varient selon les lacs et les types de produits chimiques. La variation d'une année à l'autre des concentrations de mercure et de substances fluorées chez l'omble chevalier pourrait être influencée par des facteurs tels qu'une fonte des glaces plus hâtive, l'augmentation du ruissellement de bassins ainsi que des changements dans l'abondance des invertébrés benthiques.

Key Messages

- While concentrations of mercury concentrations in landlocked Arctic char still show overall declining trends since 2005, levels have recently levelled off or increased slightly.
- Concentrations of fluorinated substances in char have generally declined since 2008-09 but the trends vary among lakes and specific chemicals.
- The year to year variation in concentrations of mercury, fluorinated substances, and legacy POPs in Arctic char may be influenced by climatic factors.

Messages clés

- Bien que les concentrations de mercure chez l'omble chevalier dulcicole continuent d'afficher, dans l'ensemble, des tendances à la baisse depuis 2005, les niveaux se sont récemment stabilisés ou ont légèrement augmenté.
- Les concentrations de substances fluorées chez l'omble chevalier ont généralement diminué depuis 2008-2009, mais les tendances varient selon les lacs et les types de substances chimiques.
- La variation d'une année à l'autre des concentrations de mercure, de substances fluorées et de POP hérités du passé chez l'omble chevalier peut être attribuable à des facteurs climatiques.

Objectives

- Determine long term temporal trends of persistent organic pollutants (POPs) and metals in landlocked Arctic char from lakes in the Canadian high Arctic islands by analysis of annual or biannual sample collections.
- Investigate factors influencing contaminant levels in landlocked char such as the influence of sampling time, water temperature, diet, and climate warming.
- Determine levels of current POPs and metals as well as "new" potential POPs in fish from lakes of importance to the community of Resolute Bay (Qausuittuq) and provide this information to the community on a timely basis.

Introduction

Landlocked char are the only top predators in most Canadian high Arctic lakes (Köck et al. 2004, Power et al. 2008), and therefore can serve as a sentinel species for changes in atmospheric inputs of bioaccumulative contaminants such as persistent organic pollutants (POPs) and mercury. The condition and diet of the char also provides information on the impacts of climate change on Arctic lakes. Analysis of landlocked char over the past 25 years has provided information on the range and time trends of chemical contaminants in Arctic freshwater systems, (Muir et al. 2013, Chételat et al. 2015). 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/trends which need to be better understood. This temporal trend study has been supported by a series of food web studies on these lakes which have investigated the pathways and processes of bioaccumulation of mercury and perfluorinated substances (Gantner et al. 2010a, 2010b; Drevnick et al. 2013; 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. This study has built on landlocked char collections begun by Köck et al. (2004) which started in Resolute Lake in 1997 (Köck et al. 2004, Muir et al. 2005). Char Lake, Amituk Lake and Lake Hazen, from which char had previously been collected and analysed in the 1990s as part of pre- or early NCP studies (Muir and Lockhart 1994, Fisk et al. 2003) were later included in the study. Fishing has been more difficult in some lakes due to low numbers (Char), weather dependent access by helicopter (Amituk), and high cost (Hazen). One goal of this study is to detect a 5% change in concentrations of mercury and POPs over a 10-15 year period with a power of 80% and confidence level of 95% (CIRNAC 2005). Annual sampling has been used to try and achieve this goal. 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. Juvenile char, chironimids, and zooplankton, along with water samples for water quality and mercury/methylmercury analysis have generally been collected at the same time as the fish. Further details on past results from these study lakes are given in previous synopsis reports by Muir et al. (2014, 2015b, 2016).

Activities in 2016-17

Sample collection

Char were successfully collected in late-July and early August 2016 from Amituk, 9-Mile, North, Small, and Resolute lakes. At Lake Hazen, Parks Canada staff at Quttinirpaaq

National Park initially tried to fish through the ice in late June as they have done in the past but lost their ice auger so were unable to complete the fish collection. Samples (skin-on fillets) were frozen in Resolute and then shipped to the Environment and Climate Change 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 Mark Lowdon (AAE Tech Services Inc, Winnipeg).

Chemical analysis

Thirty-one elements were determined in Arctic char muscle (skinless) using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) by the National Laboratory for Environmental Testing (NLET). In brief, muscle (1 g) was digested with nitric acid and hydrogen peroxide (8:1) in a high pressure microwave oven at 200ºC for 15 minutes and the digest was analysed by ICP-MS (NLET 2002). Mercury in char muscle was analyzed by the Muir research lab with a Direct Mercury Analyser using US EPA Method 7473 (US EPA 2007). Certified biological reference materials for mercury and multi-element analysis included DOLT-2, DORM-2 and TORT-2 from National Research Council of Canada.

Char muscle (+ skin) samples collected in Amituk and Resolute lakes in 2016 were homogenized under clean room conditions and submitted for analysis of emerging and new POPs including brominated flame retardants (BFRs) and perfluorinated alkyl substances (PFASs) as planned under the NCP Call for Proposals (2016-17). Samples were Soxhlet extracted with dichloromethane (DCM) and lipid removed by gel permeation chromatography by ALS Environmental (Burlington ON). Sample extraction has been completed and results of gas chromatography-tandem mass spectrometry (GC-MS/MS) analysis of BFRs being conducted by NLET organics lab are pending. The extracts are also scheduled to be analysed by NLET for short chain chlorinated paraffins (SCCPs) in 2017 using GC-ultra high resolution mass spectrometry. Analysis of SCCPs in 2016 was postponed due to instrument failure.

PFASs including C4 to C15 perfluorocarboxylates (PFCAs) and C4 to C12 perfluoroalkane sulfonates were analysed as described in Lescord et al. (2015a). The extraction procedure involved addition of mass-labeled internal standards (^{13}C2 PFCAs and PFOS) and an extraction with acetonitrile followed by carbon cleanup. PFASs in sample extracts were quantified by liquid chromatography with negative electrospray tandem mass spectrometry (LC-MS/MS). A certified biological reference material, NIST SRM-1946 lake trout homogenated, was used for PFAS analysis.

Stable isotope analyses

Muscle from all fish analysed for mercury and POPs were analysed for stable isotopes of carbon (δ^{13}C) and nitrogen (δ^{15}N) at University of Waterloo Environmental Isotope Lab in muscle samples using isotope ratio mass spectrometry.

Quality assurance (QA)

Reagent blanks were 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 for PFASs, multielements or mercury. 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 Environmental (contractor for BFR extractions) have participated in the NCP Quality Assurance Program in recent years (Myers et al. 2014; Myers and Reiner 2015; Myers and Reiner 2016).

Statistical analyses

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. Temporal trends of mercury, expressed as % per year, were determined using the PIA program (Bignert 2007).

Capacity Building

The project depends on the help of local people in the Hamlet of Resolute. Debbie Iqaluk worked on the project in 2016. 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 conditions.

Communications

A summary of results of the work in 2016 was sent to the Resolute Bay HTA in late March 2017. Muir met with the Manager of the HTA office during his trip to Resolute in early August 2016 as well as informally with members of the HTA. In December 2016, results were presented at the ArcticNet Annual Scientific Meeting in Winnipeg, MB and at Society of Environmental Toxicology & Chemistry World Congress, in November in Orlando (FL).

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.

Results

Mercury

The trends of mercury over time, updated with results from 2016 are shown graphically in Figure 1. Results for 9-Mile Lake, which was originally studied by Gantner et al. (2010b), was added to broaden the range of lakes with time trend data. The 2 year running average suggests declining concentrations in five of the six lakes over the period of 2005 to 2013. PIA software (Bignert 2007) was used to analyse data from six lakes for which we had six or more years of mercury concentrations in char muscle (Table 1). While previous measurements for the period of 2005-2013 showed significant declines in mercury concentrations in Resolute, Hazen, Amituk, and North (Muir et al. 2014), the addition of the 2015 and 2016 data shows a levelling off so that statistically significant declines are only seen in Resolute Lake and Lake Hazen. Small Lake was the only lake with an increase in concentrations in more recent years; however, the increase was not statistically significant.

Figure 1. Trends of mercury (geometric means ± 95% confidence interval) in landlocked char from Nin-Mile, Resolute, Amituk, Hazen, North and Small lakes (early 90s-2016). All results are length adjusted using analysis of covariance. Red lines represent 2 year moving averages.

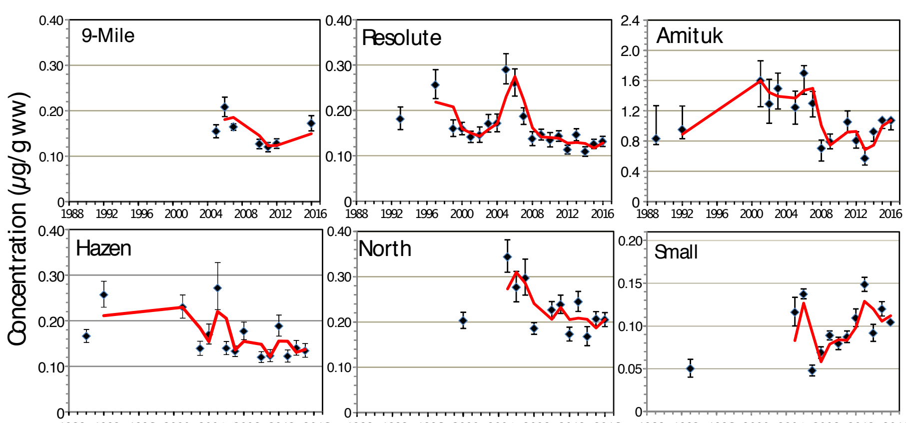


Table 1. PIA analysis of time series for mercury concentrations in landlocked char muscle (NS = not statistically significant) for the period 2005-2016

Lake		# years	Overall trend[1]	R^2	Lowest detectable change[2]	Power to detect a log-linear trend of 10%[3]
Amituk	2005-16	11	-2.1% (NS)	0.04	14%	60%
Char	2005-12	7	-19.0%	0.65	27%	20%
Hazen	2005-15	10	-7.9%	0.45	17%	61%
North	2005-16	10	-2.3%	0.05	17%	43%
Small	2005-16	11	1.8% (NS)	0.02	17%	45%
Resolute	2005-16	12	-5.9%	0.58	5.2%	100%
9-Mile	2005-16	6	-1.3% (NS)	0.07	24%	28%

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

[2] LDC = lowest detectable change in the current time series (with a power of 80% and one-sided test)

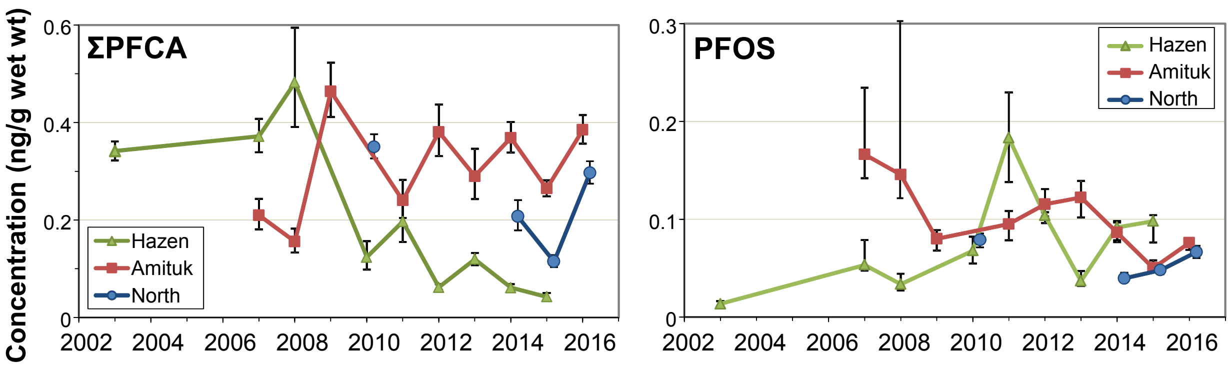
[3] The power of the time series to detect a log-linear trend of 10% with the number of years in the current time series

POPs

No analyses of legacy POPs were conducted on the 2016 samples because of the decision by the NCP to switch to every two year analyses. However, samples from 2016 were analysed for BFRs and PFASs which are on Schedule B of the NCP "Blueprint" for 2017-18. Trends of BFRs in landlocked char muscle from Lake Hazen, Amituk, Char, and Resolute Lakes were presented in our 2015-16 report (Muir et al. 2016). This year we will focus trends of PFASs in char which we last summarized in 2015 (Muir et al. 2015a).

ΣPFCAs (sum of C8-C12 PFCAs) have continued to decline in char from Lake Hazen from a maximum in 2008 (Figure 1). The rate of decline from 2008 to 2015 was 26% per year which is statistically significant (r^2=0.79, P=0.008). No significant trends of ΣPFCAs were found in Amituk or North Lake over the period 2009 to 2016 (Figure 2). PFOS declined in char from Lake Hazen over the period 2011-2015 (Figure 2) at a rate of 13% per year. However the decline was not statistically significant (r^2=0.14; P=0.53). PFOS also showed a significant decline of 8% per year in char from Amituk Lake from 2007 to 2016 (r^2=0.51; P=0.03) (Figure 2). Results for North Lake are too limited to assess trends.

Figure 2. Trends of C8-C11 perfluorinated carboxylic acids (ΣPFCAs) and perfluorooctane sulfonic acid (PFOS) in landlocked char muscle from Amituk, Hazen and North lakes (early 2000s – 2016). Symbols represent geometric means and vertical bars are standard errors.



Influence of climate

We continued to investigate relationships between mercury in char and climate variables for Resolute, Amituk and Hazen Lakes (Drevnick 2014, Muir et al. 2015b, Hudelson et al. 2017). Climatic influences on long term trends of PCBs and organochlorine pesticides (OCPs) in char were analyzed (Cabrerizo-Pastor et al. 2017). PCBs and chlorinated pesticides generally showed declining trends of concentrations in char as expected due to the past national and regional regulatory bans, and restriction on uses and emissions in circumpolar and neighboring countries. However, concentrations of POPs in char from the last two decades were also positively correlated with interannual variations of the North Atlantic Oscillation (NAO). Concentrations of POPs in Arctic char tended to be higher with positive NAO phases. This may be related to shifts in the hydrological cycle of the lakes including earlier ice out and changes in benthic invertebrate abundance.

Weight and length data for char from this study (2003-2014) combined with results from several DFO studies for 1981 to 2001 (Babaluk et al. 2007) were used to show that fish condition (based on weight•length^{-3}) had declined in Lake Hazen in the past 10 years after being steady during the 1980s and 1990s (Lehnherr et al. 2017).

Discussion and Conclusions

The significant declines in mercury concentrations in landlocked char that we observed in five study lakes (Char, Resolute, Amituk, Hazen and North) over the period of 2005 to 2013 have now given way to no change (Hazen, Resolute), or slight increases (Amituk, North) from 2014 to 2016. Given that atmospheric mercury is declining slowly at Alert and more rapidly in southern Canada (Cole et al. 2013), this suggests that pathways and processes within the lakes and their catchments are important. The extent of net methylmercury production, may be particularly important, as illustrated by increasing mercury concentrations in char in Small Lake which has higher dissolved organic carbon and methylmercury in water than the other study lakes (Lescord et al. 2015b).

The declining trend of ΣPFCAs in char at Lake Hazen but not at Amituk or North Lake may reflect differences in lake size as well as catchment to lake area ratio (A_C/A_L). Amituk and North have large A_C/A_L's (70 and 165, respectively) compared to 12.7 for Lake Hazen. This means that catchment inputs of ΣPFCAs may be more important in Amituk and North Lakes even as atmospheric inputs decline. Atmospheric measurements at Alert (Hung 2016) show recent declines of PFOA (2013-14) after a steady rise from 2007 to 2012 as well as declines in fluorotelomer alcohol precursors of PFCAs as of 2012. Atmospheric precursors of PFOS, perfluorooctane sulfonamide and sulfonamidoethanols, have declined since 2008-09 at Alert (Hung 2016) which may explain the decline of PFOS in char at Amituk Lake since 2007. However an atmospheric deposition pathway does not explain the more recent decline of PFOS in Lake Hazen. Based on preliminary results showing relationships of both mercury and POPs in char to climate indices (Cabrerizo-Pastor et al. 2017; Hudelson et al. 2017) it seems likely that shifts in the hydrological cycle of the lakes including earlier ice out, increased catchment runoff, and changes in benthic invertebrate abundance could be affecting the year to year variation of both mercury and PFASs in char. This influence may be becoming more important as atmospheric sources of the contaminants decline with global phase outs and emission controls.

Acknowledgements

We thank the Hamlet of Resolute Bay for allowing us to sample Char Lake and other lakes in the region, Parks Canada for their support of sampling at Lake Hazen, and the Polar Continental Shelf Program for accommodation and aircraft support. We thank the staff of the NLET inorganics and organics labs for conducting all the multielement and BFR analyses during 2016-17. We thank ALS Environmental (Burlington) for conducting POPs analysis, sample extraction/GPC extracts, and lipid determinations.

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Spatial and long-term trends in persistent organic contaminants and metals in Lake Trout and Burbot from the Northwest Territories

Tendances spatiales et à long terme des contaminants organiques persistants et des métaux chez les touladis et les lottes des Territoires du Nord-Ouest

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Abstract

Our Great Slave Lake Northern Contaminants Program study is measuring trends in mercury, other metals, persistent organic pollutants (POPs) and other contaminants of concern in Lake Trout and Burbot from three locations in two regions of Great Slave Lake. Lake Trout were obtained from the domestic fishery at Lutsel K'e (East Arm) and the commercial fishery operating out of Hay River (West Basin). Burbot were obtained from the domestic fishery at Fort Resolution (West Basin). In addition, under our other studies, we continue to investigate mercury concentrations in Burbot at Lutsel K'e and Northern Pike at Fort Resolution. Mercury concentrations remain relatively low

Résumé

Notre étude du Grand lac des Esclaves dans le cadre du Programme de lutte contre les contaminants dans le Nord consiste à mesurer les tendances des concentrations de mercure, d'autres métaux, de POP et d'autres contaminants préoccupants chez le touladi et la lotte de trois sites dans deux régions du Grand lac des Esclaves. Les touladis ont été fournis par des pêcheurs locaux pratiquant la pêche domestique à Lutsel K'e (bras est du lac) et par des pêcheurs pratiquant la pêche commerciale dans la rivière Hay (bassin ouest). Les lottes ont été fournies par des pêcheurs locaux pratiquant la pêche domestique à Fort Resolution (bassin ouest).

in these fish and previously reported trends of mercury increase have become less apparent. We worked on a series of posters to present our mercury findings in a clear and more understandable way; as part of this we met with several community organizations in the fall to discuss our study results and poster design. The concentrations of POPs and other contaminants of concern are declining, particularly ΣDDT and ΣHCH in Lake Trout (commercial fishery, Lutsel K'e) and Burbot (Fort Resolution). We continue to work with Fort Resolution (water intake study) and Lutsel K'e (Stark Lake concerns), and contribute to related studies being conducted by other researchers including mercury trends in fish in Dehcho lakes and Great Bear Lake.

De plus, dans le cadre de nos autres études, nous poursuivrons l'analyse des concentrations de mercure chez la lotte à Lutsel K'e et chez le grand brochet à Fort Resolution. Les concentrations de mercure demeurent relativement faibles chez ces poissons, et les tendances à la hausse du mercure précédemment signalées sont moins marquées. Nous avons travaillé sur une série d'affiches visant à présenter nos résultats sur le mercure de manière claire et plus compréhensible. Dans le cadre de cette initiative, nous avons rencontré, durant l'automne, plusieurs organismes communautaires afin de discuter de nos résultats d'études et de la conception d'affiches. Les concentrations de POP et d'autres contaminants préoccupants sont à la baisse, plus particulièrement celles du ΣDDT et du ΣHCH chez le touladi (pêche commerciale, Lutsel K'e) et chez la lotte (Fort Resolution). Nous continuons de travailler avec les chercheurs de Fort Resolution à leur étude sur les prises d'eau et avec ceux de Lutsel K'e (préoccupations concernant le lac Stark), et contribuons à des études connexes menées par d'autres chercheurs, entre autres sur les tendances du mercure chez les poissons dans des lacs du DehCho et le Grand lac de l'Ours.

Key Messages

- Mercury concentrations remain relatively low (average <0.5 $\mu g \cdot g^{-1}$) in Lake Trout, Burbot, and Northern Pike from Great Slave Lake.
- 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 $\mu g \cdot g^{-1}$) chez le touladi, la lotte et le grand brochet du Grand lac des Esclaves.
- Il y a quelques années, les concentrations de mercure semblaient à la hausse chez le touladi et la lotte, mais ces dernières années, il y a moins d'indications permettant de conclure à une augmentation sur le plan temporel.
- Les concentrations de POP sont à la baisse, en particulier chez les poissons du bassin de l'ouest.

Objectives

- Determine mercury, metals and persistent organic contaminants (POCs) 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 2016 to further extend our long-term POCs and mercury data bases.
- Investigate mercury trends in Great Slave Lake fish and the drivers of these trends.
- Investigate trends in POCs and contribute information to AMAP expert work groups for trend monitoring for POCs.
- Continue to work with Fort Resolution in their water quality monitoring of Resolution Bay waters and continue Northern Pike mercury monitoring in Fort Resolution.
- Work with Lutsel K'e in the collection of Burbot from the East Arm and provide advice where requested particularly as related to Stark Lake. 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 in 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 part of the Northern Contaminants Program (NCP) Freshwater Ecosystems Trend Monitoring Program which is designed to provide the necessary data sets for evaluating the success of the Stockholm Convention on persistent organic pollutants (POPs) and more recently the Minamata Convention. Legacy POPs concentrations are slowly declining in the environment with trends differing with the species and location investigated (Rigét et al. 2010, Muir et al. 2013). As monitoring continues, the statistical power to detect and investigate drivers of change is strengthened. Mercury concentrations appear to be increasing in biota in North America with increasing Asian mercury emissions, global warming, and changes in major atmospheric circulation patterns (Carrie et al. 2010, Chételat and Braune 2012, Evans et al. 2013, Braune et al. 2015, Lescord et al. 2015). Mercury trend assessment is of concern given the large number of consumption advisories that have been issued in recent years for lakes along the Mackenzie River. Research on new and emerging POPs and other contaminants of concern is also critical and therefore we investigate levels of perfluorocarboxylic acids (PFCAs) and polybrominated diphenyl ethers (PBDEs) and novel brominated flame retardants (BFRs).

Our study location is Great Slave Lake, NT, where we are investigating Lake Trout (*Salvelinus namaycush*) and Burbot (*Lota lota*) in the low-productivity waters of the East Arm and the more productive waters of the West Basin, which is under profound influence from the Slave River. There have been long-term concerns that activities (municipalities, agriculture, pulp and paper mills, and oil sands activities) in the upper reaches of the Peace and Athabasca rivers, which conjoin to form the Slave River, are transporting significant quantities of contaminants to the lake. Our study began in 1993 as part of the early NCP programs which focused on Lake Trout, Burbot, lake whitefish (*Coregonus clupeaformis*) and their food webs; additional funding was received under the Northern River Basins Study and the Slave River Environmental Quality Monitoring Program (Evans and Muir

2016). Since 1998, our study has focused on mercury and persistent organic contaminant trend assessments in Lake Trout and Burbot; Northern Pike were briefly monitored with NCP funding ending in 2002. 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 is important in the domestic diet of many communities, has economic importance supporting commercial fisheries in the West Basin, with a growing sports fishery in the East Arm. 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). Burbot, while not important in the commercial and sports fisheries, has some importance in the domestic fishery as its lipid-rich liver is a highly-prized food item. Persistent organic pollutants especially PCBs and toxaphene tend to be high in its liver. Burbot are sedentary predators 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 inhabit large river systems such as the Mackenzie and deeper waters in lakes. Burbot are being monitored at the northern portion of Resolution Bayat that forms the Slave River delta and also are monitored on the Mackenzie River at Fort Good Hope by Stern (Stern 2012). Burbot monitoring at Lutsel K'e under NCP ended in 2004 but resumed in 2008 as part of Environment Canada studies. Northern Pike are a nearshore predator inhabiting warm waters and often residing in weedy areas. Mercury concentrations tend to be moderately 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 during 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 (Evans et al. 2013). Under ECCC's Chemical Monitoring Program, (Sean Backus), we have been monitoring mercury (and other chemicals) in Lake Trout and cisco from Great Bear Lake. As part of our collaborative studies with George and Mike Low, we have contributed 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 database to allow us to investigate trends in warm-water lacustrine species. We also provide advice, when possible, to Lutsel K'e regarding its concerns with the health of Lake Trout from Stark Lake.

Activities in 2016-2017

In autumn 2016, we received 20 Lake Trout from Lutsel K'e, 20 Lake Trout from the commercial fishery operating out of Hay River, and 20 Burbot from Fort Resolution. 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, 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 from each location for mercury, metals, legacy organic contaminants, and PDBE and PFCA analyses; most analyses are complete.

We have been contributing to the AMAP assessment of trends in POPs and other contaminants of concern in Lake Trout and Burbot. Time trends were examined using PIA software (Bignert 2007) for Lake Trout fillet and Burbot (lipid adjusted) liver with data available for most compounds from 1993-2015. A poster presentation on our findings was given at the recent Arctic Net conference.

We have worked hard in developing more effective ways to communicate our findings of mercury concentrations in fish in Great Slave Lake and other lakes we have and/or continue to monitor including Great Bear Lake. Draft posters were developed and circulated to the NWT Regional Contaminants Committee and GNWT Health for initial comment and then to community representatives in Hay River, Fort Resolution, and Lutsel K'e.

Marlene has worked with community members over the years on various aspects of fish health (e.g. Gwich'in at Inuvik (a Burbot liver health and contaminant study), Trout Lake (skinny versus healthy walleye and mercury concentrations))and concerns about contaminants from local developments, (e.g. Fort Resolution (Pine Point mine), Lutsel K'e (Stark Lake (Evans et al. 1998a, Evans et al. 1998b, Evans and Landels 2015)An overview of these studies was provided in an oral presentation at the recent ArcticNet meeting.

In November, Marlene made a consultation trip which began in Lutsel K'e and was coordinated with an CIRNAC (Contaminated Sites) to discuss the remediation of the abandoned uranium mine on Stark Lake. Marlene discussed her findings on the health of Lake Trout in Stark Lake and presented the poster on mercury in Lake Trout and Burbot from the Lutsel K'e area of Great Slave Lake. At Fort Resolution, Marlene presented the poster about fish collections made in the West Basin. She also assisted in data interpretation and a presentation given by Kathleen Fjordy, the environmental monitor working on the water-quality study at the domestic water intake in Fort Resolution. In Hay River, Marlene met with the West Point and Katlodeechee First Nations to go over draft posters and discuss studies of potential interest to be conducted in conjunction with George Low, the AAROM coordinator. In Yellowknife, Marlene met with the Akaitcho Territory Government's Akaitcho Aquatics Monitoring Program Technical Board, a meeting attended by representatives from Lutsel K'e, Fort Resolution, Fort Smith, and Yellowknife. Marlene travelled through Yellowknife in March 2017 for Chemical Management Plan travel to Deline to discuss mercury trend monitoring of Lake Trout in Great Bear Lake. In Yellowknife, she had further discussions regarding more effective ways of presenting mercury in fish findings.

In March 2014, sediment cores were collected under Environment Canada's Clean Air Regulatory Program Mercury Science Assessment at two sites in the West Basin (as reported in Evans et al. (2013), Stark Lake, and in Kakisa Lake in the Dehcho where a small commercial fishery has existed since the 1940s (Johnson 1976, Tonn et al. 2016). Cores also were examined for diatom remains by John Smol to investigate changes in algal productivity.

Marlene continued to work with Fort Resolution on its water quality monitoring of Resolution Bay waters using its domestic water intake. This began as a capacity building study to provide training in monitoring, data management, and project management but we are hopeful that this program will continue its evolution to provide valuable data to complement this core contaminant trend monitoring program.

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 (John Chetelat); Tłı̨chǫ Aquatic Ecosystem Monitoring Program proposal development (JodyPellissey); Integrated Fishery Stock Assessment Plan for Sustainable Harvest of Lake Whitefish in Great Slave Lake, Northwest Territories (Xinhua Zhu); and Mercury Levels in Food Species in Lakes Used by Community Members (GeorgeLow). Pike, Walleye and Lake Whitefish collected by Mike Low from Buffalo Lake in January 2017 will be analyzed for mercury, age, and stable isotopes.

Results and Discussion

Lake Trout and Burbot persistent organic contaminant trends

Fish caught in 2016-2017 were not scheduled for analyses of POPs and other contaminants of concern although tissues were archived for potential future analyses. Updated POPs and other contaminants of concern trend analyses were conducted using the most recent 2015 data. Most POPs and other contaminants of concern exhibited statistically significant declines in concentration in Lake Trout and Burbot; rates of decline generally were greater for West Basin fish. This faster rate of decline may be related to the greater sedimentation rate and/or shorter residence time of water in the West Basin than East Arm (Figure 1). Analyses of PBDEs and PFCAs were completed on 2015 Lake Trout fillet and Burbot liver in 2016, with results presented at the Arctic Net meeting held December 5-9, 2016 in Winnipeg (Figure 2). PBDE concentrations were slightly higher in East Arm than West Basin Lake Trout fillet with no evidence of decline. In contrast, PBDE concentrations were substantially higher in East Arm than West Basin Burbot liver with evidence of decline since 2011. The temporal record for PFCAs in Lake Trout fillet is still being constructed by analyzing archived samples. Concentrations in East Arm fish were higher in the late 1990s and early 2000s than in more recent years. The record for Burbot liver is shorter; concentrations were again higher in East Arm than West Basin fish with no evidence of decreasing trends in recent years.

Figure 1. Rate of change in persistent organic contaminant concentrations by species, region and compound. * indicates change is statistically significant at p<0.05.

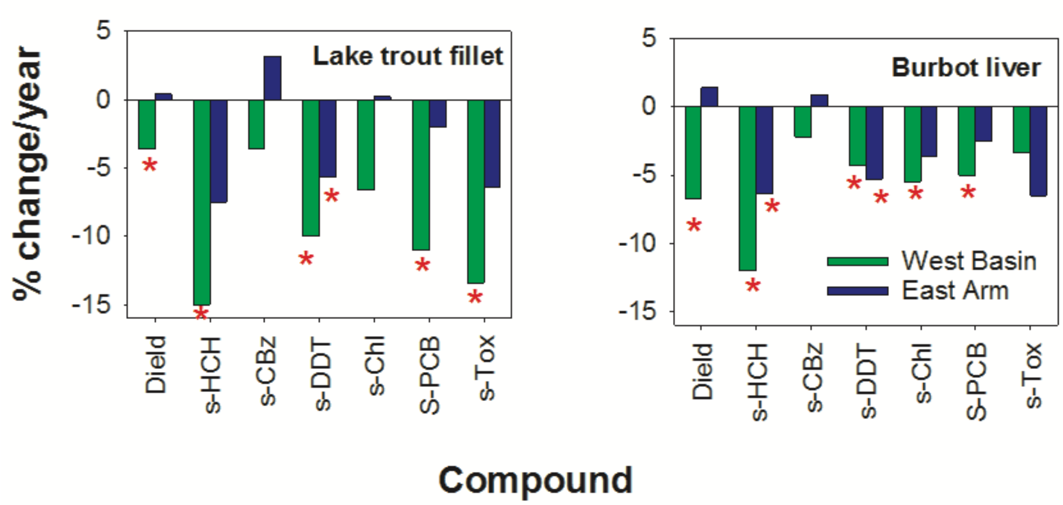
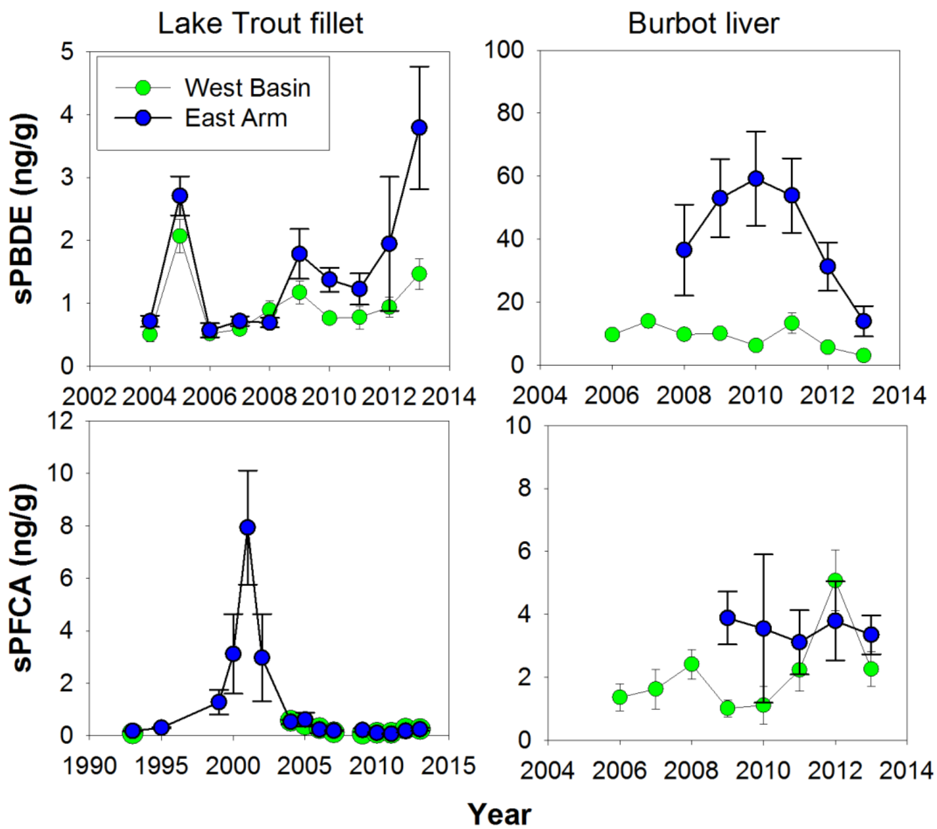


Figure 2. Trends in PBDEs and PFCAs in Lake Trout fillet and Burbot liver. Data are shown as means (± 1 standard error) and are in ng•g^{-1} wet weight.



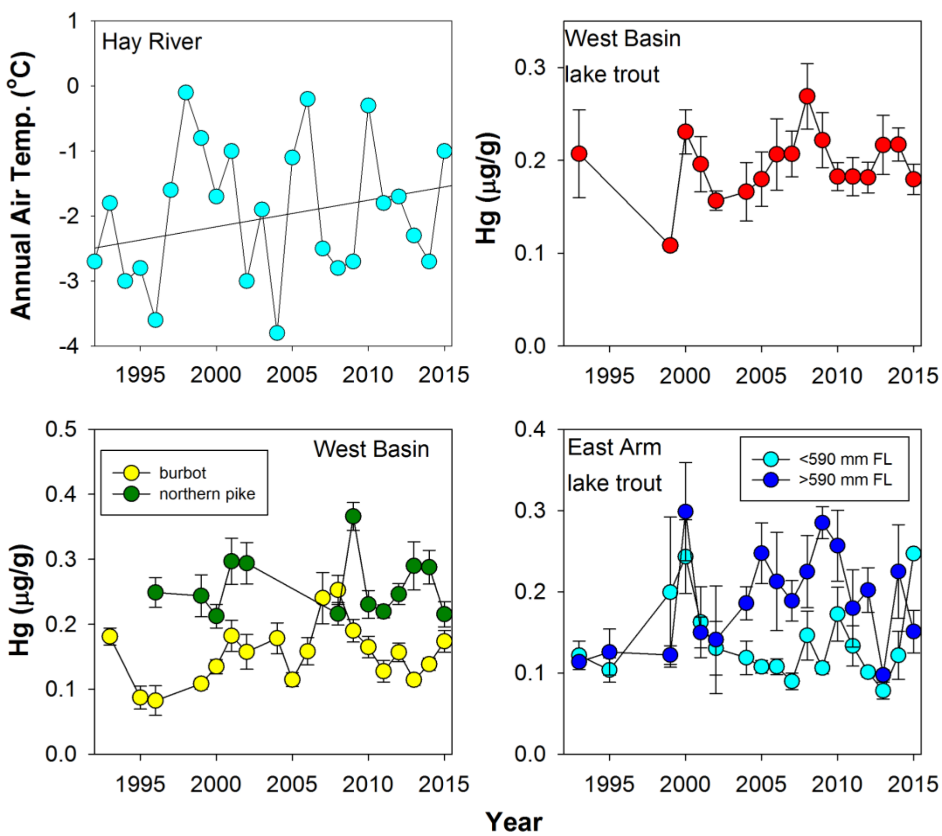
Fish mercury trend assessments

We continue to investigate trends in mercury concentrations in Burbot, Lake Trout, and Northern Pike (Evans et al. 2013). For West Basin Lake Trout (Table 1, Figure 3), variations in mercury concentration were best explained by a positive relationship with fork length (FL) and a negative relationship with annual air temperature at Hay River (HAT). Investigation of the factors affecting variation in mercury concentration in East Arm Lake Trout has been more challenging with fish needing to be divided into small (500-650 mm total length; mean age 14.2 years) and large (650-800 mm total length; mean age 15.5 years) size groups because of length-year interactions. There also may be different ecotypes of Lake Trout (with different feeding and growth characteristics) that are not being recognized (Chavarie et al. 2013, Chavarie et al. 2016). Variations in small Lake Trout were best explained by age (AG), in addition to fork length, while for large fish, mercury was explained by fork length and year. Mercury continued to show a significant trend of increase in East Arm Burbot when total length (TL) was included in the regression model; the inclusion of annual air temperature at Hay River (HAT) explained additional variance. For West Basin Burbot, there was a significant trend of mercury increase over 1995-2016. For West Basin Pike, variations in mercury concentration were explained by fork length, age, and air temperatures at Hay River. Average mercury concentrations remain below 0.5 µg•g^{-1}.

Table 1. Results of general linear model analyses of factors affecting variability in log Hg concentration in Lake Trout, Burbot, and Northern Pike collected from the West Basin and East Arm of Great Slave Lake over different time intervals. N is the number of fish in the analyses, R2 is the amount of variation explained by the model, and p is the significance level. See text for additional explanation.

Species/Location	Period	Equation	n	F-ratio	R^2	p
Lake Trout						
West Basin	1995-2016	Log Hg = 11.816 + 0.002*FL – 0.032*HAT	164	68.76	0.46	0.000
East Arm small	1995-2016	Log Hg = -1.892 + 0.001*FL + 0.021*AG	96	20.39	0.31	0.000
East Arm large	1995-2016	Log Hg = -15.602 +0.007*YR + 0.002*FL	89	7.218	0.14	0.001
Burbot						
West Basin	1995-2016	Log Hg = -10.568 + 0.005*YR + 0.001*TL	195	26.06	0.23	0.000
East Arm	1999-2016	Log Hg = -16.326+ 0.008*YR + 0.001*TL -0.029*HAT	159	7.28	0.12	0.000.
Northern Pike						
West Basin	1999-2016	Log Hg = -1.246 +0.000*FL +0.02*AG – 0.031*HAT	234	49.50	0.39	0.000

Figure 3. 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.



Mercury studies and community communications

We have worked hard in developing more effective ways to communicate our findings of mercury concentrations in fish in Great Slave Lake and other lakes we have monitored and continue to monitor. Draft posters were developed and circulated to the NWT Regional Contaminants Committee and GNWT Health for initial comment and then to community representatives in Hay River, Fort Resolution, and Lutsel K'e for further comment. The design is based on a simplified presentation of average data over the past several years and for three size or age classes with pictorial data of fish schools showing medians and data ranges (Figure 4). While much detail was lost, these posters convey a simplified message of our findings and in the form relevant to most viewers; they have been well received. These posters were further refined in summer 2017.

Fish health and related studies

We have worked with community members over the years on various aspects of fish health (e.g., skinny fish at Stark Lake and Trout lake) and concerns with local developments (decommissioned Pine Point mine at Fort Resolution and exploratory mine at Stark Lake). An overview of these studies was provided in an oral presentation at the recent Arctic Net meeting. Skinny fish (Figure 4), when provided, tended to be older fish, often with small livers, potentially due to age-related impacts on their health (Figure 5); mercury concentrations in skinny fish were not appreciably different from healthy fish suggesting that there is no link between contaminants and fish health. Lake Trout from Stark Lake had similar length-weight relationships as East Arm Lake Trout (Figure 3). Many of the Lake Trout from Stark Lake were very large and heavy. These fish also were old with the oldest fish having mercury concentrations that exceeded the 0.5 $\mu g \bullet g^{-1}$

Figure 4. a) Upper panel shows scientific way of showing the relationship between Lake Trout length and weight for fish from Stark Lake and Great Slave Lake while lower panel shows a picture of a "skinny" fish. b) Graphs showing the simplified way of viewing length-weight (upper panels) and length-mercury (lower panels) relationships for Lake Trout from the two lakes.

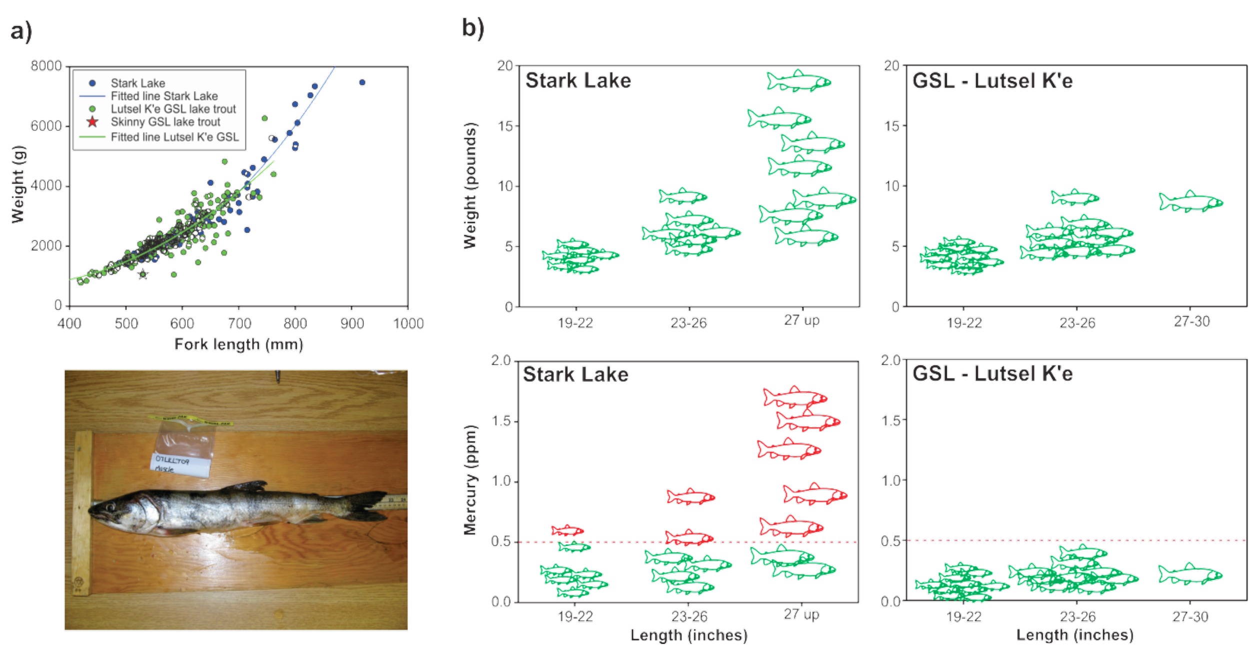
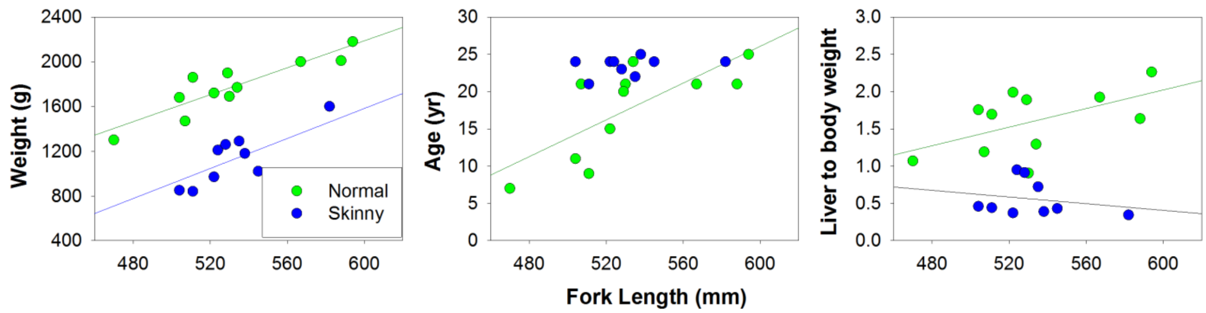


Figure 5. Graph of length versus weight relationships for normal and skinny walleye from Trout Lake. Also shown are the length-age relationships showing that skinny fish generally were >20 years old and possibly near the end of their life. These fish also had small liver weight relative to body weight.



commercial sale guidelines. Consumption advice has been issued for Lake Trout from Stark Lake by GNWT Health and Social Services. Since community members may avoid harvesting Lake Trout from Stark Lake (due to consumption advisories these fish tend to live long and hence on average are older than Lake Trout from the East Arm (Stark Lake 19.8 ± 7.5 years versus 14.7 ± 3.3 years for East Arm fish).

The water treatment plant at Fort Resolution

We continue to work with Fort Resolution in studies at their domestic water intakewith these studies starting as capacity building studies to provide training in water quality sampling and working with data. Between 2012 and 2013, with Cumulative Impact Monitoring Program funding, water samples were collected at approximately monthly intervals for nutrients, major ions, metals, and chlorophyll analyses with most analyses conducted by the Taiga Laboratory in Yellowknife. Later in 2013, the program was scaled back to recording the regular measurements made by the plant operator on untreated intake water and collecting water for total phosphorus analyzes which continued until 2014 (when funding was no-longer available). . Sampling for chlorophyll continued past 2014 with analyses being conducted by ECCC in Saskatoon. Over 2015-2016, a special study was designed by Kathleen Fjordy to measure the quality of water treatment plant water that was released onto the landscape and formed a stream which flowed into Resolution Bay. Metals and major ions were measured in this water and these measurements were collected on a number of occasions. Marlene worked with Kathleen in examining these data which were compared with the untreated water. This water apparently was waste water from the treatment process which the operating manual for the facility indicates contains backwash from the filters, sediment accumulation from the wet well, and sediment from the water treatment process (flash mixer, flocculation, and settling segments of the process); metal and major ion concentrations generally were lower than in untreated water with most of the water presumably containing backwater.

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 have warming trends. Average mercury concentrations in predatory fish are well below the 0.5 $\mu g \bullet g^{-1}$ commercial sale guidelines. 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 and Climate Change Canada (ECCC), including support from ECCC's Clean Air Regulatory Agenda (CARA) mercury science program.

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

Études sur les tendances temporelles des métaux traces et des composés organiques halogénés (COH), y compris les composés persistants nouveaux et émergents, chez la lotte du fleuve Mackenzie à Fort Good Hope (Territoires du Nord-Ouest)

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Abstract

Tissues from burbot collected at Fort Good Hope (Rampart Rapids) in December 2016 were analysed for Hg, Se and As. Data from this time point was combined with the existing metal data (1985, 1988, 1993, 1995, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015) together covering a time span of 31 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 0.364 ± 0.143 (n = 678) and 0.099 ± 0.085 (n = 684) $\mu g \cdot g^{-1}$, respectively. Muscle mercury levels are below the recommended guideline level of 0.50 $\mu g \cdot g^{-1}$ for commercial sale.

Résumé

Les tissus de lotte prélevés à Fort Good Hope (rapides Rampart) en décembre 2016 ont été analysés afin de déterminer s'ils contenaient du mercure (Hg), du sélénium (Se) et de l'arsenic (As). Ces données recueillies à ce moment ont été combinées à celles qui existaient sur les métaux (1985, 1988, 1993, 1995, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015), lesquelles couvrent une période de 31 ans. Aucune corrélation significative entre la durée et les concentrations de mercure n'a été observée dans les muscles et le foie des deux sexes. Les concentrations moyennes de mercure dans les muscles et le foie pour les ensembles complets de données étaient de 0,364 ± 0,143 (n = 678) et de 0,099 ± 0,085 (n = 684) $mg \bullet g^{-1}$,

respectivement. Les concentrations de mercure dans les muscles se situent sous la concentration recommandée dans les lignes directrices, 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 0.364 ± 0.143 (n = 678) and 0.099 ± 0.085 (n = 684) µg•g-1, respectively.
- Since the mid-1980s, an approximate 2- and 3-fold increase in mercury concentrations has been measured in Fort Good Hope 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-1 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 0,364 ± 0,143 (n = 678) et de 0,099 ± 0,085 (n = 684) mg•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 concentrations de mercure dans les muscles et dans le foie se situent sous la concentration recommandée dans les lignes directrices, qui est de 0,50 mg•g-1 pour la vente commerciale.
- Les concentrations en poids humide de ΣHCB, de ΣHCH, de ΣDDT, de ΣCHB et de ΣBPC (± écart type) en ng•g-1 pour les échantillons de foies de 2015 étaient de 5,25 (2,94), 0,47 (0,18), 8,89 (2,98), 4,54 (7,67) et 14,84 (6,10), respectivement.

Objectives

- To continue 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 past studies, much of the temporal trend data that are available are too limited to be scientifically credible because they are based on two or at most three 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 increased 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: (i) melted permafrost, increased erosion and forest fires may release increasing amounts of Hg into the river; (ii) the rate of Hg methylation processes may be increased by increasing temperature and nutrients, particularly in the wetlands and peatlands in the basin; and (iii) 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 term temporal trend studies.

FWI/UM currently maintains a very extensive archive of Fort Good Hope burbot sample tissues and data on trace metals (31 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, 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, 2016).

Activities in 2016-2017

In December 2016, 31 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 31 years and 22 time points (1985, 1988, 1993, 1995, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016). Mean Hg concentrations in muscle and liver over the entire data sets were 0.364 ± 0.143 (n = 678) and 0.099 ± 0.085 (n = 684) $\mu g \bullet g^{-1}$, respectively. Mercury levels in muscle are below the recommended guideline level of 0.50 $\mu g \bullet g^{-1}$ 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 Hope 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 arsenic concentration, 17.16 $\mu g \bullet g^{-1}$, occurred in a muscle sample from a female burbot collected in 1999.

ΣHCB, ΣHCH, ΣDDT, ΣCHB and ΣPCB wet weight concentrations (SD) in $ng \bullet g^{-1}$ 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. OC analysis was conducted in the 2016 samples.

Table 1. Mean (standard deviation) concentrations of mercury, selenium and arsenic in Fort Good Hope burbot muscle ($\mu g \bullet g^{-1}$).

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]
Dec-16	M	10	661 (104)	0.565 (0.196)	-	-
Apr-85[1]	F	6	714 (140)	0.337 (0.136)	0.480 (0.126)	-
Dec-93	F	3	812 (133)	0.297 (0.035)	0.321 (0.009)	6.450 (0.984)
Sept-95	F	2	-	0.180 (0.085)	-	-
Dec-99	F	21	735 (101)	0.259 (0.108)	0.219 (0.104)[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)	-	-
Dec-16	F	21	733 (122)	0.420 (0.097)	-	-

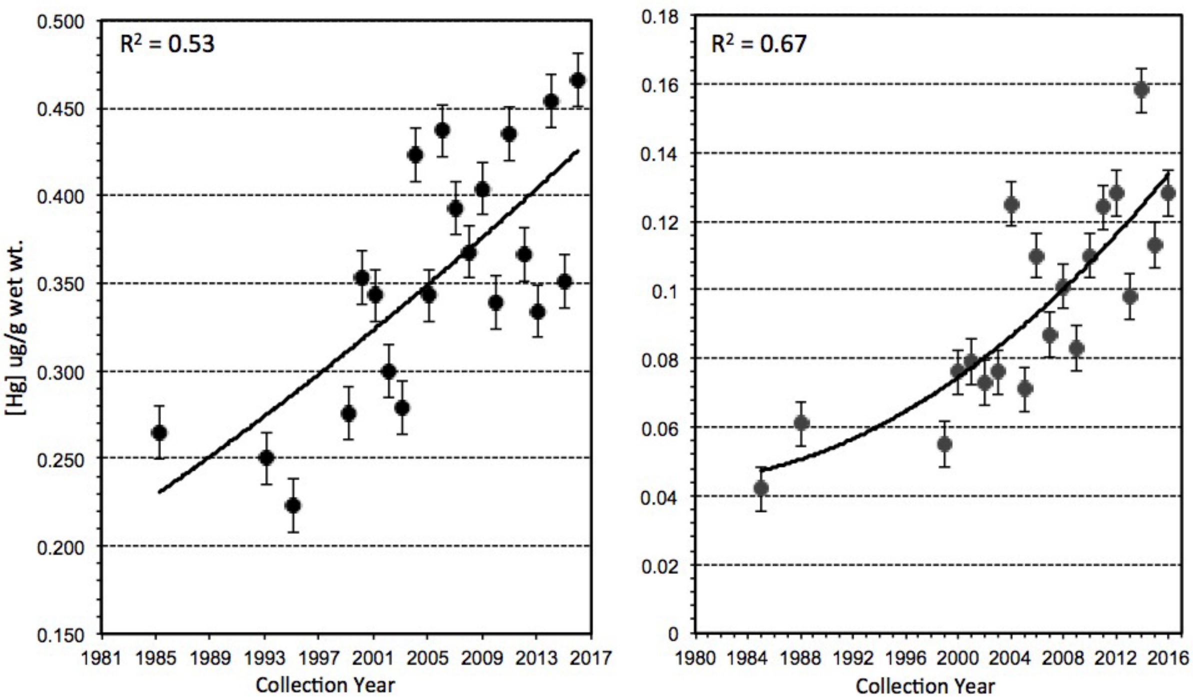
[1]n = 20; [2]n=7

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-85[1]	M	9	643 (82)	0.044 (0.019)	1.759 (0.558)	-
Dec-88	M	8	706 (84)	0.054 (0.026)	1.230 (0.555)	3.119 (1.725)
Dec-93	M	7	677 (109)	-	-	1.016 (1.328)
Dec-99	M	21	676 (107)	0.046 (0.024)	1.071 (0.628)[2]	0.607 (0.326)
Dec-00	M	21	699 (104)	0.064 (0.026)	1.646 (0.733)	0.585 (0.412)
Dec-01	M	10	720 (164)	0.063 (0.048)	1.434 (1.278)	0.839 (0.822)
Dec-02	M	12	699 (92)	0.063 (0.031)	1.437 (0.808)	0.771 (0.539)
Jan-04	M	9	705 (79)	0.126 (0.179)	1.981 (1.370)	1.994 (1.447)
Dec-04	M	17	681 (112)	0.111 (0.065)	3.267 (2.437)	0.496 (0.605)
Dec-05	M	13	616 (67)	0.053 (0.047)	1.677 (0.782)	0.527 (0.540)
Dec-06	M	17	700 (78)	0.094 (0.064)	1.939 (1.117)	-
Dec-07	M	16	642 (61)	0.076 (0.035)	2.090 (0.837)	-
Jan-09	M	15	324 (75)	0.114 (0.055)	3.416 (1.722)	0.335 (0.300)
Dec-09	M	22	703 (94)	0.064 (0.030)	2.038 (0.985)	-
Dec-10	M	21	672 (66)	0.100 (0.075)	2.571 (2.118)	0.630 (0.568)
Dec-11	M	17	701 (112)	0.119 (0.079)	2.333 (1.407)	-
Dec-12	M	8	713 (119)	0.063 (0.024)	1.946 (0.623)	0.456 (0.378)
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)	-	-
Dec-16	M	10	661 (104)	0.158 (0.084)	-	-
Apr-85[1]	F	6	714 (140)	0.097 (0.098)	1.272 (0.715)	-
Dec-88	F	2	623 (86)	0.072 (0.035)	1.460 (1.529)	1.280 (1.018)
Dec-93	F	3	812 (129)	-	-	1.062 (0.546)
Dec-99	F	20	749 (77)	0.064 (0.069)	0.687 (0.552)[2]	1.353 (0.811)
Dec-00	F	15	732 (127)	0.094 (0.056)	1.203 (0.469)	0.632 (0.349)
Dec-01	F	10	747 (122)	0.098 (0.108)	1.235 (0.720)	1.074 (1.227)
Dec-02	F	17	727 (118)	0.082 (0.067)	1.488 (1.203)	1.063 (0.890)
Jan-04	F	22	726 (98)	0.057 (0.033)	1.245 (0.511)	1.522 (1.348)
Dec-04	F	17	700 (112)	0.138 (0.081)	2.616 (2.030)	0.489 (0.335)
Dec-05	F	25	710 (104)	0.080 (0.050)	1.585 (1.013)	0.489 (0.585)
Dec-06	F	21	695 (106)	0.125 (0.076)	1.906 (1.006)[3]	-
Dec-07	F	24	674 (113)	0.094 (0.098)	2.064 (1.096)	-
Jan-09	F	22	689 (118)	0.092 (0.059)	1.690 (1.095)	0.451 (0.401)
Dec-09	F	18	701 (110)	0.107 (0.141)	1.752 (1.023)	-
Dec-10	F	18	672 (105)	0.122 (0.135)	1.399 (0.688)	0.556 (0.571)
Dec-11	F	24	725 (108)	0.128 (0.043)	1.664 (0.973)	-
Dec-12	F	32	703 (119)	0.144 (0.114)	2.730 (2.410)	0.409 (0.586)
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)	-	-
Dec-16	F	21	733 (122)	0.114 (0.067)	-	-

[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 propositions and thus annual sampling is projected into the foreseeable future.

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Trace metals and organohalogen contaminants in fish from selected Yukon lakes: A temporal and spatial study

Métaux traces et contaminants organohalogénés chez les poissons de certains lacs au Yukon : études 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 covers 23 years, with 20 and 18 time points, respectively. The mean Hg levels over the entire data sets for the Laberge and Kusawa samples were 0.47 ± 0.21 (n=218) and 0.40 ± 0.29 (n=204) μg•g^{-1}, respectively. In both lakes, levels are below the recommended guideline level of 0.50 μg•g^{-1} for commercial sale. No significant trends have been observed in 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

Résumé

Nous avons analysé des échantillons de muscles de touladis prélevés dans deux lacs du Yukon, soit le lac Kusawa et le lac Laberge, afin de détecter divers contaminants organohalogénés (pesticides organochlorés [OC], BPC, produits ignifuges bromés [PIB] et composés organiques fluorés [COF]) et en métaux lourds (Hg, Se et As). À l'heure actuelle, les données sur les tendances temporelles relatives aux métaux lourds dans les muscles des touladis des lacs Laberge et Kusawa couvrent une période de 23 ans, et on a prélevé des échantillons à 20 et à 18 moments, respectivement, dans ces lacs. Pour l'ensemble des données, la concentration moyenne de mercure était de 0,47 ± 0,21 (n = 218) au lac Laberge et de 0,40 ± 0,29 (n = 204) μg•g^{-1}, au lac Kusawa. Ainsi, dans les

have been observed. The current length adjusted mean Hg concentration is now at its highest level since 1999. Analysis of the HOCs in the 2016 muscle tissue is in process.

deux lacs, les concentrations sont inférieures à la limite de 0,50 µg•g^{-1} recommandée dans les lignes directrices 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 baisse importante des concentrations moyennes de mercure dans les muscles des touladis corrigée en fonction de la longueur des individus 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. L'analyse des COH prélevés dans les tissus musculaires en 2016 est en cours.

Key Messages

- Currently heavy metal (mercury, selenium and arsenic) time trend data from Laberge and Kusawa Lake trout covers 23 years, with 20 and 18 time points, respectively.
- The mean Hg levels over the entire data sets for the Laberge and Kusawa samples were 0.47 ± 0.21 (n=218) and 0.40 ± 0.29 (n=204) µg•g^{-1}, respectively. In both lakes, levels are just below the recommended guideline level of 0.50 µg•g^{-1} for commercial sale.
- No significant trends have been observed in the Laberge 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

- À l'heure actuelle, les données sur les tendances temporelles des métaux lourds (mercure, sélénium et arsenic) dans les muscles des touladis des lacs Laberge et Kusawa couvrent une période de 23 ans; des échantillons ont été prélevés à 20 et à 18 moments, respectivement, dans ces lacs.
- Pour l'ensemble des données, la concentration moyenne de mercure était de 0,47 ± 0,21 (n = 218) au lac Laberge et de 0,40 ± 0,29 (n = 204) µg•g^{-1} au lac Kusawa. Ainsi, dans les deux lacs, les concentrations sont tout juste inférieures à la limite de 0,50 µg•g^{-1} recommandée dans les lignes directrices 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 baisse importante des concentrations moyennes de mercure dans les muscles des touladis corrigée en fonction de la longueur des individus 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

- maintain current data on contaminants levels in lake trout from two Yukon lakes (Laberge and Kusawa) in order 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 its precursors).
- use data to determine the health of the fish stock and thus whether or not exposure to contaminants in the people who consume the fish is increasing or decreasing with time.
- use these results 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 organochloride (OC) pesticide and polychlorinated biphenyl (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 weight 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. These biotic changes could be due to variations in the fish population that are related to the cessation of commercial fishing or potentially an increase in lake plankton productivity related to annual climate variation (Ryan et al. 2005).

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 2016/17

Crown-Indigenous Relations and Northern Affairs Canada (Whitehorse)/Fisheries and Oceans Canada (Winnipeg) maintain together a very extensive archive of fish tissues and data for Hg, Se, As, and HOCs in Yukon lakes (see Tables 1-4). In 2016, nine lake trout were collected from Kusawa Lake and 10 from Lake Laberge.

Results and Discussion

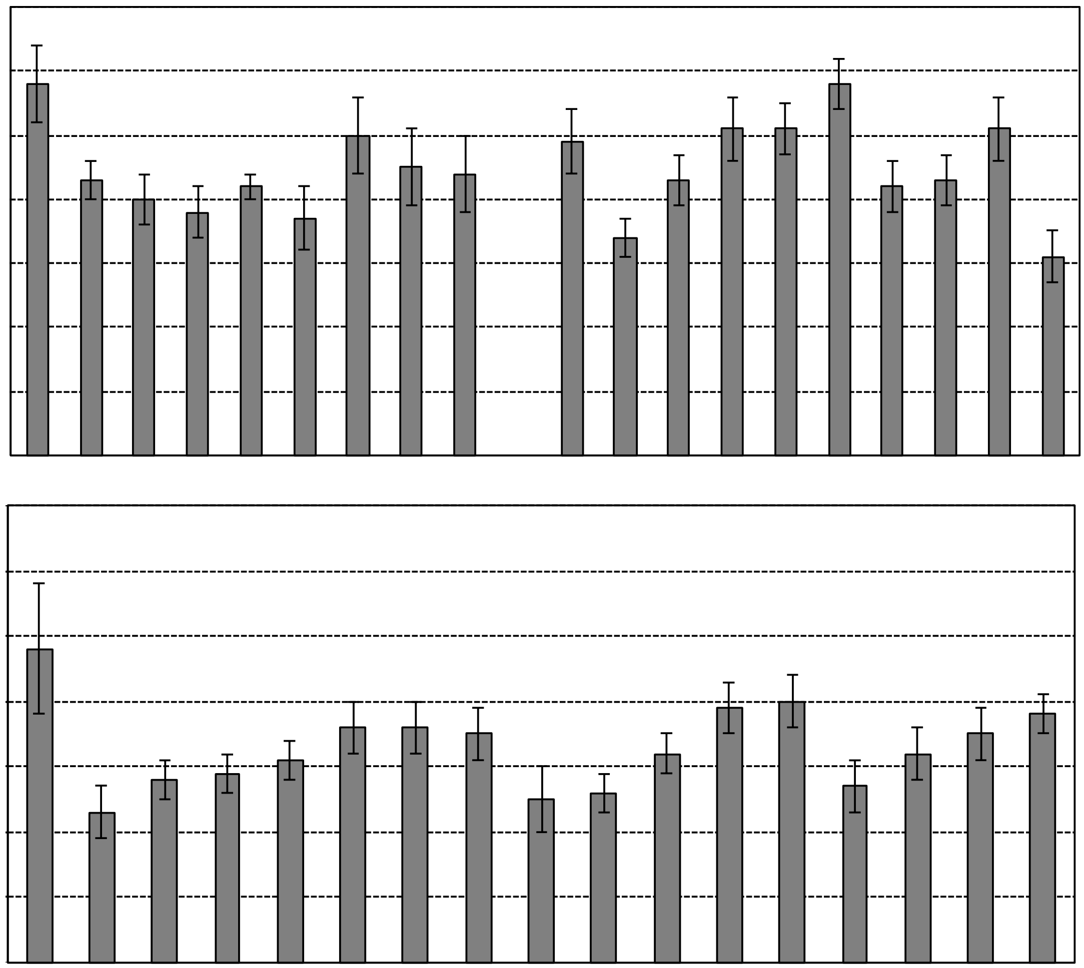
Hg, Se, As

Currently heavy metal (mercury, selenium and arsenic) time trend data from Laberge and Kusawa Lake trout cover 23 years, and 20 and 18 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=218) and 0.40 ± 0.29 (n=204) μg•g^{-1}, respectively. In both lakes, levels are just below the recommended guideline level of 0.50 μg•g^{-1} for commercial sale. A significant correlation between length and muscle mercury concentration was observed in the Laberge trout ([Hg] = 0.0013*length - 0.2892, r^2 = 0.59, p<0.001, n=204) and Kusawa trout ([Hg] = 0.0018*length -0.5046, r^2 = 0.52, p<0.001, n=192). ANCOVA was used to assess the effects of year to year collections (temporal trends), length and length*year interactions (homogeneity of the slope between length and [Hg]). No significant trends have been observed in the Laberge lake trout over the last 23 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.

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^{-1}.

	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)	-	-
	2016	10	451 (94)	0.37 (0.15)	-	-
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)	-	-
	2016	9	541 (55)	0.34 (0.09)	-	-

Figure 1. Length adjusted Hg concentrations in trout muscle from Lake Laberge (Top: 1993-2016) and Kusawa (Bottom; 1993–2016). Only Kusawa trout less than 700 mm in length were used in the ANCOVA as trout with lengths >700 mm were considered outliers .



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. Analysis of the 2016 samples is underway. 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 noted below (2015 and 2016 samples are currently being analyzed):

Laberge (ng•g^{-1}, wet wt.)
2006 (n=1); PFOS = 2.18 ng g^{-1}, wet wt.
2007 (n=9); PFOS = 2.47 (1.86); PFNA = 5.78 (6.33); PFDA = 32.40 (30.34)
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); PFDA
2013 (n=10); PFNA = 0.54 (0.46); PFOSA = 0.28 (0.50)
2014 (n=12): PFNA = 0.42 (0.84); PFDA = 0.44 (1.58)

Kusawa (ng•g^{-1}, wet wt.)
2006 (n=9); PFOA = 2.93 (7.78) ng•g^{-1}, wet wt.
2007 (n=9); PFOS = 0.50 (0.54); PFNA = 0.36 (1.08); PFDA = 12.78 (16.93)
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)
2010 (n=10); PFOS = 0.19 (0.60); PFNA = 2.93 (3.48); PFDA = 3.85 (5.25)
2011 (n=10); PFOS = 0.21 (0.40); PFNA = 1.53 (2.51); PFDA = 5.68 (5.71)
2012 (n=10); PFOS = 0.31 (0.67); PFNA = 3.51(4.12); PFDA = 1.37 (4.23)
2013 (n=10); PFUA = 0.45 (0.66)
2014 (n=12): PFNA = 0.27 (0.35); PFDA = 0.51 (1.26)

Table 2. Mean (S.D.) HOC levels (ng•g^{-1} wet wt.) in lake trout muscle from Lake Laberge

Laberge	N	Age	% lipid	ΣPCB	ΣDDT	ΣCHL	ΣHCH	ΣCHB	ΣCBz
1993	24	15 (2)	7.9 (0.9)	328.28 (121.49)	391.54 (132.69)	47.60 (8.84)	4.69 (0.78)	310.96 (62.36)	3.92 (0.57)
1996	13	22 (5)	9.6 (1.4)	209.32 (52.08)	236.51 (41.39)	53.38 (13.74)	6.50 (1.79)	212.23 (28.31)	4.90 (1.24)
2000	6	12 (2)	3.7 (0.8)	138.95 (60.89)	96.46 (14.21)	22.36 (5.84)	2.30 (1.08)	207.33 (49.90)	2.26 (0.59)
2001	16	14 (2)	4.9 (0.5)	139.71 (53.75)	89.46 (14.04)	26.37 (5.14)	0.80 (0.07)	154.20 (60.46)	2.11 (0.17)
2002	5	12 (4)	4.2 (0.9)	48.60 (8.81)	54.50 (11.58)	7.26 (1.59)	1.58 (0.50)	139.23 (16.88)	1.15 (0.25)
2003	8	12 (1)	4.7 (0.8)	81.01 (29.83)	61.48 (8.55)	7.44 (2.24)	0.54 (0.10)	179.31 (42.79)	1.21 (0.28)
2004	6	12 (4)	8.7 (3.9)	48.93 (34.30)	94.09 (60.68)	7.46 (4.90)	0.19 (0.09)	79.92 (52.01)	0.49 (0.28)
2005	10	14 (7)	2.0 (1.22)	28.94 (20.27)	50.91 (30.27)	2.61 (1.28)	0.16 (0.10)	34.50 (19.97)	0.35 (0.27)
2006	1	21	1.0	25.52	31.25	4.82	0.07	76.87	0.35
2007	9	14 (5)	1.2 (0.80)	37.36 (25.89)	43.98 (29.93)	5.32 (4.05)	0.10 (0.09)	25.78 (14.58)	0.27 (0.80)
2008	10	12 (5)	2.3 (1.1)	50.23 (36.89)	70.06 (41.29)	4.04 (2.88)	0.18 (0.08)	24.48 (16.85)	0.77 (0.23)
2009	10	10 (3)	2.9 (1.1)	28.92 (14.89)	35.33 (20.81)	2.30 (1.06)	0.14 (0.06)	37.60 (19.57)	0.60 (0.34)
2010	10	9 (2)	2.3 (1.3)	12.08 (3.74)	40.43 (12.12)	1.18 (0.47)	0.12 (0.05)	24.91 (13.84)	0.29 (0.12)
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)
2016	7	14 (4)							

Table 3. Mean (S.D.) OC levels (ng•g-1 wet wt.) in lake trout muscle from Kusawa Lake

Kusawa	N	Age	% lipid	ΣPCB	ΣDDT	ΣCHL	ΣHCH	ΣCHB	ΣCBz
1993	10	19 (2)	1.8 (1.6)	85.62 (26.07)	44.16 (21.50)	17.33 (2.78)	1.21 (0.36)	120.80 (24.94)	1.15 (0.28)
1999	14	18 (1)	4.6 (3.0)	91.09 (11.85)	139.16 (19.72)	17.82 (2.74)	1.68 (0.23)	148.38 (29.29)	1.52 (0.20)
2001	9	12 (1)	2.4 (1.4)	48.55 (7.91)	56.58 (15.30)	7.45 (2.35)	0.91 (0.14)	61.03 (8.55)	0.84 (0.14)
2002	10	12 (1)	1.4 (0.8)	32.45 (3.66)	26.66 (4.15)	3.01 (0.48)	0.62 (0.08)	43.47 (5.02)	0.61 (0.09)
2003	9	9 (3)	5.8 (3.6)	8.16 (5.86)	8.21 (15.67)	3.50 (2.28)	0.14 (0.08)	45.05 (32.20)	0.44 (0.30)
2004	9	13 (4)	7.9 (4.7)	11.29 (3.78)	5.70 (3.70)	4.52 (2.16)	0.15 (0.07)	49.73 (30.17)	0.50 (0.27)
2005	10	15 (6)	0.61 (0.51)	5.48 (4.84)	2.35 (3.02)	1.17 (0.88)	0.03 (0.03)	12.37 (11.57)	0.12 (0.10)
2006	9	12 (4)	1.82 (1.49)	6.28 (4.58)	2.97 (2.57)	2.49 (1.84)	0.09 (0.06)	42.63 (34.97)	0.47 (0.26)
2007	9	10 (4)	1.52 (1.43)	9.88 (9.93)	2.35 (1.88)	2.78 (2.90)	0.10 (0.06)	22.44 (23.88)	0.42 (0.33)
2008	10	9 (2)	1.16 (0.42)	18.30 (27.27)	2.35 (0.94)	1.30 (0.40)	0.13 (0.26)	22.55 (7.87)	0.47 (0.13)
2009	10	9 (1)	1.51 (1.11)	2.55 (1.59)	0.78 (0.67)	0.95 (0.72)	0.05 (0.03)	21.20 (17.20)	0.18 (0.11)
2010	10	10 (3)	1.9 (1.6)	3.20 (2.24)	2.12 (2.13)	0.93 (0.81)	0.06 (0.03)	22.00 (23.05)	0.20 (0.12)
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)
2016	7	16 (7)	-						

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

Expected Project Completion Date

Temporal trend studies are long-term propositions and thus annual sampling is projected until well into the future.

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Arctic Caribou Contaminant Monitoring Program

Programme de surveillance des contaminants dans le caribou de l'Arctique

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Abstract

This project investigates 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 2016/17 samples were collected from 23 Porcupine, 40 Qamanirjuaq, 23 Bluenose West and 10 Ahiak caribou. Samples were taken from an additional 20 Qamanirjuaq cows immediately post-rut to explore the possible effect of mercury on pregnancy. Sample analyses for these collections had not been completed at the time this report was prepared. Porcupine, Qamanirjuaq, Bluenose East and Dolphin & Union samples collected in the 2015/16 year have been analyzed, and results are presented in this report. Age was positively correlated with renal Cd and Zn in the Porcupine, Qamanirjuaq and Beverly caribou. Renal lead declined over time in those three herds as well. Mercury appears to be stable over the long term in the Porcupine and Qamanirjuaq herds. Toxic elements tended

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 (d'après les charges de contaminants), si cette ressource alimentaire importante continue d'être une source de nourriture saine et sécuritaire pour les résidents du Nord et si les concentrations de contaminants évoluent au fil du temps. En 2016-2017, des échantillons ont été prélevés sur 23 caribous de la Porcupine, 40 de Qamanirjuaq, 23 de Bluenose Ouest et 10 d'Ahiak. Des échantillons ont été prélevés sur 20 autres femelles de Qamanirjuaq immédiatement après le rut afin d'étudier les effets possibles du mercure sur la gestation. Leur analyse n'était pas terminée au moment où le présent rapport a été rédigé. Les échantillons recueillis en 2015-2016 chez les caribous de la Porcupine, de Qamanirjuaq, Bluenose Est et Dolphin-et-Union ont été analysés, et les résultats obtenus sont présentés dans le présent rapport. On a observé chez les caribous de la Porcupine, de Qamanirjuaq et de Beverly

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. 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 25 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.

une corrélation positive entre l'âge et les concentrations de cadmium et de zinc présentes dans les reins. Les concentrations de plomb dans les reins des caribous de ces trois hardes ont également diminué avec le temps. Les concentrations de mercure semblent demeurer stables à long terme chez les hardes de la Porcupine et de Qamanirjuaq. Les éléments toxiques tendaient à être plus abondants chez les caribous femelles que chez les caribous mâles, probablement à cause du volume relativement plus élevé d'aliments consommés (et donc d'éléments toxiques) par les femelles, de leur plus petite taille et des besoins énergétiques plus importants découlant de la mise bas et de la lactation. 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 dans une certaine mesure 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 25 rognons de caribous de la harde de la Porcupine par année). L'avis sanitaire confirme que les concentrations de métaux lourds sont très faibles dans la viande (muscles) de caribou, et que cette source de nourriture demeure un choix alimentaire 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.
- Mercury concentrations in the Porcupine and Qamanirjuaq caribou appear to be stable over the long term.

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 dans une certaine mesure pour la santé humaine, selon la quantité d'organes consommée. La viande (muscles) des caribous n'accumule pas de grandes concentrations de contaminants et constitue donc un aliment sain.

- This program will continue to monitor the Porcupine and Qamanirjuaq caribou herds annually to maintain confidence in the health-related safety of this traditional food and to better understand the dynamics of contaminants within this ecosystem (particularly mercury).

- Les concentrations de mercure semblent demeurer stables à long terme chez les hardes de la Porcupine et de Qamanirjuaq.

- Dans le cadre de ce programme, on continuera de surveiller les hardes de caribous de la 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:

- Provide information to Northerners regarding contaminants in these traditional foods, so that:
  - Northerners may be better able to make informed choices about food consumption. This includes providing information for health assessments and/or advisories as required.
  - Wildlife managers can assess possible health effects of contaminants on Arctic caribou populations.

- Further understand the fate and effects of contaminant deposition and transport to the Canadian Arctic.

Introduction

Caribou provide an important food resource for Northerners across the Arctic, and have been designated in the NCP blueprint as key species for monitoring contaminants in the terrestrial Arctic ecosystem. Two barren-ground caribou herds, one from the eastern (Porcupine) and one from the western (Qamanirjuaq) Arctic, have been designated for annual sampling, and two additional herds are sampled each year on a rotating basis.

Activities in 2016/17

Samples were collected from 23 Porcupine caribou in the fall of 2016 by hunters in Old Crow with the assistance of Environment Yukon (Martin Kienzler and Mike Suitor). 20 Samples were collected from the Qamanirjuaq caribou herd in Arviat in the fall of 2016 in cooperation with the Arviat Hunters and Trappers Organization. An additional 20 Qamanirjuaq caribou cows were sampled in the fall of 2016 immediately post-rut to explore the potential relationship between mercury and pregnancy. GNWT (Stephanie Behrens) provided 23 kidneys from the Bluenose West caribou herd, 13 collected in the spring of 2005 and 10 collected in the spring of 2014. This herd was previously sampled in the spring of 1994 and 2002. Samples were collected from 10 Ahiak caribou in cooperation with the Spence Bay Hunters and Trappers Organization in Taloyoak, NU.

Current-year kidney samples are currently being analyzed for a suite of 34 elements using ICP-MS by NLET, Environment and Climate Change 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). Twenty fecal samples from the post-rut Qamanirjuaq caribou cows were analyzed for pregnancy at the Toronto Zoo and twenty liver and kidney samples from the same animals are currently being analyzed for total mercury at

NLET. Liver and muscle samples were archived at the National Wildlife Research Centre (Environment and Climate Change Canada). Incisors were used to analyze age of the animal using the cementum technique (Angela Milani, Government of Yukon).

Capacity Building

In October 2016, the Mary Gamberg 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 will be offered again in November 2017.

Communications

Results of this project were communicated in the following ways:

- presented "Contaminants in Arctic Caribou: 20 years of research from Yukon, NWT, Nunavut and Greenland" as part of a Climate Change Lecture series offered by MacBride Museum of Yukon History and the Northern Climate Exchange, Yukon Research Centre, Yukon College in September, 2016;
- presented to Environmental Technology Program of Arctic College in Iqaluit in September, 2016, as part of an NCP project: Wildlife Contaminants Workshop–linking wildlife and human health through a hands-on workshop;
- presented to the experiential class at Wood St. School in Whitehorse in October, 2016;
- presented to the Arviat HTO on October 2, 2016;
- distributed "Report to Hunters of the Porcupine Caribou Herd" widely to stakeholders, in November, 2016;
- distributed 'Report to Hunters of the Qamanirjuaq Caribou"(fact sheet and poster formats) widely to stakeholders (English and Inuktitut) in January, 2017; and
- presented to Yukon community members at part of the Yukon Contaminants Workshop in Whitehorse in March, 2017.

Three 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 element data collected under the NCP, but will also include data provided collaboratively by other researchers on caribou from Banks Island NWT, Greenland, Sweden, Svalbard, and Russia. The second paper will be a comparison of Perfluorinated compounds in the same herds. The third paper will focus on temporal trends of contaminants in the Porcupine caribou and whether environmental drivers can be used to explain some of the temporal changes in contaminant levels.

Traditional Knowledge Integration

This program relies on the traditional knowledge of both Aboriginal and non-Aboriginal people when collecting samples from caribou for analysis. Local hunters use traditional knowledge when hunting caribou as a food source for their families and when submitting samples for analysis. Meetings between Mary Gamberg and local HTOs provided an opportunity for the exchange of traditional and western scientific information that enhances understanding of contaminants in caribou and facilitates 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 a companion project exploring mercury in seaweed, lichens and mushrooms in the Kivalliq region.

Results and Discussion

Results are presented for samples collected in 2015 in the spring (Bluenose East herd) and fall (Porcupine, Qamanirjuaq and Dolphin & Union herds). 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]). Porcupine, Qamanirjuaq, and Dolphin & Union results were compared to previous results from fall-collected animals and Bluenose East results were compared with previous results from spring-collected animals. 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.

Results for the seven elements of interest are presented in Table 1. Age was positively correlated with renal Cd and Zn in the Porcupine, Qamanirjuaq and Beverly caribou. These correlations were not apparent in the Dolphin & Union caribou, likely because of lower sample numbers. Correlations between some 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).

Levels of most elements measured in these 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 25 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.

Porcupine Caribou

Only two cows were sampled in 2015, so differences in element concentrations between genders were unable to be tested.

Renal As and Pb have declined significantly over time in fall-collected bulls from the Porcupine caribou herd, while none of the other elements studied changed significantly (Figure 1). These declines may reflect reductions in emissions since the shift to unleaded gasoline and away from arsenical pesticides, or they may reflect increased precision and accuracy in laboratory analyses. Renal Hg continues to be stable over the long term in this herd, while undergoing cyclic fluctuations (Figure 2). These fluctuations are likely affected by atmospheric patterns of deposition of Hg as well as local environmental conditions affecting Hg concentrations in winter forage in conjunction with forage availability and selection by the caribou. This includes timing of green-up in the spring and the subsequent switch to lower-Hg forages and could therefore be impacted by a changing climate.

Table 1. Renal element concentrations (X ± SD; •g·g^{-1} dry weight).

Year	N	Age	Arsenic			Cadmium			Copper			Lead			Mercury			Selenium			Zinc		
Porcupine herd; Fall-collected Males																							
1997	14	4.1	0.42	+	0.32	23.2	+	12.1	21.2	+	2.1	0.17	+	0.11	1.47	+	0.32	3.8	+	0.6	93.4	+	11.8
1998	14	4.7	0.19	+	0.05	26.9	+	21.0	25.6	+	3.7	0.25	+	0.28	1.76	+	0.72	5.2	+	1.2	108.4	+	16.6
1999	11	4.7	0.08	+	0.04	36.0	+	25.9	23.5	+	6.4	0.18	+	0.09	1.23	+	0.63	4.6	+	0.8	113.5	+	16.3
2000	8	4.8	0.30	+	0.11	37.4	+	17.6	25.1	+	4.3	0.25	+	0.39	1.23	+	0.18	4.9	+	1.0	121.6	+	21.5
2001	12	5.1	0.36	+	0.12	29.8	+	11.9	22.5	+	2.6	0.17	+	0.15	1.74	+	0.78	4.4	+	1.1	115.8	+	27.2
2002	9	5.6	0.18	+	0.04	26.8	+	8.4	25.1	+	3.4	0.13	+	0.05	1.39	+	0.27	5.4	+	0.6	123.3	+	14.1
2003	23	5.8	0.25	+	0.06	37.5	+	18.1	25.4	+	3.4	0.16	+	0.18	1.19	+	0.25	6.1	+	0.7	121.6	+	15.4
2004	16	4.9	0.05	+	0.01	24.2	+	13.8	22.8	+	3.0	0.14	+	0.04	1.62	+	0.59	4.2	+	0.6	121.0	+	15.9
2005	14	3.5	0.05	+	0.04	23.1	+	14.8	23.1	+	2.4	0.15	+	0.04	1.81	+	0.33	4.5	+	0.6	121.9	+	18.0
2006	9	5.1	0.07	+	0.02	41.6	+	23.7	24.9	+	3.0	0.10	+	0.02	2.18	+	0.51	5.1	+	0.6	130.6	+	14.5
2007	12	4.7	0.04	+	0.01	28.3	+	12.2	24.5	+	4.6	0.12	+	0.08	1.58	+	0.45	4.4	+	0.7	120.0	+	27.5
2008	20	6.1	0.03	+	0.02	27.3	+	16.8	26.7	+	7.1	0.18	+	0.38	1.34	+	0.60	4.3	+	0.5	138.4	+	33.7
2009	21	6.3	0.05	+	0.04	38.1	+	16.6	24.6	+	5.2	0.10	+	0.06	0.98	+	0.43	4.6	+	0.7	139.5	+	39.5
2010	4	6.8	0.07	+	0.01	26.6	+	9.9	21.3	+	1.6	0.11	+	0.03	1.53	+	0.51	5.3	+	0.8	130.1	+	17.8
2011	11	4.9	0.05	+	0.04	23.0	+	12.7	22.8	+	2.3	0.07	+	0.03	1.42	+	0.45	4.5	+	0.6	112.8	+	8.0
2012	20	6.2	0.11	+	0.11	34.7	+	21.9	22.8	+	2.1	0.09	+	0.03	1.84	+	0.70	4.8	+	0.5	107.8	+	9.3
2013	22	5.3	0.04	+	0.02	21.2	+	9.2	24.3	+	2.6	0.07	+	0.02	1.79	+	0.50	4.3	+	0.5	109.4	+	6.5
2015	15	5.2	0.04	+	0.04	23.0	+	10.6	24.6	+	2.9	0.08	+	0.03	1.37	+	0.40	4.3	+	0.4	116.2	+	10.1
Qamanirjuaq caribou; Fall-collected																							
Females																							
2006	7	7.3	0.03	±	0.007	18.7	±	5.3	26.3	±	0.8	0.58	±	0.31	3.37	±	0.36	3.6	±	0.2	104.1	±	3.2
2007	10	5.1	0.04	±	0.003	24	±	5.0	25.1	±	2.8	0.44	±	0.05	5.57	±	0.74	4.1	±	0.4	110.1	±	9.6
2008	10	8.1	0.04	±	0.005	29.7	±	3.7	24.4	±	1.3	0.36	±	0.02	4.99	±	0.50	4.0	±	0.2	105.7	±	5.1
2009	4	0.5	0.04	±	0.009	19.8	±	7.4	21.1	±	1.7	0.25	±	0.03	5.32	±	1.08	3.5	±	0.1	94.7	±	5.6
2010	1		0.05			21.5			18.9			0.49			6.69			3.8			96.5		
2011	17	6.0	0.04	±	0.005	21	±	6.0	22.0	±	0.7	0.30	±	0.03	5.04	±	0.46	4.2	±	0.1	107.9	±	2.6
2013	4	5.5	0.03	±	0.004	31.1	±	17.6	27.2	±	0.9	0.26	±	0.05	3.96	±	0.36	4.4	±	0.1	120.5	±	7.9
2014	10	10.0	0.04	±	0.004	28.6	±	4.4	19.9	±	2.1	0.27	±	0.07	5.45	±	0.55	3.5	±	0.3	98.2	±	11.0
2015	9	7.1	0.03	±	0.011	26.2	±	9.8	25.8	±	2.5	0.16	±	0.03	5.22	±	1.39	4.5	±	0.4	117.7	±	4.4

Table 1 (continued). Renal element concentrations (X + SD; mg·g[-1] dry weight).

Year	N	Age	Arsenic			Cadmium			Copper			Lead			Mercury			Selenium			Zinc		
Qamanirjuaq caribou; Fall-collected																							
Males																							
2006	14	5.8	0.01	±	0.003	14	±	2.4	25.8	±	0.5	0.34	±	0.07	2.58	±	0.23	3.6	±	0.1	112.3	±	3.7
2007	8	4.0	0.03	±	0.004	11.5	±	2.9	20.8	±	0.9	0.39	±	0.08	4.23	±	0.57	3.6	±	0.2	94.2	±	3.6
2008	11	5.0	0.03	±	0.003	16.8	±	2.8	24.4	±	1.3	0.27	±	0.03	3.10	±	0.47	4.1	±	0.1	105.8	±	2.6
2009	1		0.04			3.84			22.4			0.36			4.72			3.6			90.0		
2011	2	5.5	0.03	±	0.014	15.3	±	2.9	22.9	±	1.3	0.25	±	0.09	4.77	±	1.94	4.7	±	0.5	110.5	±	2.6
2014	10	6.9	0.04	±	0.004	19.2	±	3.9	23.0	±	3.1	0.18	±	0.02	5.42	±	0.68	4.1	±	0.3	99.9	±	3.5
2015	9	6.8	0.03	+	0.011	17.1		7.0	23.9	+	2.5	0.15	+	0.07	3.55	+	1.18	4.3	+	0.3	114.4	+	6.2
Dolphin & Union herd; Fall-collected Males																							
1993	9	5.7				4.3	±	6.5	23.0	±	6.4	0.16	±	0.14	1.62	±	1.79				98.5	±	22.2
2006	3	3.7	0.05	±	0.018	5.3	±	4.1	22.5	±	2.2	0.13	±	0.06	2.73	±	0.19	3.4	±	0.5	104.4	±	16.7
2015	14	4.1	0.02	+	0.005	12.2	+	4.2	19.1	+	3.5	0.07	+	0.07	1.40	+	0.79	3.4	+	0.4	108.0	+	17.7
Bluenose East herd; Spring-collected																							
Females																							
1998	10					18.9	±	14.6	23.4	±	7.6	0.28	±	0.13	2.19	±	1.14				108.7	±	27.4
2005	5	6.8	0.03	±	0.011	46.7	±	32.5	18.0	±	1.4	0.23	±	0.06	4.49	±	2.02	3.5	±	0.4	97.5	±	8.0
2013	13	6.4	0.10	±	0.035	62.9	±	19.2	22.1	±	1.1	0.19	±	0.06	4.60	±	1.35	4.5	±	0.4	120.7	±	8.6
Males																							
2006	15	4.6	0.04	±	0.013	22.9	±	10.7	17.4	±	2.2	0.4	±	0.78	4.67	±	0.97	4.1	±	1.0	101.5	±	24.2
2013	7	3.1	0.10	+	0.04	30.4	+	15.1	21.4	+	2.5	0.15	+	0.04	3.53	+	0.80	4.1	+	0.5	112.1	+	10.8

Qamanirjuaq Caribou

Renal As, Cd and Hg were higher in fall-collected cows than bulls from the Qamanirjuaq herd. This likely reflects the proportionally greater intake of food (and hence contaminants) by the smaller cows that have higher energetic requirements due to parturition and lactation. Homeostatically controlled essential elements did not generally follow this trend. It is notable that although lead did not follow the trend for toxic elements (being higher in cows), the three bulls that had higher Pb concentrations had smaller kidneys, likely indicative of a smaller body size, making them more similar to cows. Renal Pb decreased over time in the Qamanirjuaq caribou as it did in the Porcupine and Bluenose East herds (Figure 1). Renal Se increased over time in both genders and renal Zn increased over time in just cows. In both cases the changes were small and likely of little biological significance. Renal Cd did not change over time. Although it appears that renal As and Hg increased over time in bulls, this is likely an artifact of the minimal number of bulls sampled since 2008. In fact, both elements in bulls closely follow those in cows which are not changing over time (Figure 2).

Bluenose East Caribou

Results from Bluenose East caribou collected in the spring of 2013 were compared to those from four other spring collections (1998, 2002, 2005 and 2006). Renal Cd was higher in cows than bulls, as was seen in the Porcupine and Qamanirjuaq caribou. The lack of differences between genders for other elements demonstrates a difference from the other herds, possibly reflecting the sporadic nature of the sampling for the Bluenose East herd, as compared with the more frequent annual sampling of the Porcupine and Qamanirjuaq herds. Renal Pb has declined over time in the Bluenose East caribou, as in the Porcupine and Qamanirjuaq herds (Figure 1), and likely for the same reason. Renal As, Cd, Hg, Se and Zn demonstrated significant increases over time in the Bluenose herd, although with large gaps among sampling years, it is difficult to say whether these are true increases or simply parts of cycles that are not evident due to the paucity of data (Figure 2).

Figure 1. Average renal lead concentrations in four Arctic caribou herds.

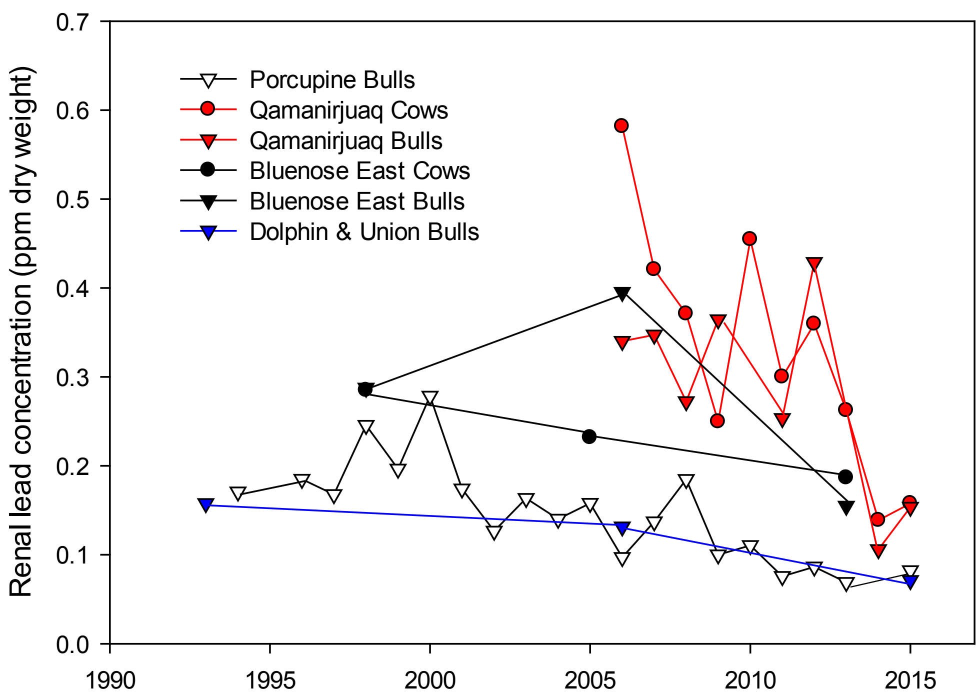
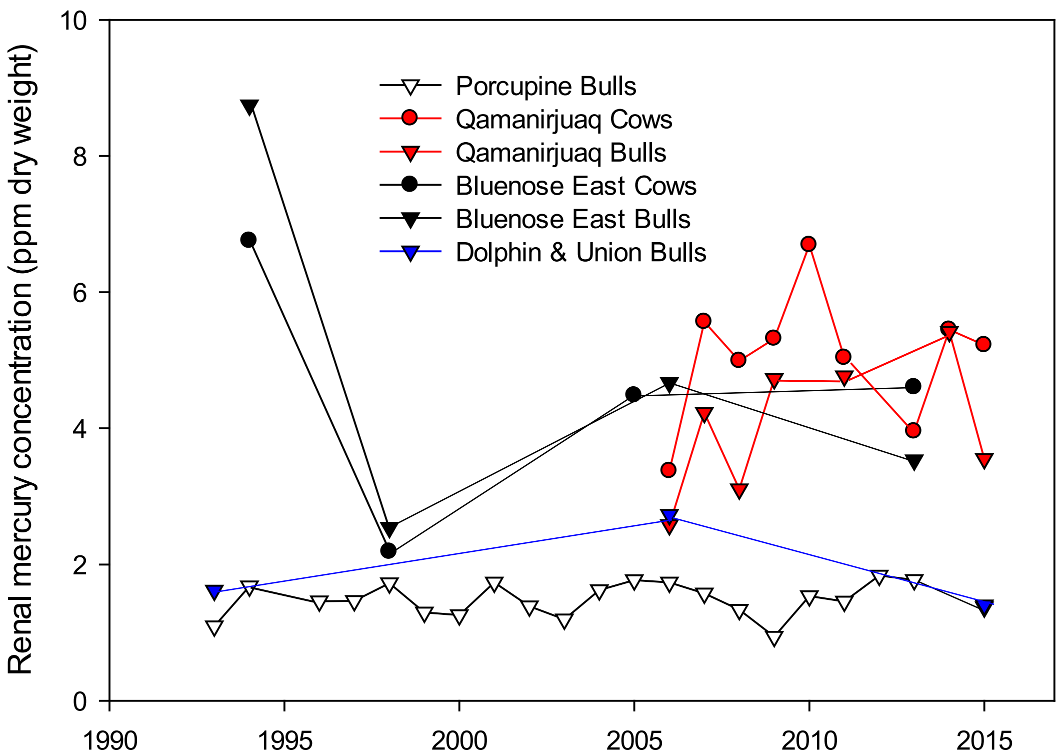


Figure 2. Average renal mercury concentrations in four Arctic caribou herds.



Dolphin & Union Caribou

Results from Dolphin & Union caribou collected in the fall of 2015 were compared to bulls collected from the fall of 1993 and 2006. Renal Cu, Pb, Hg, Se and Zn showed no differences among years while As showed a decreasing trend and Cd showed an increasing trend. As with the Bluenose East caribou, it is difficult to say whether these are true increases or an artifact of large gaps among sampling years.

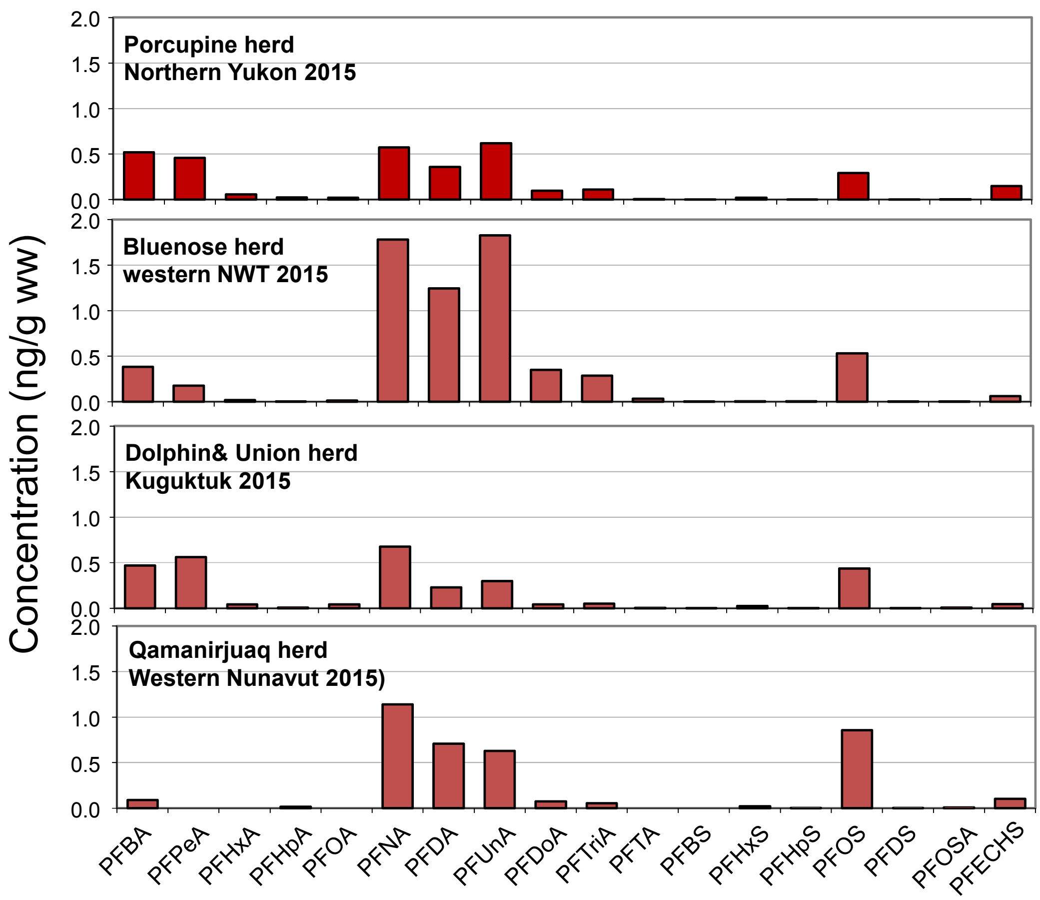
Comparisons among herds

Data were compared among fall-collected bulls from the Porcupine, Qamanirjuaq and Dolphin & Union caribou. As, Cd, Se and Zn were higher in the Porcupine caribou than the other two herds while Se was also higher in the Qamanirjuaq herd compared to the Dolphin & Union herd. It is not clear why these elements are higher in the Porcupine herd, but it is common, both biologically and geologically to find an association between Cd and Zn. Pb and Hg were higher in the Qamanirjuaq caribou than the other two herds. This has been seen in the past and is currently being investigated under the NCP project "Mercury in Seaweed and Lichens from the Home Range of the Qamanirjuaq Caribou." Cu was lower in the Dolphin & Union caribou than the other two herds. This is consistent with the findings of the NCP project "Muskox Health program: Contaminants in Country Foods in Kitikmeot, NU" which found that 76% of the muskox from the Cambridge Bay are of Victoria Island are likely to be copper deficient and 33% of the muskox from the Kugluktuk region of the mainland are likely to be so (Gamberg 2017). The Dolphin & Union caribou range from Cambridge Bay to the mainland and, although they have lower renal copper levels than the other two herds, they have almost double the concentration found in muskox from the area (10.3 ppm dry weight). It should be noted that although hepatic levels of Cu are a much better indicator of body status than renal levels, we could not make that comparison because we have not analyzed caribou liver for Cu.

Perfluorinated chemicals in caribou liver

Results for PFASs in caribou liver from the Porcupine, Bluenose, Dolphin & Union, and Qamanirjuaq herds are shown in Figure 3. Major PFASs are the long chain perfluorocarboxylates (PFCAs) with 9, 10 and 11-carbon chains (PFNA, PFDA and PFUnA) as well as perfluorooctane sulfonate (PFOS). However, short chain PFCAs with 4 and 5 carbon chains (PFBA, PFPeA) were also detectable especially in the Porcupine, Bluenose, Dolphin & Union caribou. PFBA and PFPeA are degradation products of the replacements for PFOS, which was phased out in Canada and the USA in the early 2000s. PFBA is also a degradation product of HCFCs used in automobile air conditioners. Concentrations of total PFCAs (with 9 to 12 carbon chains) and PFOS in the Porcupine and Qamanirjuaq herds appear to have declined by about 50% compared to previous liver sample analyses (2007-2008) (Müller et al 2011). However, trends for PFBA and several other PFASs such as PFECHS (perfluoroethylcyclohexane sulfonate) are unknown because they were not measured in earlier samples.

Figure 3. Average concentrations of 18 perfluorinated alkyl substances in caribou liver. Each bar represents the mean of 10 samples from each herd.



Conclusion

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 contaminants of concern (e.g. Hg) within the terrestrial ecosystem. This program will continue to collect and analyze 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 and Mike Suitor 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 organize collections of the Qamanirjuaq caribou and to Lisa Leclerc for organizing collections of the Dolphin & Union caribou. Thanks also to Brett Elkin, GNWT for providing samples from the Bluenose East caribou herd. This project was funded by the Northern Contaminants Program, Crown-Indigenous Relations and Northern Affairs Canada.

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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 project addresses a knowledge gap that was identified under the NCP "Blueprint", related to the lack of data on levels and time trends of contaminants in the marine waters. The project started in May 2014 and built on previous work in Barrow Strait near Resolute in 2011 and 2012. The project became a core monitoring project last year. Seawater samples for a full suite of contaminants were successfully collected from

Résumé

Le projet vise à combler une lacune dans les connaissances recensée dans le plan directeur du PLCN relativement au manque de données sur les concentrations et les tendances temporelles des contaminants dans les eaux marines. Il a été entrepris en mai 2014 et s'articule autour des travaux réalisés en 2011 et 2012 dans le détroit de Barrows, près de Resolute. Il est devenu un projet de surveillance

Barrow Strait under ice covered conditions (May-June) and from open water (August-September 2016) using (i) passive samplers (thin plastic films) deployed for 5 to 6 week periods, (ii) large volume water samplers (200 L), and (iii) Niskin samplers to obtain1 L samples at various depths. A full suite of collections were carried out in Anaktalak Fiord near Nain using passive and Niskin samplers in the open water season in July. Passive samplers were successfully deployed in Wellington Bay near Cambridge Bay, in Barrow Strait, and in the Beaufort Sea near Sachs Harbour in open water in August 2016. Analysis of stain repellent and industrial additive (perfluorinated) chemicals shows that PFOS has declined to non-detectable levels since the mid-2000s. Mercury concentrations at Barrow Strait (2014-2016) remain unchanged compared to 10 years earlier (2004-05). This project is continuing in 2017-2018 so that a long term temporal data set can be developed that can be used to predict and better understand the impacts of changing ice, permafrost, and snow on contaminant levels in seawater.

de base l'an dernier. On a réussi à prélever des échantillons d'eau de mer afin d'y détecter une gamme complète de contaminants dans le détroit de Barrows, sous la couverture de glace (mai-juin) et dans les eaux libres (août-septembre 2016) à l'aide i) d'échantillonneurs passifs (pellicule de plastique mince) déployés pendant des périodes de cinq à six semaines, ii) d'échantillonneurs d'eau de grand volume (200 litres) et iii) d'échantillonneurs Niskin pour obtenir des échantillons d'un litre à différentes profondeurs. Plusieurs prélèvements ont aussi été effectués dans le fjord d'Anaktalak, près de Nain, en utilisant des échantillonneurs passifs et Niskin pendant la période d'eaux libres en juillet. Des échantillonneurs passifs ont été déployés avec succès dans la baie de Wellington, près de Cambridge Bay dans le détroit Barrows et dans la mer de Beaufort près de Sachs Harbour dans les eaux libres, en août 2016. L'analyse des concentrations de substances chimiques (perfluorées) utilisées dans les produits antitaches et comme additifs industriels montre que les concentrations de PFOS ont, depuis le milieu des années 2000, diminué jusqu'à n'être plus détectables. Les concentrations de mercure dans le détroit de Barrows (2014-2016) demeurent inchangées par rapport à il y a 10 ans (2004-2005). Ce projet, qui se poursuit en 2017-2018, produira un ensemble de données temporelles à long terme, pouvant être utilisé pour prévoir et mieux comprendre les répercussions de l'évolution des glaces, du pergélisol et de la neige sur les concentrations de contaminants dans les eaux de mer.

Key Messages

- Concentrations of numerous legacy and new/emerging persistent organic pollutants and mercury were measured in seawater samples from Barrow Strait near Resolute Bay, Nunavut and other Arctic locations.
- Very low concentrations of brominated flame retardants were found in seawater using passive samplers (plastic films) at Resolute Bay.

Messages clés

- On a mesuré les concentrations de nombreux POP hérités du passé et nouveaux ou émergents et de mercure dans des échantillons d'eau de mer prélevés dans le détroit de Barrows près de Resolute Bay, au Nunavut et dans d'autres régions de l'Arctique.
- On a relevé des concentrations très faibles de produits ignifuges bromés dans les échantillons d'eau de mer qui ont

- Phosphorus based flame retardants were detected in seawater for the first time at Resolute Bay.
- Analysis of stain repellent and industrial additive (perfluorinated) chemicals has been completed and showed that PFOS has declined to non-detectable levels since the mid-2000s.
- Mercury/methylmercury concentrations at Barrow Strait (2014-2016) remain unchanged compared to 10 years earlier (2004-05).

été prélevés à l'aide d'échantillonneurs passifs (minces pellicules de plastique) à Resolute Bay.

- Des produits ignifuges à base de phosphore ont été détectés dans l'eau de mer pour la première fois à Resolute Bay.
- L'analyse des concentrations de substances chimiques (perfluorées) utilisées dans des produits antitaches et comme additifs industriels a été menée à bien; elle montre que les concentrations de PFOS ont, depuis le milieu des années 2000, diminué jusqu'à n'être plus détectables.
- Les concentrations de mercure et de méthylmercure dans le détroit de Barrows (2014-2016) demeurent inchangées par rapport à il y a 10 ans (2004-2005).

Objectives

- 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 such as Anaktalak Fiord near Nain, in the Beaufort Sea near Sachs Harbour, and in Wellington Bay near Cambridge Bay.
- Compared results from passive samplers with those from high volume "active" water samples collected during 2016.
- Collect seawater profiles for perfluorinated alkyl substances (PFASs), organophosphate ester flame retardants and plasticizers (OPEs also known as OPFRs) and mercury/methylmercury using Niskin samplers during early melt (May-June) and during the open water (August) in Barrow Strait/Lancaster Sound and in Anaktalak Fiord.
- Combine data accumulated from previous studies in order to establish temporal trends in high central Canadian Arctic seawater.
- Develop a practical standard operating procedure for passive and low volume active sampling e.g. with video that could be used by community members to set up community-based seawater sampling programs.

Introduction

This project is examining a full suite of contaminants, including hydrophobic legacy organic contaminants, new emerging contaminants including perfluorinated alkyl substances (PFASs) and organophosphate ester flame retardants and plasticizers (OPEs also known as OPFRs), as well as mercury/methylmercury in Arctic seawater. Seawater samples are collected by community members at Barrow Strait/Lancaster Sound and other Arctic locations (such as Anaktalak Fiord near Nain) using passive samplers, active high volume samplers, and Niskin samplers from both under ice covered conditions (May-June) and the open water (August-September 2016). Passive samplers are also deployed in the Beaufort Sea near Sachs Harbour and in Wellington Bay near

Cambridge Bay. This project addresses gaps highlighted in the "(2016-17) NCP Blueprint for Environmental Monitoring and Research", which stated a need for Arctic seawater data to "collect a set of baseline data for contaminants in Arctic seawater against which future trends, sources and sinks in the ocean may be evaluated". Our original proposal was initially funded by the NCP for 2014-15 year and was included as a core monitoring project in 2016-17 as it is contributing to the long-term monitoring plan for marine ecosystems.

Our initial proposal provided an extensive review of published seawater data; however since then, additional work has been published. 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^{-1} concentrations of 6 organo-phosphorus flame retardants and plasticizers (OPEs) in samples collected during the same cruises and noted that concentration of OPEs in arctic waters were high compared to PBDEs, OCPs and CUPs. Morris et al. (2014, 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. Sampling for the Morris et al. project was done from 2007-2010 with partial NCP support. 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 highest levels in invertebrates and arctic cod.

Heimburger et al. (2015) reported the first central Arctic Ocean (79–90°N) profiles for total mercury (THg; all forms of Hg in a sample) and methylated mercury (MeHg; includes both methylmercury and dimethylmercury, the toxic forms of Hg) from sampling in 2013. Similar to our findings for the Resolute Bay/ Barrow Strait area, they showed a MeHg concentration maximum in the pycnocline waters, but at much shallower depths (150–200 m) than in other open oceans of the world. They suggest that this shallow MeHg maxima may result in enhanced biological uptake at the base of the Arctic marine food web and that thinning sea ice, extension of the seasonal sea ice zone, intensified surface ocean stratification, and shifts in plankton dynamics will likely lead to higher marine MeHg production.

Activities in 2016-2017

Field work

Seawater samples were successfully collected from 4 locations this year including (i) Barrow Strait near Resolute Bay (74.612, -95.026), (ii) Wellington Bay near Cambridge Bay (69.2363, -106.4448), (iii) Beaufort Sea near Sachs Harbour (71.9327, -125.3251), and (iv) Anaktalak Fiord near Nain (56.4481, -62.0045). Passive samplers for hydrophobic organic contaminants were deployed by Resolute Bay resident Peter Amaraulik in Barrow Strait in May-June 2016 for a 5-6 week period as well as in August 2016 (these latter samplers will be recovered in July 2017 to obtain a year-long record). Similarly, in Wellington Bay, passive samplers were deployed in August 2016 by Jean-Sebastien Moore (a postdoctoral fellow at Université Laval), and will be recovered in July 2017. At the Beaufort Sea and Anaktalak Bay sites, passive samplers were deployed in August 2016 for 4-6 weeks by Sachs Harbour resident Wayne Gully, and Nain resident and Nunatsiavut Environment Divisione employee Liz Pijogge, respectively. Collection of smaller (1L) samples at various depths using Niskin samplers for analysis of total mercury/methyl mercury, OPEs and perfluorinated substances (PFASs) was also successful at Barrow Strait (May and August).

To compare contaminant values obtained from large volume and passive sampling methods, large volume (~265 L through XAD resin column/filter system) water samples were collected in Barrow Strait in May and August by Ana Cabrerizo working with Peter Amaraulik. In May samples were collected directly by pumping water from under the ice. In August water was collected into 14 x 19L stainless steel soft drink cans which were then extracted by pumping water through XAD resin at the PCSP lab in Resolute.

Chemical analyses

Samples were distributed to various labs in October 2016 and are being analysed for several contaminant groups. Results for organic contaminants from 2015 are available while some results for 2016 are pending. Data for mercury/methylmercury for 2016 are available.

Capacity Building

Peter Amarualik Sr., who is a respected member of the Resolute Bay community and a member of our project team, carried out sampling out of Resolute Bay in May and August 2016 with Ana Cabrerizo who provided training on clean sampling protocols. At Nain, the seawater sampling was carried out by Liz Pijogge of the Nunatsiavut Environment Division with the help of Amber Gleason who provided training.

Communications

A summary of project activities during 2016 and preliminary results was prepared for the Resolute Bay HTA in English and Inuktitut. Derek Muir was in Resolute at the end of July 2016 and provided HTA members with more information on the seawater project as he has done in previous years. In Nain, we worked with team members from the Nunatsiavut Environment Division (Rodd Laing and Liz Pijogge) for consultations and communications. Progress was also made on a training video in August 2016 during sampling at Anaktalak Fiord near Nain by Amber Gleason and Liz Pijogge. Footage of sampling with vocal instruction was obtained with a GoPro camera and is currently being edited so that it can be distributed.

Indigenous Knowledge Integration

The success of this project is heavily dependent on the community field team's knowledge of the ice and water conditions in the area. We have also asked the teams to take photos of the ice conditions while they are sampling.

Results

Temporal trend analyses of PFAAs generally indicate that PFAAs are lower in more recent years (Figure 1). The lower concentrations could be a result of international restrictions on production and usage of PFAAs and their precursors. For example, PFOA was 0.47 ± 0.41 ng•L^{-1} in 2011, 0.11 ± 0.056 ng•L^{-1} in 2012, 0.16 ± 0.093 ng•L^{-1} in 2014 and 0.028 ±0.0032 ng•L^{-1} in 2015. Similarly, PFHxA was 0.42 ±0.40 ng•L^{-1} in 2011 and 0.033 ± 0.015 ng•L^{-1} in 2015 (Figure 1). PFOS was 0.0089 ± 0.0026 ng•L^{-1} in 2011 and has been below detection limits since 2014. PFECHS, a cyclic perfluoroalkyl sulfonate, which we started monitoring in 2012, was 0.21 ± 0.37 ng•L^{-1} in 2012 and 0.0085 ± 0.0039 ng•L^{-1} in our 2015 samples.

Since 2015, we have expanded our analyses to include 16 OPEs. Our preliminary data is presented in Figure 2, which demonstrate a predominance of TBEP and TPP as well as the chlorine containing OPEs, TCPP, and TCEP. These substances were also detected in ship-based air sampling in Resolute Bay (Sühring et al. 2016), suggesting the potential for long range transport of these substances. This is further evidenced by a similar profile of OPEs determined further north in Lake Hazen on Ellesmere Island (Figure 2).

Depth profiles of total mercury (THg; all forms of Hg in a sample) and methylated Hg (includes both monomethylmercury, the toxic and bioaccumulative form of methylated Hg and dimethylmercury, the toxic, gaseous form of methylated Hg) from 2014-2016 are shown in Figure 3 and are compared to earlier data from 2004 and 2005 (St. Louis et al. 2007; Kirk et al. 2012). Measurement of THg at various depths of the water column in 2004-2005 and 2014-2016 showed that there is little variation with time, depth, or among ice-covered and open water conditions. Concentrations of methylated Hg in 2014-2016 were also similar to measurements made in 2004-05. However concentrations of methylated Hg are lower at the surface in open water than under the ice due to photo-degradation and exchange of dimethyl Hg with the atmosphere. Analysis of both frozen (preserves monomethylmercury only) and acidified samples (preserves all methylated Hg in a sample including monomethyl Hg and dimethyl Hg) indicates that a large portion of methylated Hg at this site is dimethyl Hg (data not shown). Interestingly concentrations of both THg and methylated Hg were much lower throughout the water column in open water conditions at both the Clyde River area in summer 2015 and Anaktalak Bay near Nain in summer 2016 than at our Barrow Strait location.

Figure 1. Depth profiles of select PFAAs taken in summer 2011-2015 in Barrow Strait near Resolute Bay. The darkest line represents the most recent sample in 2015.

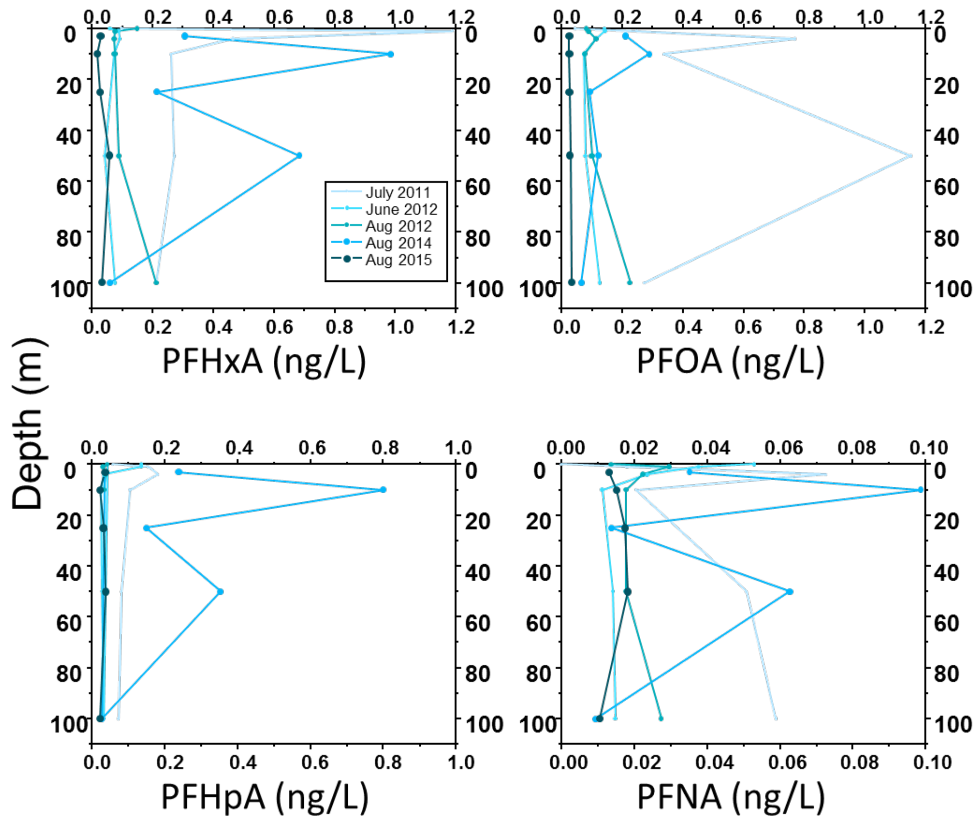


Figure 2. Concentration of OPEs in Barrow Strait near Resolute Bay sampled May and August 2015 in comparison to surface water grabs from Lake Hazen obtained in July 2015.

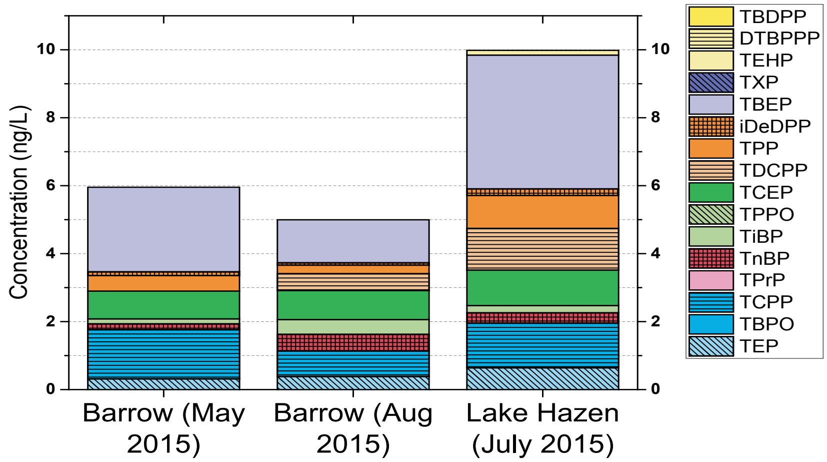
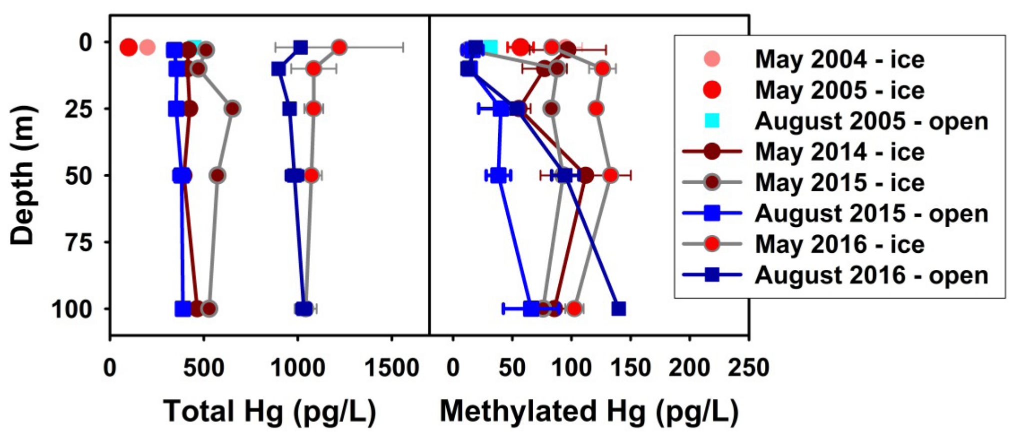


Figure 3. Total mercury (left) and methylated mercury (right) profiles in Barrow Strait (2014-16) and comparison with earlier measurements from St Louis et al. 2007 and Kirk et al. 2012.



Concentrations of polybrominated diphenyl ethers (PBDEs) and total polychlorinated biphenyls (ΣPCBs) in passive samplers deployed in 2015 and 2016 at Resolute are shown in Table 1. Concentrations of PBDEs ranged from 0.9-2.9 pg•L^{-1} and the tetrabromo-BDE (BDE47) was the dominant PBDE in all locations. We found BDE 47 concentrations in large volume sample, collected with a filtration and XAD system, ranging from 0.9-2.3 pg•L^{-1} in samples collected in 2010 to 2014 (Muir et al. 2015). However previous passive sampling in 2012 and 2014 had yielded lower concentrations of PBDEs (Muir et al. 2015) so we are re-evaluating the calculations used for that earlier work.

Table 1. Average concentrations of PBDEs and PCBs in seawater (pg•L^{-1}) at 3 locations in the Canadian arctic based on polyethylene membrane (PEM) passive samplers and high volume XAD column extractions

Location	Deployment period	BDE 47	ΣPBDEs	PCB11	Σ10PCBs (PEMs)	Σ10PCBs (XAD)
Resolute	Aug-Sept 2015	0.9	0.9	[a]	[a]	
Resolute	May-Jun 2016	2.4	3.2	0.8	6.0	14.1
Sachs Harbour	August 2016	2.9	2.9	1.0	7.0	[b]
Nain	July-Aug 2016	2.3	3.1	1.1	6.2	[b]

[a] Results for 2015 are pending

[b] High volume (100 L) XAD extraction at Resolute only.

PCBs (sum of 10 congeners from trichloro- to hexachloro-) ranged from 6.0 to 7.0 p pg•L^{-1} based on measurements in passive samplers in 2016. A high volume sample taken from under the ice in May 2016 had Σ10PCBs (sum of 10 PCB congeners) concentrations of 14 pg•L^{-1}. PCB11, which is a by-product in paint pigment, was a prominent congener in seawater. These are the first measurements of PCB11 in Arctic seawater, however, it has been detected in arctic ice caps (Garmash et al. 2013). There is limited recent data for PCBs in Canadian arctic seawater because recent studies have focused on current use pesticides (Jantunen et al 2015) and flame retardants (Jantunen 2014; Morris 2015). Carrizo and Gustafsson (2011) reported dissolved Σ12PCB concentrations of 1.7 pg•L^{-1} (sum of 12 congeners) in central Baffin Bay using high volume sampling from the Oden icebreaker. In a previous AMAP assessment, deWit et al. (2004) reviewed the data for PCBs in seawater and noted that concentrations of Σ10PCBs from the Canadian arctic archipelago tended to be higher than in the open Arctic Ocean. However it wasn't clear whether this was due to differences in methods or real differences due to the influence of terrestrial sources in the Arctic Archipelago.

Discussion and Conclusions

The lower concentrations of PFAAs, especially of PFOS, could be a result of international restrictions on production and usage of PFAAs and their precursors. As far as we are aware, this is the first study showing the declining trend of PFOS and PFCAs in ocean water. The relatively high concentrations of OPEs (compared to PFAAs, PBDEs and PCBs) adds to growing evidence that these substances are globally distributed in the oceans and atmosphere. Concentrations of total Hg and methylated Hg in 2014-2016 were similar to measurements made in 2004-05 at a similar location. Concentrations of PCBs in seawater also appear to be similar to previous measurements in the Canadian Arctic Archipelago waters in the early 2000s. With the data now becoming available for several consecutive sampling years and multiple sites, this study is starting to provide temporal and spatial trend information for contaminants in seawater in near shore locations which are also important fishing and hunting areas for local communities. These data will also feed into international assessments and will contribute to our understanding of the impacts of emission controls, such as the Minamata Convention on Mercury, on contaminant levels in Arctic seawater.

Expected Project Completion Date

This is an ongoing core monitoring project that is planned over the long-term to develop temporal trend information.

Acknowledgments

We would like to acknowledge the Northern Contaminants Program for funding, the Hamlet of Resolute Bay for permission to sample in nearby Barrow Strait, and the Polar Continental

Shelf Program for accommodating the project by providing laboratory space during May-August 2016.

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Investigation of the toxic effects of mercury in Arctic char

Enquête sur les effets toxiques du mercure chez l'omble chevalier dulcicole

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Abstract

In the Canadian Arctic, mercury (Hg) concentrations in the tissues of landlocked Arctic char are elevated with ~30% of the sampled populations exceeding toxicity thresholds. Starting in 2011, with NCP funding, we began collecting tissues from landlocked Arctic char from "NCP focal ecosystem lakes" on Cornwallis Island in cooperation with the "core" monitoring project (Muir, Köck, Kirk and Wang) to determine whether wild populations are indeed experiencing Hg toxicity. To build upon our previous work, we measured biomarkers of oxidative stress (GSH-Px, SOD, and TBARS) in the livers and brains of Arctic char sampled from four lakes on Cornwallis Island (Small, 9-Mile North, and Amituk) in 2016. Mean GSH-Px activity was significantly higher in the livers of Amituk Lake char than in char from the other three study lakes, which could be a response to

Résumé

Dans l'Arctique canadien, les concentrations de mercure dans les tissus de l'omble chevalier dulcicole sont élevées. Environ 30 % des populations échantillonnées dépassent les seuils de toxicité. À partir de 2011, grâce au financement provenant du PLCN, nous avons pu entreprendre la collecte de tissus d'ombles chevaliers dulcicoles dans des « lacs situés dans des écosystèmes présentant un intérêt pour le PLCN » sur l'île Cornwallis, en collaboration avec le projet de surveillance « de base » (Muir, Köck, Kirk et Wang) afin de déterminer si les populations sauvages étaient effectivement confrontées à la toxicité du mercure. En nous appuyant sur nos travaux antérieurs, nous avons mesuré les concentrations de biomarqueurs de stress oxydatif (glutathion peroxydase [GSH-PX], superoxyde dismutase [SOD] et substances réactives à l'acide thiobarbiturique [TBARS])

high levels of hepatic Hg. Across lakes, GSH-Px activity was significantly correlated with total Hg in the livers of Arctic char. Conversely, the activity of SOD was not related to hepatic concentrations of Hg. Lipid peroxidation (measured as TBARS) was highest in the livers of fish from the lowest Hg lake, which may be due to other metals present in the system. None of the biomarkers measured in char brains varied significantly across lakes or with concentrations of Hg. Additionally, we sampled and analyzed blood from Arctic char for Hg, in order to determine whether it could be used as a non-invasive biomarker. Results indicate that both total Hg and methylmercury in blood are highly correlated with total Hg in other tissues of Arctic char, and therefore it is suitable to use blood to estimate Hg concentrations in other tissues.

dans le foie et le cerveau d'ombles chevaliers de quatre lacs de l'île Cornwallis (Small, Nine Mile, North et Amituk) en 2016. L'activité moyenne du GSH-PX était nettement plus élevée dans le foie de l'omble chevalier du lac Amituk que dans celui de l'omble chevalier des trois autres lacs à l'étude, ce qui pourrait être en réponse aux niveaux élevés de mercure hépatique. Dans les lacs, l'activité du GSH-PX était étroitement liée aux concentrations de mercure total dans le foie de l'omble chevalier. Inversement, l'activité de la SOD n'était pas liée aux concentrations de mercure dans le foie. C'est dans le foie des poissons provenant des lacs ayant le taux de mercure le moins élevé que la peroxydation lipidique (mesurée sous forme de TBARS) était la plus importante, ce qui pourrait être dû à la présence d'autres métaux dans le système. Aucun des biomarqueurs mesurés dans le cerveau des ombles chevaliers ne variait de façon significative d'un lac à l'autre ou en fonction des concentrations de mercure. De plus, nous avons prélevé et analysé des échantillons de sang des ombles chevaliers pour y détecter du mercure, afin de déterminer si nous pouvions l'utiliser en tant que biomarqueur non invasif. Les résultats indiquent que la teneur en mercure total et en méthylmercure dans le sang est fortement liée au mercure total dans d'autres tissus de l'omble chevalier et, par conséquent, il est convenable d'utiliser des échantillons de sang pour évaluer les concentrations de mercure dans d'autres tissus.

Key Messages

- We sampled landlocked Arctic char from four lakes on Cornwallis Island, which span a gradient of mercury contamination.
- We measured biomarkers of oxidative stress in livers and brains of Arctic char sampled along the mercury gradient as a measure of effect.
- Blood was collected to determine if its mercury levels could be used to estimate mercury levels in other tissues.
- We noted differences in biomarkers within the livers of Arctic char sampled along the

Messages clés

- Les résultats obtenus pour les ombles chevaliers dulcicoles échantillonnés dans quatre lacs de l'île Cornwallis indiquent un gradient de contamination par le mercure.
- Nous avons mesuré les biomarqueurs de stress oxydatif dans le foie et le cerveau des ombles chevaliers échantillonnés suivant le gradient de contamination par le mercure, en tant que mesure d'effet.
- Nous avons prélevé des échantillons de sang afin de déterminer si les concentrations de mercure qu'il contenait pouvaient être

mercury gradient, which may be related to both mercury and other metals present in the fish.

- Biomarkers in Arctic char brains were not related to concentrations of mercury.
- Mercury concentrations in blood were highly correlated with concentrations in other tissues, suggesting that blood can be collected and used to estimate mercury in other tissues without killing the fish.

utilisées pour évaluer les concentrations de mercure dans d'autres tissus.

- Nous avons constaté des différences relativement aux biomarqueurs dans le foie des ombles chevaliers échantillonnés suivant le gradient de contamination par le mercure, ce qui pourrait être lié à la présence de mercure et d'autres métaux dans le poisson.
- Les biomarqueurs relevés dans le cerveau des ombles chevaliers n'étaient pas liés aux concentrations de mercure.
- Les concentrations de mercure dans le sang sont fortement liées aux concentrations dans d'autres tissus, ce qui porte à croire que l'on peut prélever et utiliser des échantillons de sang pour évaluer les concentrations de mercure dans d'autres tissus sans devoir tuer le poisson.

Objectives

- Continue our study of Hg exposure and potential exposure-associated neurotoxicity and hepatotoxicity in landlocked Arctic char from "NCP focal ecosystem lakes" on Cornwallis Island.
- Validate non-invasive methods to determine Hg exposure and health status (focus on oxidative stress) in landlocked Arctic char.
- Expand collaborations with the Nunavut Research Institute (NRI) by involving their students in the proposed research in the field and at McGill University.
- Provide this information to the Hamlet of Resolute Bay (Qausuittuq) and to the Niqiit Avatittinni Committee (Nunavut) on a timely basis, as well as to the scientific community (conferences, papers) and international programs (e.g., AMAP, Minamata Convention).

Introduction

Recent analyses of the available data for Hg toxicity in fish by us and others indicate that toxic effects are likely to occur at whole-body concentrations (wet weight) exceeding 0.2 $\mu g \bullet g^{-1}$ (Beckvar et al. 2005), or 0.3 $\mu g \bullet g^{-1}$ (Dillon et al. 2010; Sandheinrich and Wiener 2011) (equivalent concentrations in edible muscle are 0.33 and 0.5 $\mu g \bullet g^{-1}$, respectively), or dietary concentrations at 0.2 $\mu g \bullet g^{-1}$ (Depew et al. 2012). It is unclear how the aforementioned thresholds apply to Arctic fishes, though as elaborated upon below, our NCP-funded work on char has started to fill knowledge gaps in this area that were identified in the 2011 AMAP Mercury Assessment (see Dietz et al. 2013).

Arctic char are widely distributed in the Arctic and are a main food source for Arctic peoples. An analysis of the data for Hg in landlocked char indicates that certain populations sampled in northern Canada and Greenland are at risk for Hg toxicity, according to the thresholds estimated by Beckvar et al. (2005) and Dillon et al. (2010).

To investigate the effects of Hg on landlocked char, we began collecting char in 2011 from four "NCP focal ecosystem" lakes (Small, 9-mile, North, Amituk) near Resolute Bay, NU. 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. Since 2011, we have 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 (enzymes and organelles) contributed 73% and 61% of the contributions in Small and Amituk livers. This suggests, that at low (Small Lake) and high (Amituk Lake) concentration Hg is not effectively detoxified in the livers of these fish. 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 previous NCP-funded work suggests 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 and 2016, with funds provided by the NCP, we sampled Arctic char from "NCP focal ecosystem" lakes to test a suite of hypotheses related to Hg hepatotoxicity and neurotoxicity.

Activities in 2016-2017

To investigate the hepato- and neurotoxic effects of Hg on landlocked char, we collected char (n=60) in 2016 from four "NCP focal ecosystem" lakes (Small, 9-Mile, 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 the projects. Arctic char livers and brains were collected for Hg determinations and for analyses of endpoints relating to measures of oxidative stress including glutathione peroxidase (GSH-Px) superoxide dismutase (SOD), and thiobarbituric acid reactive substances (TBARS). Additionally, we collected blood from Arctic char in order to determine if it could be used in other systems as a non-invasive indicator of Hg concentrations and oxidative stress in other char tissues. All of the lab analyses related to char livers and brains were carried out at McGill University.

Communications

Community: Muir has presented reports and posters to the Resolute Bay Hamlet office and the HTA for char projects conducted collaboratively in the lakes of Cornwallis Island (i.e., "core" monitoring led by Muir and this project). Over the years, there have been many communication events for the char "core" monitoring project, and thus local residents are familiar with the work.

Scientific conferences: Barst presented results at User's Science Seminar Argonne National Laboratory (platform), the 2016 SETAC North America Annual Meeting (Orlando, FL, USA), and the 2016 University of Windsor Graduate Research Seminar Series (platform). Basu and Muir have been active with AMAP for 10+ years, and they and Barst participated in the 2016 AMAP POPs/Hg Biological Effects Workshop and report. Barst recently received an award from L'Institut national de la recherche scientifique (INRS-ETE) for his outstanding international collaborations stemming from the NCP-funded char work.

Capacity Building

The project depends on the help of local people in the Hamlet of Resolute Bay. Debbie Iqaluk of Resolute Bay has worked on the char "core" monitoring project since 2005. Debbie has helped sample char from many of the lakes on Cornwallis Island during a wide range of weather and ice conditions. Debbie received previous training in dissection (from Günter Köck). In addition, we have taken preliminary steps to begin a relationship with the Nunavut Research Institute to invite students from NRI to McGill University to take an active role in research in our facilities (e.g., Dr. Basu has furthered conversations with Jean Allen at Crown-Indigenous Relations and Northern Affairs Canada in Iqaluit and Erika Marteleira at Nunavut Arctic College). This builds upon recent engagements by Dr. Muir with the Nunavut Research Institute in which he went to the Institute to deliver lectures and hands-on training.

Indigenous Knowledge Integration

Over the course of the project, Debbie Iqaluk has been a major source of Indigenous Knowledge, and we have been able to compare some of her observations on general landlocked char health with our measurements in the field. For example, Debbie's observation that char appear healthiest from Resolute and Meretta lakes agrees with our measures of char relative weight (mean relative weights of char from Resolute and Meretta are highest out of the 6 char populations sampled near Resolute Bay for the "core monitoring" program). As in past years, Indigenous Knowledge was used for an initial assessment of fish health (e.g., Does that fish look healthy? Is that an unusual parasite burden? Is that a normal looking liver?). During fish dissection for a previous study, we observed differences in liver color among individual fish, and this observation eventually led to the discovery of lipofuscin (which is a yellow-brown pigment) and other pathologies in livers (Drevnick et al. 2008).

Results

Summary data for fish size and Hg_T concentrations in muscle, liver, brain, and blood are given in Table 1. Individuals from each lake, except Small, exceed the toxicity threshold of Beckvar et al. (2005; 0.3 $\mu g \bullet g^{-1}$ wet wt in muscle), but only individuals from North and Amituk exceed the threshold of Dillon et al. (2010; 0.5 $\mu g \bullet g^{-1}$ wet wt in muscle). Liver Hg_T concentrations were one to two times higher than muscle Hg concentrations – to a maximum of 6.3 $\mu g \bullet g^{-1}$ 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 = 101 % of total Hg). Our work in 2015 demonstrated that Hg_T 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. For char collected in 2016, brain Hg_T concentrations followed a similar trend as muscle and liver concentrations across the four lakes (Small < 9-Mile < North < Amituk). Brain and liver Hg_T 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 Arcitc char was in the form of MeHg (mean= 107 % of total Hg). Total Hg concentrations in blood followed a similar trend as muscle, liver, and brain across the four study lakes (Small < 9-Mile < North < Amituk). In Arctic char blood, the predominant form of Hg is MeHg and our results indicate that blood is an excellent predictor of Hg concentrations in muscle (r^2=0.89, p<0.0001), liver (r^2=0.89, p<0.0001), and brain (r^2=0.87, p<0.0001).

We measured the activities of GSH-Px and SOD, and measured TBARS in the livers of Arctic char from Small, 9-Mile, North, and Amituk lakes. Mean GSH-Px activity was significantly higher in the livers of Amituk Lake char than in char from North and Small lakes (p=0.0001), which could be a response to high levels of hepatic Hg. Across lakes, GSH-Px activity was significantly correlated with HgT in the livers of Arctic char (r^2=0.14, p=0.0002). Conversely, the activity of SOD was not related to HgT, however lipid peroxidation (measured as TBARS) decreased significantly along the bioaccumulation gradient (r^2=0.30 p<0.0001). In contrast, TBARS levels and the activities of SOD and GSH-Px were not significantly correlated with concentrations of Hg in the brains of Arctic char from the four lakes.

Table 1. Summary data for fork length, mass, and concentrations of total mercury (HgT) in edible muscle, liver, brain, and blood of landlocked Arctic char collected from "NCP focal ecosystem" lakes in 2016.

				HgT (μg•g^{-1} wet wt) muscle			HgT (μg•g^{-1} wet wt) liver			HgT (μg•g^{-1} wet wt) brain			HgT (μg•g^{-1}) blood		
Lake	n	Fork Length (cm)	Mass (g)	mean	SD	range	mean	SD	range	mean	SD	range	mean	SD	range
Small	16	34.1	307.0	0.12	0.040	0.06 - 0.22	0.21	0.120	0.13 - 0.51	0.12	0.050	0.07 - 0.23	0.16	0.08	0.09 - 0.39
9-Mile	11	30.0	185.3	0.17	0.07	0.09 - 0.31	0.29	0.24	0.12 - 0.95	0.15	0.1	0.09 - 0.60	0.20	0.26	0.06 - 0.92
North	18	36.0	445.0	0.25	0.150	0.08 - 0.58	0.51	0.270	0.18 - 1.06	0.23	0.030	0.13 - 0.54	0.41	0.28	0.14 - 0.98
Amituk	15	41.6	644.1	1.33	0.560	0.48 - 2.63	2.20	1.290	0.87 - 6.33	1.60	0.830	0.49 - 4.1	2.62	0.93	1.34 - 4.16

Discussion and Conclusions

A growing body of evidence suggests that Hg concentrations regularly found in predatory fish may be toxic to the fish; however it is unclear how toxicity thresholds apply to Arctic char. Nevertheless, individual fish from three of the four study lakes exceeded the 0.3 μg•g^{-1} threshold for Hg, and therefore may be at risk for toxicity. Our NCP-funded work suggests that landlocked Arctic char do not effectively detoxify MeHg in their livers, as evidenced by the high proportion of MeHg maintained in the liver and the presence of Hg in sensitive subcellular sites. This apparent lack of a detoxification mechanism in the liver may have implications for downstream organs such as the brain. Our results indicate that Arctic char accumulate MeHg in the brain, which increases in concentration along the bioaccumulation gradient.

The significantly higher GSH-Px activity in the livers of Amituk Lake char than in char from the North and Amituk lakes could be a response to high levels of hepatic Hg. We were surprised to find significantly higher levels of lipid peroxidation (measured as TBARS) in Small Lake char than char from the other three study lakes (p<0.0001), since char from this lake have the lowest hepatic Hg concentrations. However, our previous NCP-funded work demonstrated that hepatic Fe concentrations were elevated in Small Lake char (Barst et al. 2016), and we hypothesized that redox-active Fe may play a role in the generation of lipid peroxidation in the livers of char. This is supported by the significant correlation observed between TBARS levels and Fe concentrations in the livers of Arctic char from the four study lakes (r^2=0.71, p=0<0.0001). Additionally, our previous work demonstrated that landlocked char from Small Lake had elevated numbers of hepatic melano-macrophage aggregates, which serve as repositories for oxidized lipids and proteins, and therefore increased lipid peroxides would be expected to increase with increasing macrophages. Taken together, these results indicate that Hg and Fe may affect hepatic TBARS, GSH-Px, and SOD levels in populations of landlocked Arctic char sampled from "NCP focal ecosystem" lakes.

The activities of SOD and GSH-Px were not significantly correlated with concentrations of Hg in the brains of Arctic char from the four lakes. In a lab study with zebrafish (*Danio rerio*), Gonzalez et al. 2005 reported that zebrafish exposed to dietary MeHg had no (detoxification) response in brain tissue; they suggested that this lack of response may explain the high neurotoxicity of MeHg.

Similar to SOD and GSH-Px activities, there was no significant correlation between TBARS levels and concentrations of Hg in char brains. The lack of correlation between HgT and TBARS in the brains of Arctic char was surprising given results of the laboratory study by Berntssen et al. (2003), who 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 to result in lipid peroxidation in Arctic char. In a recent study by Graves et al. (2017), brain transcripts involved in the oxidative stress response were measured in wild female yellow perch (*Perca flavescens*) to determine potential alterations associated with MeHg exposure. Whole brain concentrations in yellow perch (0.38 to 2.0 $\mu g \bullet g^{-1}$ wet wt) were similar to those in Arctic char collected from "NCP focal ecosystem" lakes. The expression of six transcripts, including GSH-Px and SOD, did not show differential expression in perch collected from five lakes representing a Hg gradient. However, catalase mRNA levels were significantly lower in perch collected from high-Hg lakes, suggesting that this enzyme may be particularly sensitive to Hg exposure in the brains of wild fish.

In 2016 we collected blood from Arctic char in order to determine if it could be used in other systems as a non-invasive indicator of Hg concentrations and oxidative stress. Results to date show that blood is an excellent predictor of Hg concentrations in muscle (r^2=0.89, p<0.0001), liver (r^2=0.89, p<0.0001), and brain (r^2=0.87, p<0.0001).

Expected Project Completion Date

June 2018

Acknowledgments

Funding was provided by NCP (to Basu), NSERC CREATE (Barst), and Canada Research Chairs (to Basu). Polar Continental Shelf Program (Resolute base) provided housing, meals, laboratory space, field equipment, and flight time.

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Impact of climate change on the mobilization and bioaccumulation of persistent organic pollutants in arctic freshwater systems

Effets des changements climatiques sur la mobilisation et la bioaccumulation des polluants organiques persistants dans les systèmes d'eau douce de l'Arctique

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Abstract

Legacy persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs), and other emerging pollutants such as perfluoralkyl substances (PFASs) were measured in snow, water, and char samples collected from selected areas of Cape Bounty lakes, rivers, and surrounding ecosystems. An intense sampling campaign covering pre-melting, melting, and open lake waters conditions (May-June-August 2016) was carried out to assess POPs levels in order to study the main controls on the remobilization of organic pollutants from the terrestrial environment into two lakes and their main tributaries at Cape Bounty. Overall, the patterns of legacy and emerging pollutants in snow and water were dominated by low molecular weight PCB congeners and short chain PFAS rather than heavier compounds, suggesting long-range atmospheric transport of POPs is the main vector for the introduction of these chemicals in Cape

Résumé

Nous avons mesuré des polluants organiques persistants (POP) hérités du passé, tels que les BPC, et d'autres nouveaux polluants comme les substances perfluoroalkyliques (PFAS) dans des échantillons de neige, d'eau et d'omble chevalier prélevés dans certains secteurs des lacs, des rivières et des écosystèmes environnants de Cape Bounty. On a mené une vaste campagne d'échantillonnage couvrant les conditions lacustres de préfonte, de fonte et d'eaux libres (mai-juin-août 2016) afin d'évaluer les concentrations de POP et d'examiner les éléments clés régissant la remobilisation des polluants organiques issus de l'environnement terrestre dans deux lacs et leurs principaux affluents à Cape Bounty. Dans l'ensemble, les profils de polluants anciens et émergents dans la neige et l'eau étaient dominés par des congénères de BPC à faible poids moléculaire et des PFAS à chaîne courte plutôt que par des

Bounty ecosystem. Snow and lake ice cover were also found to be an important reservoirs of legacy PCBs, as sharp increases of PCB concentrations were detected in East and West rivers and lakes during melting processes compared with pre/post melting measurements.

Although fish lipid content has declined significantly in West Lake, with the lowest values associated with high turbidity (2013-2016). No statistically significant differences were observed in West and East Lakes on the concentrations of total PFASs in water, which may reflect the high solubility of these compounds. Temporal trends (2008-2016) of PCBs in char from East Lake showed significant declining trends, as expected due to the past national and regional bans. This contrasts with significant increases of PCBs in char from West Lake, probably due to greater inputs of PCBs bound to terrestrial carbon, associated with permafrost disturbances (e.g huge input of dissolved organic and particulate carbon) occurring in West Lake and its watershed. Temporal series of PFASs (2008-2015) on char showed declining trends in both lakes, which suggest that disturbances occurring in West Lake and its catchment are not significantly altering the temporal trends of emerging PFASs in char. This change is probably a result of the smaller affinity of these chemicals to organic carbon.

composés lourds, ce qui porte à croire que le déplacement atmosphérique sur de longues distances des POP constitue le principal vecteur pour l'introduction de ces substances chimiques dans l'écosystème de Cape Bounty. La neige et la de glace constituent également des réservoirs importants de BPC hérités, car de fortes augmentations des concentrations de BPC ont été détectées dans les rivières et les lacs East et West durant les processus de fusion comparativement aux mesures avant et après la fonte.

Bien que la teneur en lipides des poissons ait diminué de façon considérable dans le lac West, les valeurs les plus faibles étant associées à une turbidité élevée (2013-2016), aucune différence statistiquement significative n'a été observée dans les lacs West et East relativement aux concentrations de PFAS totales (perfluorocarboxylates, PFCA; PFOS + perfluoroalcanesulfonates, ASPF) dans l'eau, ce qui pourrait être une indication de la solubilité élevée de ces composés. Bien que la teneur en lipides des poissons ait diminué de façon significative dans le lac West, avec les valeurs les plus faibles associées à une turbidité élevée (2013-2016) ont été observées, aucune différence statistiquement significative n'a été observée dans les lacs West et East quant aux concentrations totales de SPFA dans l'eau, ce qui pourrait refléter la grande solubilité de ces composés. Les tendances temporelles (2008-2016) des concentrations de BPC dans l'omble de l'est du lac ont révélé des tendances à la baisse importantes, comme prévu en raison des interdictions nationales et régionales antérieures. Cela contraste avec les augmentations significatives des BPC dans le lac West, probablement en raison des apports accrus de BPC liés au carbone terrestre associés aux perturbations du pergélisol (p. Ex. Énorme apport de carbone organique et particulaire dissous) dans le lac West et son bassin versant. Les séries temporelles de SPFA (2008-2015) sur l'omble ont montré des tendances à la baisse dans les deux lacs, ce qui suggère que les perturbations dans le lac West et son bassin ne modifient pas significativement les tendances temporelles des PFAS émergents dans l'omble. Ce changement est probablement le résultat de la plus faible affinité de ces produits chimiques pour le carbone organique.

Key Messages

- Legacy POPs such as PCBs and emerging pollutants (PFASs) were measured for the first time in snow, water and arctic char samples collected at Cape Bounty (Melville Island).
- Snow melting is an important input of PCBs to riverine and lake water.
- Fish lipid content has declined significantly in West Lake likely due to the associated high lake turbidity.
- The time series (2008-2015) of PFAS showed declining trends in Arctic char from East and West Lakes
- Temporal trends (2008-2016) of legacy PCBs in char from East Lake showed significant declining trends while significant increases were observed in West Lake, likely associated to major ongoing disturbances in West Lake and catchment.

Messages clés

- On a mesuré pour la première fois des POP hérités du passé tels que les BPC et de nouveaux polluants (PFAS) dans des échantillons de neige, d'eau et d'omble chevalier prélevés à Cape Bounty (île Melville).
- La fonte de la neige représente un apport important en BPC pour les eaux fluviales.
- La teneur en lipides des poissons a diminué de façon considérable dans le lac West, probablement en raison de la turbidité élevée y étant associée.
- Les séries temporelles (2008-2015) de SPFA ont montré des tendances à la baisse de l'omble chevalier des lacs Est et Ouest
- Les tendances temporelles (2008-2016) des BPC présents dans l'omble de l'East Lake ont montré des tendances à la baisse importantes tandis que des augmentations significatives ont été observées dans le lac West, probablement associées à d'importantes perturbations continues dans le lac West et le bassin versant.

Objectives

This project aims to:

- Identify and quantify the main controls on the remobilization of organic pollutants from the terrestrial environment into two lakes and their main tributaries at Cape Bounty (Melville Island) by
  - collecting water, soil, vegetation, biota and sediment samples and analyzing them for legacy pollutants such as polychlorinated biphenyls (PCBs), recently regulated, flame retardants such as brominated diphenyl ethers (PBDEs) and surface active poly-perfluorinated alkyl substances (PFASs) and
  - stable $\delta^{13}C$ signatures to assess changes in the sources of carbon delivered to these water bodies.
- Examine temporal trends of PCBs, PBDEs and PFASs in archived landlocked arctic char samples from the selected area (2008-2016) in order to assess the effects over time of remobilization due to warming and compare with ongoing analyses of mercury and other elements.
- Provide the new information to local communities and the Nunavut Environmental Contaminants Committee.

Introduction

Research performed over the past 10 years in the two paired watersheds and lakes at the Cape Bounty Arctic Watershed Observatory (CBAWO) has revealed ongoing permafrost disturbances, which are of significant magnitude and importance in both West Lake watershed and West Lake even though both catchments are broadly similar (Lamoureux and Lafrenière 2014; Lamoureux et al 2014; Roberts et al. 2017). Extremely warm temperatures in 2007 resulted in a huge input of suspended solids, particulate organic carbon (POC) and dissolved organic carbon (DOC) into West Lake compared to nearby East Lake and to earlier pre-warming conditions (Dugan et al. 2012). This high turbidity combined with elevated POC and DOC, and other water chemistry parameters, has persisted with continued permafrost disturbances in the West Lake watershed (Lamoureux and Lafrenière 2014). The water chemistry and discharge record at Cape Bounty is the longest of its kind in the North American Arctic (Favaro and Lamoureux 2015). These changes are also being observed in the Mackenzie Delta region (Kokelj et al. 2005) and in tundra lakes of northern Alaska (Jorgenson et al. 2006). Global warming, affecting Arctic ecosystems with great magnitude, is expected to induce large changes in the carbon cycle (C-cycle) and perturbation of the external nutrient loadings (IPCC 2007). However, the coupling of these perturbations of the carbon(C), nutrient, and hydrological cycles by climate change with the cycling of organic pollutants are still far from being well understood (Macdonald et al. 2005; Cabrerizo et al. 2013).

Concern has been raised over the last years as to whether, due to enhanced warming, Arctic ecosystems will continue to be sinks of atmospheric carbon or if they will, or have already become carbon sources to adjacent rivers, lakes, and oceans. Increased levels of POC and DOC could affect water quality and arctic food webs, which are important concerns for northern residents. Those concerns appear to be supported by observations of rapidly rising DOC concentrations in aquatic ecosystems draining boreal aquatic systems (McGuire et al. 2009), peatlands (Parmentier et al. 2012) or permafrost thaw (Schuur et al. 2009). If destabilized, these carbon stores could dramatically increase organic pollutants as suggested recently for the sub-Antarctic environment (Cabrerizo et al. 2013). Therefore, it is important to study and predict the impact of the mobilization of organic pollutants (legacy and emerging pollutants), due to climate disturbances, from C-rich reservoirs into aquatic polar ecosystems and their impact on Arctic food webs. This will provide the assessment on how Arctic food webs will respond to changing climate and anthropogenic threats.

Activities in 2016-2017

Collection of samples

An extensive field campaign was conducted at Cape Bounty rivers and lakes and surrounding ecosystems, starting with pre-melt conditions in early June (May-June 2016) and ending with collection of Arctic char in early August 2016. The collections added to previous preliminary work conducted in August 2015.

Samples from aquatic and terrestrial environments:

Water from rivers and lakes: A portable micropump connected to a cellulose filter and XAD columns were used to pump water from lakes and rivers catchments for analysis of POPs. At the same time, 1L bottles were also filled with lake and river water for the analysis of PFAs. Water pumping in May was performed though a drilled hole as shown in Figure 1, while 20L cans were used to collect lake water in August during open water lakes. A total of 15 samples were collected.

Snow samples: 4 snow samples were collected for the analysis of POPs and PFAs. Samples were collected in 20L Cans, melted and extracted with Filter/XAD pumping system in PCSP facilities as shown in Figure 2.

Figure 1: Lake and river water pumping for POPs analysis

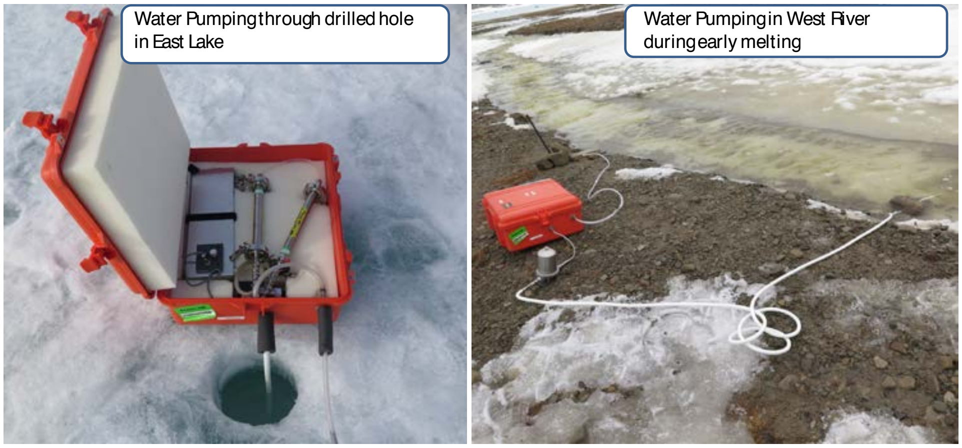


Figure 2: Snow filtering in PSCP facilities

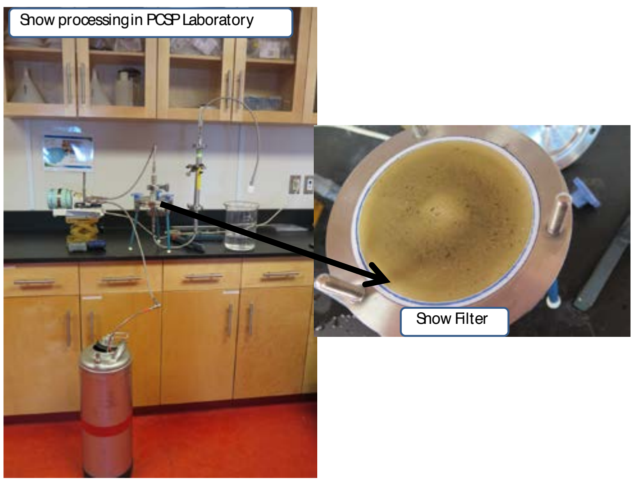


Figure 3. Dissection work and char and zooplankton samples

Adult char were collected in late July by gill netting. N=11>200g adult char from East Lake and a limited number of adult fish were collected from West Lake (n=6>200 g). All char were dissected (Figure 3) in situ within 1 to 4 hours after collection and subsamples of muscle and skin, liver, otoliths, and GI tract were kept frozen for transport and storage in an ultra-clean freezer (-30°C). One sample of zooplankton from each lake was also collected with 125 µm mesh plankton net. Collection of zooplankton was complicated by challenging conditions in West Lake due to turbidity.

Sediment cores from West and East Lakes (3 per each lake), soil (n=20), vegetation samples including grass, mosses and lichens (n=20) were also collected.

Analytical Methods

Analyses of the legacy POPs, PBDEs and PFASs were conducted at the Canada Centre for Inland Waters laboratory under clean room conditions (Class 10000 equivalent lab with carbon/ HEPA air filtration). Liquid-liquid extraction, Accelerated Solvent Extraction (ASE) and Soxhlet extraction were the methods used, depending on the sample matrix, followed by a silica chromatography. Fish samples for POPs also required a gel permeation chromatography (GPC) to remove lipids. The extraction and lipid removal using GPC columns for those samples were contracted to ALS laboratories.

Legacy POPs (PCBs and organochlorine pesticides) were analyzed by GC-MS/MS; PBDEs by GC-MS in chemical ionization mode and LC-MS/MS was used for PFASs analysis. Instrument analysis is being carried out at the facilities of the Canada Centre for Inland Waters.

Northern Capacity Building and Training

Debbie Iqaluk from Resolute led the fishing on the two study lakes as well as logistics for water collection in August 2016. A video was recorded while Debbie Iqaluk and Derek Muir were dissecting the fish for future training purposes. Debbie will co-author future presentations and scientific papers on this study due to her key role.

Traditional Knowledge

Traditional knowledge from Inuit communities was used during fishing and other sample collections conducted for this project. Collection of char in these lakes was particularly challenging due to turbidity in West Lake and required careful consideration of where to place nets and how long to leave them.

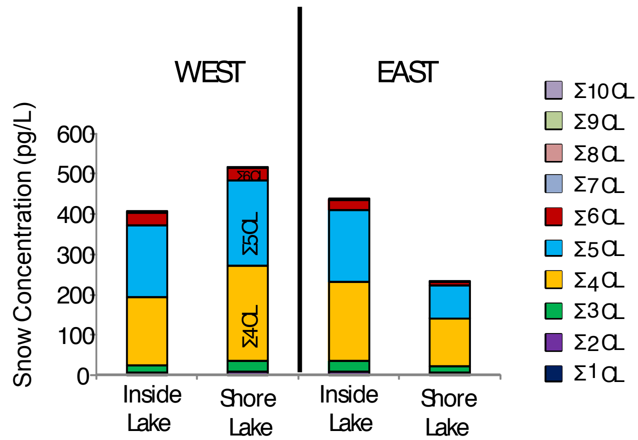
Results and Discussion

Occurrence of legacy and emerging POPs in Water and Snow samples

Legacy POPs in snow and water samples:

PCBs were detected in snow samples collected in East and West Lakes (snow were collected inside and at the shore of each lake). Σ_{71}PCB (sum of 71 PCBs congeners) concentrations in this study ranged from 233 to 515 pg•L^{-1} (meltwater) with a profile dominated by low molecular weight (MW) homologues (mainly those having between 3-5 Cl atoms), as shown in Figure 4. Concentrations found in snow samples from Cape Bounty Lakes are in the same range of those previously reported in the literature from the Norwegian Arctic (Herbert et al 2005).

Figure 4. Concentration profile (pg•L-1) of PCBs homologues group in snow samples collected inside West and East lakes and at the shore of the lakes in 2016



Legacy PCBs were also detected in water from both lakes and rivers, with a profile dominated by low MW PCBs (mainly those having between 2-5 Cl atoms) (Figure 5) suggesting the importance of long range atmospheric transport for the introduction of these chemicals in remote environments (Wania and Mackay, 1996). Concentration of Σ_{71}PCB in lake water before the ice/snow cover melt (early June 2016) were in the range of 16-33 pg•L^{-1} (Panel A, Figure 5), while a sharp increased on PCB concentration in both lakes, up to 200 pg•L^{-1} (West Lake) and 223 pg•L^{-1} (East Lake) were observed after melting of the ice cover (August 2016). The same pattern was observed in East and West rivers (Panel B, Figure 5) with a sharp increase of PCB concentration (up to 301-324 pg•L^{-1} for East and West rivers respectively) in the river water collected during snow melting conditions (late June). The sharp increase of PCB concentration detected in water from both lakes and rivers suggest that both ice cover melting and river runoff contributed to increasing concentration of PCBs in Arctic Lakes. Indeed, snow, has been suggested as an efficient scavenger of POPs from the atmosphere (Wania et al 1999).

Figure 5. Sum of Σ_{71}PCB concentration (pg•L^{-1}) during pre-melting (early June 2016), melting (late June 2016) and post-melting (August 2016) conditions in West and East lakes and rivers water samples collected.

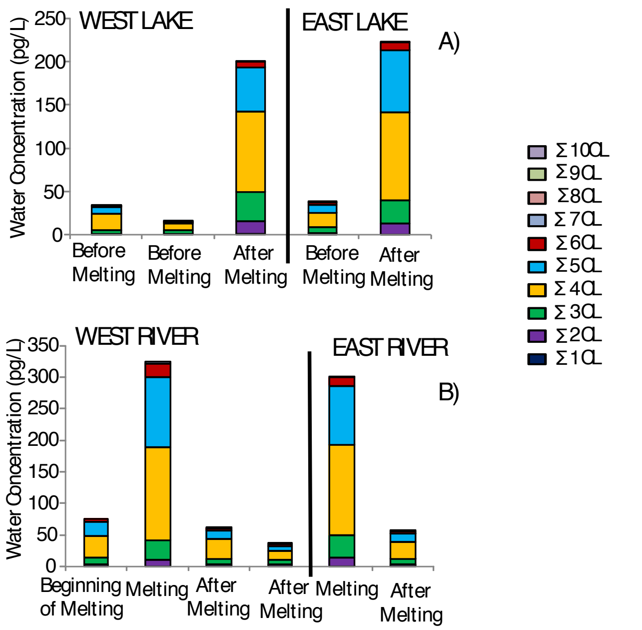
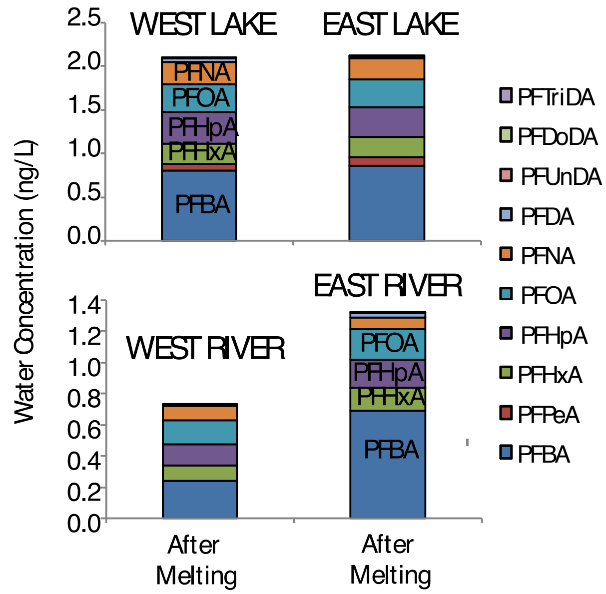


Figure 6. Results of perfluorinated alkyl substances in the West and East lakes (top panel) and in West and East rivers (bottom panel).



Emerging POPs in water samples:

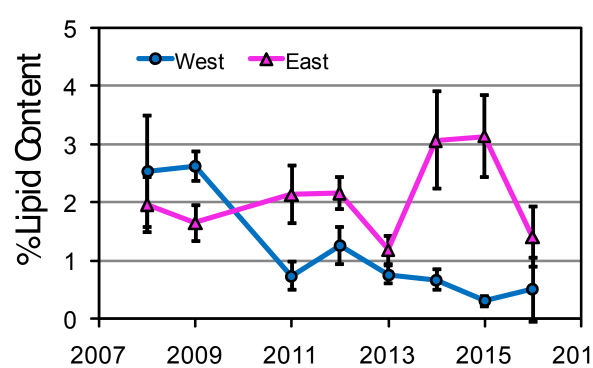
Analyses of river and lake water samples show the presence of PFASs (Figure 6). Perfluorocarboxylic acids (PFCAs) accounted for ~ 97% of the total PFASs in lake water. The most important group among the PFCAs, were perfluorobutanoic acid (PFBA), at levels up to 0.85 ng•L^{-1}. Perfluorooctanesulfonic acid (PFOS) was not detected in rivers or in lake water. Individual PFCAs show slightly higher concentrations in West Lake but no significant differences for total PFASs concentrations in East Lake (2.16 ng•L^{-1}) and West Lake (2.10 ng•L^{-1}) were observed. PFCAs concentrations were generally higher in East River (1.37 ng•L^{-1}) in comparison to West River (0.76 ng•L^{-1}). Overall, the PFASs levels found in this study were similar to observations for lakes near Resolute (Lescord et al. 2015). The lack of differences between the lakes, despite large differences in turbidity was surprising but may reflect the high solubility of these compounds.

Lipid content and temporal trends of PCBs and PFASs in char samples:

Lipid Content:

Lipid content has declined significantly in West Lake at a rate of 29% per year with the lowest values observed from 2013 to 2016, likely due to the stressors and limited access of the char, which are visual feeders, to food supply in this lake. An overall increase of 2% per year in the lipid content has been observed in char from East Lake (Figure 7).

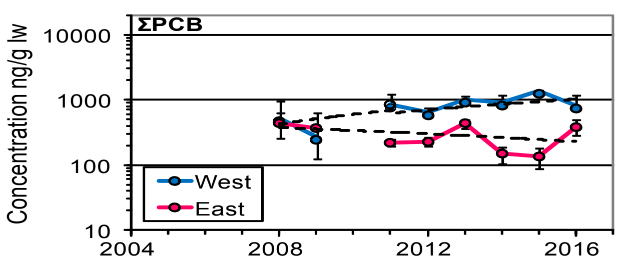
Figure 7. Percent Lipid Content for char in East and West Lake (2008-2016).



Trends of PCBs in Arctic char:

Σ_{71}PCB showed significant declining trends of concentrations in Arctic char from East Lake (-1.4 % per year) as expected due to the past national and regional bans/ restrictions on use and emissions of these chemicals in circumpolar and neighbouring countries (Figure 8). However, the concentrations of PCBs were found to increase significantly (+2.1 % per year) in char collected in West Lake (Figure 8). The increases of PCBs in char from West Lake in comparison to East Lake may be in response to greater inputs of PCBs bound to terrestrial carbon, due to permafrost disturbances (e.g. huge input of DOC and POC) greatly affecting concentrations in char from West Lake and its catchment.

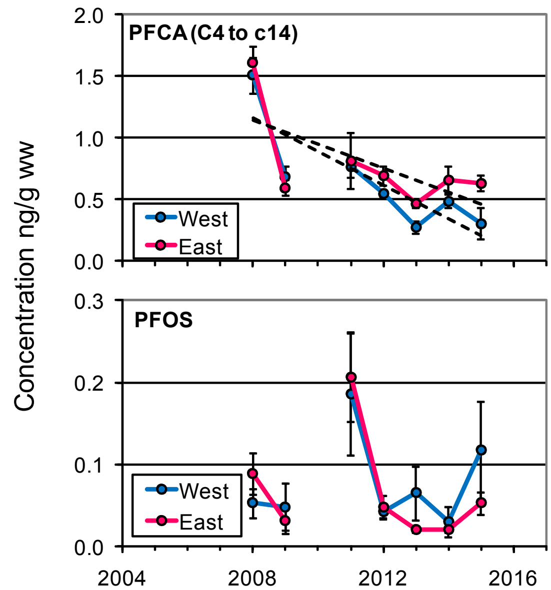
Figure 8. Long term trends of of Σ71PCBs (ng·g-1 lipid weight (lw)) in muscle of landlocked char from West and East Lakes (2008 to 2016). Data are presented in geometric means±SE of ~6-7 fishes per year. Dashed lines show significant trends.



Trends of emerging PFASs in Arctic char:

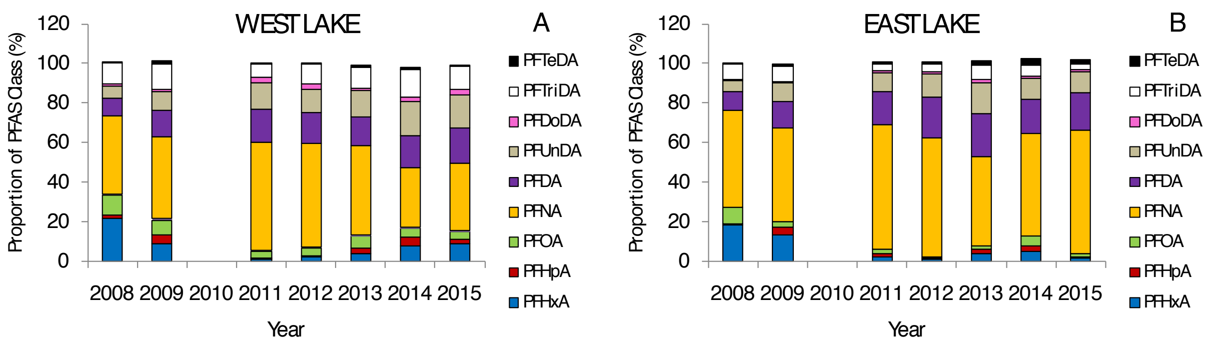
Concentrations of PFCAs, PFOS (Figure 9) and other perfluorosulfonates (PFSs) in Arctic char muscle from East and West Lake were not significantly different over the time period of 2008 to 2015. Data from year 2016 will be included shortly. Results from 2008-2015 suggest that PFCAs in char are decreasing at a rate of 31 % per year in West Lake and 22 % per year in East Lake. This contrasts with minimum decreasing rates for PFOS of 1.8 % per year in East Lake; while a slight increase of 0.5% per year was observed in West Lake. Other PFSs also showed slightly decreasing rates of 0.1% per year in East Lake and 1.6% per year in West Lake.

Figure 9. Temporal series of PFCAs (ng•g-1 wet weight (ww)) in muscle of landlocked char from West and East Lakes (2008 to 2016). Data are presented in geometric means±SE of ~15 fishes per year. Dashed lines show significant declining trends.



Most abundant PFCAs detected in char from both lakes were perfluorononanoate (PFNA) and perfluorodecanoate (PFDA) (Figure 10). While shorter chain lengths PFCAs (i.e perfluorohexanoic acid (PFHxA), perfluoroheptanoic acid (PFHpA), perfluorooctanoate (PFOA) remain almost constant in East Lake, increases of these PFCAs have been detected in char from West Lake since 2012, which may be related to West Lake permafrost disturbances.

Figure 10. Proportion of PFCAs in Char from West and East Lakes



Conclusions

Legacy POPs, such as PCBs, and PFASs, a group of emerging pollutants, were measured in snow, water and arctic char samples collected at Cape Bounty lakes and rivers. Snow and lake ice cover were found to be important reservoirs especially for legacy pollutants. Higher inputs of PCBs into East and West lakes and rivers occurred during melting processes, increasing significantly the concentration of Σ_{71}PCB in comparison to pre/post melting measurements.

Although greater inputs of terrestrial carbon and higher turbidity have occurred in West Lake in comparison to East Lake due to permafrost disturbances, no significant differences in concentration of PFASs in water and on temporal trends in char were observed, likely due to the low sorption of these pollutants to the organic carbon. Temporal trends (2008-2016) of PCBs in char from East Lake showed significant declining trends, as expected due to the past national and regional bans. This contrasts with significantly increases of PCBs in char from West Lake, likely associated to greater inputs of PCBs bound to terrestrial carbon, due to permafrost disturbances occurring in great magnitude in West Lake and its catchment.

Expected Project Completion Date

The funding for this project is projected to end on March 31 2018. Completion of data analysis and manuscript preparation will follow.

Project website (if applicable)

A Facebook account was set up for the project that includes relevant information of the project. https://www.facebook.com/Biopollar.

Acknowledgments

Funding was provided by the NCP. We thank the Queen's University Cape Bounty team, for providing field support and accommodation during the sampling. PSCP is also acknowledged for providing laboratory space. Ana Cabrerizo also acknowledges funding from her postdoctoral fellowship to the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme (FP7/2007-2013) under REA grant agreement n° PIOF-GA-2013-628303.

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Climate change, contaminants, ecotoxicology: interactions in Arctic seabirds at their southern range limits

Changements climatiques, contaminants, écotoxicologie : interactions chez les oiseaux marins de l'Arctique à leurs limites méridionales

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Abstract

Pagophilic (ice-associated) Arctic species are facing multiple stressors from climate change and toxic contamination. We investigated whether contaminants compounded the impact of climate change on wildlife by limiting their ability to respond to changes in ice availability. In particular, 38 thick-billed murres were tracked via GPS-accelerometers, and concentrations of hormones, mercury, and brominated flame retardants (BFRs) were measured in all 38 individuals. Per-/polyfluoroalkyl substances (PFAS) levels were measured in the plasma of 10 individuals. Levels of BFRs and PFASs were low, and unrelated to hormones or behaviour. However, mercury levels were associated with pre-trip levels of circulating triiodothyronine (T3) hormones. The pre-trip levels of T3 were associated with foraging behaviour; higher levels of T3 were associated with higher diving rates. We found

Résumé

Les espèces arctiques pagophiles (associées aux glaces) font face à de multiples facteurs de stress liés aux changements climatiques et aux contaminants toxiques. Nous avons cherché à savoir si les contaminants aggravaient l'impact des changements climatiques sur les espèces sauvages en limitant leur capacité à réagir aux changements quant à la disponibilité de la glace. Plus particulièrement, on a suivi 38 guillemots de Brünnich au moyen d'accéléromètres GPS et on a mesuré les concentrations d'hormones, de mercure et de produits ignifuges bromés (PIB) chez les 38 individus. Les concentrations de composés perfluoroalkyliques et polyfluoroalkyliques (PFAS) ont été mesurées dans le plasma de 10 individus. Les concentrations de PIB et de PFAS étaient faibles et n'avaient aucun lien avec les hormones ou le comportement. Toutefois, les niveaux de mercure étaient associés aux

no associations with corticosterone. GPS tracks demonstrated that birds were foraging near regions of floating ice, which may improve foraging success and lower diving rates. Thus, mercury was positively associated with T3, which may relate to increased diving rates away from ice concentrations. Based on our 2016-17 data, we tentatively conclude that mercury may be influencing the ability of thick-billed murres to adjust to variation in ice cover, and we will further examine that hypothesis in 2017 with a larger sample size and different environmental conditions.

concentrations d'hormones circulantes de type triiodothyronine (T3) avant sorties. Les concentrations de T3 avant sorties étaient associées au comportement de recherche de nourriture; des concentrations plus élevées de T3 étaient associées à un taux de plongée plus important. Nous n'avons trouvé aucun lien avec la corticostérone. Les suivis GPS ont permis de démontrer que les oiseaux s'alimentaient près des régions de glaces flottantes, ce qui pourrait améliorer leurs chances de s'alimenter et diminuer le taux de plongée. Par conséquent, il existe une corrélation positive entre le mercure et le T3, ce qui pourrait avoir un lien avec l'augmentation du taux de plongée loin des concentrations de glace. En nous fondant sur nos données recueillies en 2016-2017, nous concluons provisoirement que le mercure pourrait avoir une incidence sur la capacité des guillemots de Brünnich à s'adapter aux variations de la couverture de glaces. Nous examinerons de manière plus poussée cette hypothèse en 2017 à l'aide d'une gamme d'échantillons plus vaste et dans différentes conditions environnementales.

Key Messages

- Levels of BFRs and PFAS observed were quite low.
- However, mercury may influence the ability of murres to adjust to variation in ice cover via associations with hormones.

Messages clés

- Les concentrations de PIB et de PFAS observées étaient plutôt faibles.
- Toutefois, les concentrations de mercure pourraient avoir une incidence sur la capacité des guillemots à s'adapter aux variations de la couverture de glaces en raison de leur association avec les hormones.

Objectives

- Obtain plasma samples from 50 incubating murres before and after each GPS deployment. Analyze initial blood samples from all 50 murres for mercury. To reduce costs and because diet, age and sex variation mean that individuals with high levels of one contaminant tend to have high levels of a second contaminant, we will use the 50 mercury samples to select the 10 individuals with highest mercury levels and 10 individuals with the lowest mercury levels for subsequent analysis of chemicals. From those 20 murres (10 murres with high contaminant load and 10 murres with low contaminant load), plasma samples will be analyzed for legacy POPs and NCP-priority brominated compounds and perfluorinated compounds.
- Measure biomarkers (thyroid hormones: free/total T3/thyroxine (T4); free/total corticosterone) on those same plasma samples from before and after each GPS deployment. This will allow determination of possible relationships among contaminant concentrations, changes in hormone status, behaviours and energetics, in the same individual birds.
- Determine DNA methylation status of the receptor for corticosterone (Glucocorticoid Receptor; GR) in red and white blood cells from adult murres and their offspring. Contaminant-associated alterations in patterns of DNA methylation in the GR would indicate persistent and potentially multi-generational impacts on the stress axis.
- Monitor energy expenditure and gain of birds monitored for contaminants by attaching GPS-accelerometers to 50 incubating thick-billed murres at Coats Island. The GPS will provide foraging locations which will be linked to ice cover from satellite imagery available from the Canadian Ice Service.
- Use a path analysis to link contamination with energy expenditure, and intake with hormone levels and DNA methylation status.

Introduction

Environmental contaminants accumulate to levels of concern in many Arctic wildlife species, including seabirds. Toxic contaminants are only one of multiple natural and anthropogenic stressors impacting wildlife populations, including climate change, increased industrialization and Northern community population growth (Letcher et al. 2010; McKinney et al. 2015). Contaminants and climate change may be a particularly potent combination in the Arctic where both stressors are on the rise. The Arctic is warming at twice the average global rate, and increasing trends in contaminants are occurring against that backdrop of rapid climate change (Letcher et al. 2010; McKinney et al. 2016). One mechanism by which climate change is impacting wildlife populations is via a mismatch in the timing of breeding and environmental cues (Gaston et al. 2009). Primary productivity can respond rapidly to increases in energy associated with climate change while animals at higher trophic levels may use other cues to determine optimal timing of breeding (Gaston et al. 2009). In the case of Arctic seabirds, phytoplankton bloom immediately after the ice departs and set a timeline that dictates the food available for seabird offspring (Laidre et al. 2007). Seabirds must be able to time their egg laying a month ahead of time to match that peak in food availability, yet climate change can cause ice to melt more rapidly than seabirds are able to respond, creating a mismatch in the time when seabirds rear their offspring and the time of peak food availability (Gaston et al. 2009). This mismatch leads to unsustainable levels of energy expenditure (Gaston et al. 2009).

There is growing evidence that contaminant levels currently measured in Arctic wildlife are disrupting endocrine systems and causing altered reproductive behaviours (Appendix 1). Specifically, those individuals with high levels of mercury and/or persistent organic pollutants (POPs) have altered endocrine status. This may compromise the ability of individuals to respond to environmental change, and lead to reduced reproductive success. Because a myriad of factors can impact reproductive success, it is important to establish a strong mechanistic linkage between contamination, the endocrine system, behavior, and reproduction.

To date, contaminant studies have focused on correlations between contaminant concentrations and behaviours, such as nest attentiveness, lay date, and chick feeding rates (Appendix 1). The assumption is that high levels of those behaviours are associated with fitness (i.e. reproductive success and survival). However, there is growing awareness that fitness is poorly associated with individual values for any behavior; rather, fitness is associated with plasticity in those traits (Charmantier et al. 2008; Reed et al. 2011). Such flexibility is regulated by hormones that allow the body to respond to variation in food availability. A key insight in this proposed research, then, is to move beyond previous studies (Appendix 1) to examine plasticity in behaviour—which is particularly important in the context of climate change.

A major factor, then, in determining the resilience of Arctic wildlife to climate change is their behavioural plasticity (or flexibility) to accommodate changes in food availability. The overarching hypothesis of this proposal is that toxic contaminants disrupt behavioural plasticity in response to changes in food availability. We specifically test the idea that contaminants disrupt hormones that allow such behavioural plasticity.

Activities in 2016-2017

Sample Collection/Analysis

Between July 5-25, 2016, Kyle Elliott, along with students Tianna Burke and Emile Brisson-Curadeau, and research assistant Josiah Nakoolak (Coral Harbour) collected blood samples from 38 thick-billed murres at Coats Island. Blood samples were taken before and after each foraging trip, and a GPS-accelerometer was attached to individual birds to monitor foraging during each trip. The Lab Services Unit at the National Wildlife Research Center (NWRC) analyzed total mercury in the red blood cells of all 38 birds. NWRC Lab Services also used red blood cells to confirm the genetic sex of 28 birds (Method MET-DNA-SEX-01C); the genetic sex of the remaining 10 birds was confirmed through previous research at the colony. NWRC Lab Services analyzed the concentrations of BFRs in the plasma of all 38 birds (exceeding our original objective of 20 birds), with levels of PFASs being identified in 10 of these birds in the Letcher Organic Contaminants Research Laboratory (ORCL). Also, plasma from all 38 birds was analyzed for free and total forms of triiodothyronine and thyroxine (NWRC Lab Services) and corticosterone (Jessica Head). Behavioural analyses from GPS-accelerometers were undertaken by PhD student Allison Patterson and MSc student Emile Brisson-Curadeau.

Although an exceptional presence of polar bears necessitated the unexpected early closure of the field site in August 2016 (a permanent bear fence has since been installed so we do not foresee similar problems in 2017), we successfully achieved our objectives as described in our 2016-2017 NCP proposal. Due to the early closure, we were not able to sample the expected 50 individuals and we were unable to collect samples from chicks to measure glucocorticoid receptor methylation. The exceptionally high number of bears was reported to the Conservation Officer in Coral Harbour, and is likely an effect of ice leaving earlier in 2016 than previous decades.

Analytical Methods

Analyses of legacy POPs (including PCBs), PBDEs, HBCDD, and total Hg were carried out by NWRC Lab Services in Ottawa, Ontario. Analysis of the legacy organochlorines (OCs) was carried out by gas chromatography using a mass selective detector (GC/MSD) operated in the electron impact (EI) mode, and analysis of 22 PBDE congeners and total-α-HBCDD was carried out using GC/MSD run in negative chemical ionization (NCI) mode according to NWRC Method No. MET-CHEM-OC-06D. The ORCL at the NWRC determined a suite of 16 perfluorinated carboxylic acids (PFCAs) and perfluorinated sulfonic acids (PFSAs) by a UHPLC-MS/MS-based method according to published methods and detailed in the SOP MET-OCRL-EWHD-PFAS-Version 4-August 2014. 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). In addition, both Lab Services and the OCRL at NWRC participated separately in the NCP's QA/QC Program. All samples are archived in the National Wildlife Specimen Bank at the NWRC in Ottawa.

Capacity Building

We built substantial capacity in 2016-17 via the training of four students: Tianna Burke, Emile Brisson-Curadeau, Ashley Hanas and Allison Patterson. Tianna and Emile conducted field research in the North. Ashley learned how to conduct corticosterone hormone assays. Allison and Emile learned how to analyze GPS-accelerometer data. In addition, Josiah Nakoolak acted as a research assistant and bear monitor in 2016, and spent time helping to select birds for blood sampling, capturing birds, and handling birds.

A major emphasis within the broader Coats Island project in 2016 was the bear-proofing of camp including the construction of new cabins. Josiah Nakoolak and Juipie Angootealuk (Coral Harbour) were instrumental in these efforts. We tried to recruit four other individuals from Coral Harbour to help with the cabin construction, but all four declined for various reasons. Also, with NCP support, students in the NAC Environmental Technology Program attended a lecture that highlighted seabird contaminant monitoring work in Nunavut.

Communications

We presented a poster entitled "Climate change, contaminants, ecotoxicology: interactions in Arctic seabirds at their southern range limits" at the 37th Annual Meeting of the Society of Environmental Toxicology and Chemistry (SETAC), 7th SETAC World Congress.

Paul Smith (ECCC, Ottawa), who also has a field camp on Coats Island, met with the Aiviit HTO and the Irniurviit ACMC in Coral Harbour in March 2016 to present information on the monitoring and research activities on migratory birds in the region, including the current project. Paul attempted to meet with the Aiviit HTO and the Irniurviit ACMC again in March 2017, but poor weather prevented the plane from landing in Coral Harbour. Consultation was, therefore, limited to phone and e-mail. Annual reports of the results to date are made to the NCP each year and results will continue to be published in peer-reviewed scientific journals.

Indigenous Knowledge Integration

Inuit advice from Josiah was solicited as to what birds to sample. We selected individuals in communication with Josiah, who has extensive experience with murres and other Arctic wildlife.

Results

Objective 1

Total mercury levels averaged 1.65 $\mu g \cdot g^{-1}$ dry weight (dw), ranging from 1.1 to 2.74 $\mu g \cdot g^{-1}$ dw. Levels of organochlorines, brominated flame retardants and PFAS were uniformly quite low (Tables 1-3). Hexachlorobenzene, DDE and dieldrin were the organochlorines present in the highest concentrations (Table 1). BDE47 and BDE100 were the brominated flame retardants present in the highest concentrations (Table 2). PFOS and PFUdA were the PFASs present in the highest concentrations (Table 3).

Table 1. Levels of organochlorines in thick-billed murre plasma (in ng•g^{-1} wet weight (ww)). Compounds that were never detected were excluded from the table. Minimum concentrations for all compounds were non-detectable (i.e. for all compounds, at least one individual had levels that were not detectable).

Compound	Average	SD	Maximum
1,2,3,4-Tetrachlorobenzene	0.0003	0.0006	0.0017
Pentachlorobenzene	0.0001	0.0001	0.0004
Hexachlorobenzene	0.0045	0.0012	0.0081
p,p-DDE	0.0039	0.0018	0.0077
Dieldrin	0.0042	0.0221	0.1170
PCB28/31	0.0013	0.0014	0.0055
PCB70	0.0004	0.0016	0.0072
PCB74	0.0015	0.0016	0.0043
PCB105	0.0002	0.0002	0.0006
PCB118	0.0008	0.0011	0.0032
PCB138	0.0006	0.0004	0.0013
PCB153	0.0004	0.0005	0.0015
PCB158	0.0000	0.0001	0.0007
PCB187	0.0003	0.0002	0.0007

Table 2. Concentrations of brominated flame retardants in thick-billed murre plasma (ng•g^{-1} ww). Compounds that were never detected were excluded from the table. ∑5PBDEs are the summation of the concentrations of BDE-47, -99, -100, -153, and -154 that co-eluted with BB-153.

Compound	Mean	SD	Maximum
∑5PBDEs	0.0766	0.1029	0.4570
BDE47	0.0325	0.0602	0.2530
BDE99	0.0075	0.0180	0.0700
BDE100	0.0366	0.0457	0.1340
BDE138	0.0241	0.1276	0.6750
BDE85	0.0131	0.0695	0.3680

Table 3. Concentrations of PFAS in thick-billed murre plasma (ng•g^{-1} ww). Compounds that were never detected were excluded from the table.

Compound	Mean	SD	Maximum
PFBS	0.02	0.00	0.02
PFHxS	0.07	0.03	0.10
PFOA	0.11	0.04	0.19
PFNA	0.85	0.32	1.57
PFOS	3.74	0.79	4.90
PFDA	0.90	0.30	1.41
PFUdA	4.10	1.02	5.91
PFDS	0.12	0.06	0.22
PFDoA	0.84	0.22	1.21
PFTrDA	2.08	0.59	3.15
PFTeDA	0.25	0.10	0.42
PFODA	0.03	0.00	0.03

Objective 2

We recorded the pre- and post-foraging trip levels of five biomarkers: free and total T3, free and total T4, and corticosterone (Table 4). Levels of thyroid hormones were not significantly different between pre- and post-trip (all $p > 0.05$). In contrast, corticosterone levels were higher post-trip than pre-trip (paired $t(37) = 3.96$, $p < 0.001$).

Table 4. Hormone levels in thick-billed murre plasma pre- and post- foraging trips.

Biomarker	Mean	SD	Minimum	Maximum
Pre-trip Free T4 (pg/mL)	8.49	2.92	3.86	14.80
Pre-trip Free T3 (pg/mL)	2.20	0.58	1.39	3.04
Pre-trip Total T4 (ng/mL)	7.56	5.63	1.80	20.40
Pre-trip Total T3 (ng/mL)	0.80	0.30	0.20	1.28
Post-trip Free T4 (pg/mL)	7.06	2.76	2.36	13.60
Post-trip Free T3 (pg/mL)	2.35	0.80	1.18	4.43
Post-trip Total T4 (ng/mL)	5.77	6.40	1.80	22.60
Post-trip Total T3 (ng/mL)	0.78	0.17	0.61	0.95
Pre-trip Corticosterone (pg/mL)	75.02	68.34	8.58	230.86
Post-trip Corticosterone (pg/mL)	118.68	86.80	8.58	290.44

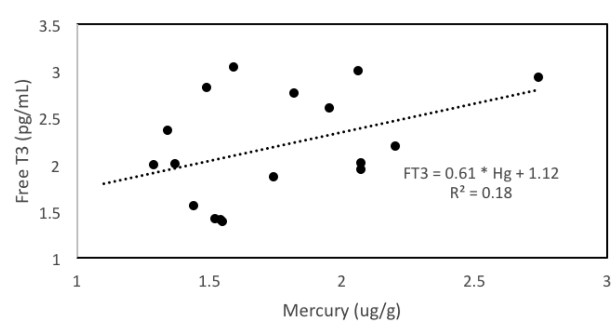
Objective 3

Daily energy expenditure was measured from the accelerometers using dynamic body acceleration. Dynamic body acceleration averaged 0.32 ± 0.12 g, which translated into an estimate of daily energy expenditure of 1711 ± 547 kJ per day. Daily energy expenditure was lower when ice was present (1422 ± 609 kJ/d) than when it was not (2062 ± 710 kJ/d). The primary foraging area was northwest of the colony, with several individuals spending significant time in an area of small ice clusters off Bencas Island.

Objective 4

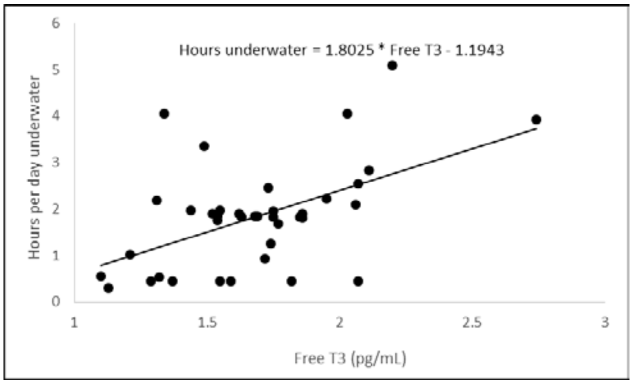
A principal component analysis was conducted on the data for the three organohalogen contaminant groups: organochlorines, perflorinated compounds and brominated compounds. The first two principal components explained over 90% of the variance for all three groups, and so we disregarded additional components. There was no relationship between the first or second principal component of any of the three organohalogen contaminant groups and any of the biomarkers (all $p > 0.05$). However, there was a significant, but weak, relationship between mercury levels and free T3 across individuals ($t(14) = 1.83$; one-tailed $p = 0.04$; $R^2 = 0.18$; slope = 0.27 pg•(mL*ppm)$^{-1}$ [95% confidence interval on slope = 0-0.54] Figure 1).

Figure 1. Pre-trip free T3 levels as a function of mercury levels in thick-billed murres at Coats Island.



There was a significant, positive association between free T3 and hours per day underwater ($t(34) = 2.99$, $p = 0.005$; $R^2 = 0.27$; slope = 1.15 h*mL•pg^{-1} [95% confidence interval on slope = 0.61-1.76]; Figure 2).Figure 2). There were no other associations between hormone levels and daily energy expenditure, time spent diving, or time spent flying. As indicated by Figure 1 and 2, and relationships therein, the overall path analysis indicated that mercury had a statistically-significant effect on free T3, which then affected time spent diving.

Figure 2. Pre-trip free T3 levels relative to time spent diving for thick-billed murres at Coats Island.



Discussion and Conclusions

T3 is the biologically active thyroid hormone in vertebrates. High mercury levels were associated with high levels of T3, which were associated with substantial time spent diving. Thus, those individuals with high levels of mercury may have lacked the hormonal flexibility to respond to changing ice conditions, and consequently foraged in poorer habitats where they had to work harder (spend more time diving). Arctic cod is the keystone species for the northern Hudson Bay ecosystem, and is the key forage fish for thick-billed murres, ringed seals, beluga, and other predators. Arctic cod occurs primarily in cool waters (below 4 degrees Celsius), and is consequently associated with ice. Thick-billed murres spend less time underwater when hunting for cod, because cod travel in large schools and therefore require less underwater search times. Apparently, those individuals with higher levels of mercury, had higher levels of T3, which may have influenced their ability to dive to the depths needed to obtain cod. For example, we speculate that birds with high levels of mercury may have switched to other prey than cod because they are unable to find the optimal location for catching cod.

Levels of BFRs, OCs and PFAS were relatively low in plasma. Not surprisingly, there were no significant relationships between those contaminants and behaviour, in contrast to some previous studies reporting higher levels of contaminants (Appendix - Table 1). The lipid content of plasma is low, notably in comparison to other avian tissues such as eggs. Consequently, low concentrations of lipophilic compounds will occur in tissues with low lipid content (e.g., plasma) compared to high lipid tissues (e.g., eggs).

We were able to increase the capacity of the Coats Island project in 2016-2017, by training four students in field work, hormone analysis, and behavioural analysis. Those students will form the basis for a strong cohort going forward, facilitating work in 2017.

The presence of a polar bear at the murre colony in 2016 made working at the colony unsafe, and we were forced to leave early. Thus, our sample size (38) was somewhat lower than anticipated (50). In 2017, we will be continuing the project to increase our sample size and statistical power. For instance, the statistically-significant relationship between mercury and total T3 has a one-tailed P-value of 0.04. With a larger sample size, and by restricting our sampling to males (reducing variance), we believe we can increase statistical power in 2017. Moreover, ice cover in December 2016 was at a record low for Hudson Bay, and a lack of resilience to variation in ice cover may be particularly important in 2017. With a second year's data, we will be able to make stronger inferences.

Expected Project Completion Date

31 March 2018.

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Appendix

Table 1. Studies that have investigated the relationships between POPs contaminants, behaviour, reproductive success and the endocrine system in polar seabirds.

The table is meant to be representative rather than exhaustive. Contaminants examined included polychlorinated biphenyls (PCBs), organochlorines (OCs), organohalogens (OHs), legacy persistent organic pollutants (Legacy POPs) and polybrominated diphenyl ethers (PBDEs). Species examined included glaucous gulls (*Larus hyperboreus*), great black-backed gulls (*Larus marinus*), black-legged kittiwakes (*Rissa tridactyla*) and snow petrels (*Pagodroma nivea*). Hormones examined include prolactin (PRL), thyroid hormones (THs), corticosterone (CORT) and luteinizing hormone (LH). Because reproductive hormones are often inter-correlated, relationships with one hormone often imply a relationship with other (potentially unmeasured) hormones; it is not necessary to measure all hormone groups.

Species	Contaminant	Effect	
Glaucous gull	PCBs	Decreased nest attentiveness	Bustnes et al. 2001, 2005
Glaucous gull	OCs	Later lay date, reduced second chick size	Bustnes et al. 2003
Great black-backed gull	PCBs	Later lay date, higher predation rate, lower egg size	Helberg et al. 2005
Glaucous gull	PCBs	Lower THs	Verreault et al. 2004
Glaucous gull	PCBs	Higher progesterone in males	Verreault et al. 2006
Glaucous gull	OHs	Tendency for lower PRL	Verreault et al. 2008
Glaucous gull	PCBs	Lower nest temperature	Verboven et al. 2009
Glaucous gull	PCBs/PBDEs	Higher baseline CORT	Verboven et al. 2009
Black-legged kittiwake	PCBs	Higher baseline CORT (pre-laying)	Verboven et al. 2009
Snow petrel	Legacy POPs	Higher baseline CORT	Tartu et al. 2015a
Snow petrel	Hg	Higher baseline PRL	Tartu et al. 2015a
Black-legged kittiwake	Hg	Higher LH and skipped breeding	Tartu et al. 2013
Black-legged kittiwake	Hg	Skipped breeding	Tartu et al. 2013
Black-legged kittiwake	Legacy POPs	Increased CORT	Tartu et al. 2014
Black-legged kittiwake	Hg	Reduced PRL and breeding success	Tartu et al. 2015b

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Plastics as a vector of contaminants in Arctic seabirds

Les plastiques comme vecteur de contaminants chez les oiseaux marins de l'Arctique

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Abstract

Plastic debris is commonly ingested by seabirds, even in high Arctic waters, but only recently has attention turned to what the impacts of this ingested pollution may be. There is increasing evidence that once marine plastic pollution is in the gut of seabirds, plastics release contaminants that may have negative effects on wildlife. We assessed how plastic-associated chemical contaminants may be transferred to Arctic food webs via ingested plastics in Arctic marine birds (northern fulmars; *Fulmarus glacialis*). This work was done through the use of samples already in hand and stored at the National Wildlife Research Centre (Environment and Climate Change Canada, Ottawa, ON). Although plastics are both a source and a vector for chemical contaminants in marine animals, little work has been done in the Arctic region beyond initial plastic ingestion studies. Marine plastic debris has been listed by the United Nations Environment Program (UNEP) as one of the most important emerging environmental concerns, and the Arctic Monitoring and

Résumé

Les oiseaux de mer ingèrent souvent des débris de plastique, même dans les eaux de l'Extrême-Arctique, mais ce n'est que tout récemment qu'on a commencé à s'interroger sur les répercussions de cette pollution ingérée. Des preuves de plus en plus nombreuses indiquent que lorsque la pollution plastique marine atteint l'intestin des oiseaux de mer, les plastiques libèrent des contaminants susceptibles de produire des effets négatifs sur la faune. Nous avons évalué les modalités du transfert des contaminants chimiques associés aux plastiques vers les réseaux alimentaires de l'Arctique par l'intermédiaire des plastiques ingérés par les oiseaux marins de l'Arctique (fulmars boréaux; *fulmarus glacialis*). Ces travaux ont été réalisés en ayant recours aux échantillons déjà recueillis et stockés au Centre national de la recherche faunique d'Environnement et Changement climatique Canada, à Ottawa (Ontario). Bien que les matières plastiques constituent à la fois une source et un vecteur pour les contaminants chimiques chez les animaux marins, on a

Assessment Program (AMAP) working group of the Arctic Council has included marine plastics in their upcoming emerging contaminants assessment. Therefore studies demonstrating the extent and impact of plastics are critical to both domestic and international chemical assessment activities. This work is also relevant to informing studies on the health of harvested species.

effectué peu de travaux à ce jour dans la région arctique au-delà des études initiales d'ingestion des matières plastiques. Le Programme des Nations Unies pour l'environnement (PNUE) a classé les débris marins plastiques comme l'une des plus importantes préoccupations environnementales émergentes et le groupe de travail du Programme de surveillance et d'évaluation de l'Arctique (PSEA) du Conseil de l'Arctique a inclus les plastiques marins dans sa prochaine évaluation des contaminants émergents. C'est pourquoi les études démontrant l'étendue de la pollution par les plastiques et ses répercussions s'avèrent essentielles pour les activités d'évaluation de substances chimiques, tant à l'échelle nationale qu'internationale. Ces travaux sont également pertinents pour servir de base à des études sur la santé des espèces récoltées.

Key Messages

- There are a large variety of synthetic polymers entering the Arctic food web through seabird ingestion of plastic debris.
- While visual sorting methods group plastics into categories based on physical characteristics, FTIR results demonstrate that within these groups there can be a number of polymer types.

Messages clés

- Il existe une grande variété de polymères synthétiques qui entrent dans les réseaux alimentaires de l'Arctique par l'intermédiaire des débris de plastique ingérés par les oiseaux marins.
- Bien que les méthodes de tri visuel regroupent les plastiques en catégories en fonction des caractéristiques physiques, les résultats du spectromètre infrarouge à transformée de Fourier (IRTF) montrent qu'il peut y avoir un certain nombre de types de polymère parmi ces groupes.

Objectives

This project aims to:

- contribute to our growing understanding of the link between macro-contaminants (i.e. plastics) and micro-contaminants (i.e. chemicals)
- improve our understanding of how plastic pollution may act as a source and long-range vector for contaminants to enter Arctic ecosystems and cycle within marine animals.
- Examine how plastic-associated contaminants relate to accumulated plastics levels in an Arctic bird species known to ingest high levels of plastics (northern fulmars).
- Examine how levels of phthalates in preening gland oil in northern fulmars relate to accumulated plastic levels.
- Through the use of Fourier transform infrared spectroscopy (FTIR) examine what types of polymers and debris northern fulmars are ingesting and accumulating in the Canadian Arctic.

Introduction

Marine plastic debris has been listed by the United Nations Environment Program (UNEP) as one of the most important emerging environmental concerns (UNEP 2014). UNEP's estimate of financial damage from plastics to marine ecosystems is in excess of US$13 billion each year, not including loss of commercial fish stock, damaged ocean infrastructure, and rescue costs when plastics entangle vessel engines. The presence of plastic debris in remote environments, such as the high Arctic as detected through seabirds, demonstrates that plastics are persistent and subject to long-range transport (Lusher et al. 2015; Mallory 2008; Provencher et al. 2009), just as micro-contaminants are.

Beyond the physical impact associated with plastics, there is also increasing awareness of the chemicals associated with marine plastic debris. Plastics are made from a number of chemical components such as UV stabilizers and phthalates (Zhang et al. 2015). Additionally, marine plastic pollution can also absorb contaminants from the surrounding waters, and in some cases can concentrate chemicals on their surfaces (Endo et al. 2005; Hirai et al. 2011; Mato et al. 2001). Importantly, there is also growing evidence demonstrating that plastics can move toxic chemicals into food webs through animal ingestion (Avio et al. 2015; Bakir et al. 2014; Hamlin et al. 2015; Teuten et al. 2009; Van Cauwenberghe and Janssen 2014), and this movement of chemicals into food webs can have potentially deleterious impacts for both wildlife and human health (Hamlin et al., 2015).

Much of the work on ingestion of plastics has focused on seabirds in temperate and tropical regions where ingested rates of plastics are high (Colabuono et al. 2010; Young et al. 2009). Although the Arctic region was once considered to be pristine and have minimal risk from micro-contaminants, history seems to be repeating itself and recent work over the last decade has shown that, once again, this remote region is vulnerable to long range transport of plastic pollution (Kühn and van Franeker 2012; Mallory 2008; Mallory et al. 2006). Ingested plastics were first reported in seabirds from Arctic Canada using birds caught as fisheries bycatch (Mallory et al. 2006). Since this time, several studies have reported ingested plastics in seabirds in the Canadian Arctic (Mallory 2008; Mallory et al. 2006; Poon et al. 2016; Provencher et al. 2010, 2009). Importantly, studies have suggested that plastic ingestion by seabirds may be increasing in Arctic Canada (Provencher et al. 2009), making plastic pollution an emerging threat even in the most remote, undeveloped and seemingly improbable habitats for contamination.

This study aims to help inform questions around the transfer of plastic-related contaminants in marine birds, and aims to inform larger global questions about how plastics are potentially affecting marine wildlife. Since marine birds and other country food species (such as marine mammals) are known to ingest plastics, this study will also inform how marine plastics in the environment may be influencing the health of harvested species in the Arctic. This work is timely as the Arctic Monitoring and Assessment Program (AMAP) working group of the Arctic Council is including marine plastics as an emerging contaminant of concern in their recent assessments (currently underway). This project allows the NCP to provide critical knowledge to this emerging field of study. Importantly for the NCP, plastics are both a source and a vector for chemical contaminants in marine animals (Endo et al. 2005; Teuten et al. 2009), but little work has been done in the Arctic region. This includes contaminants of concern to the NCP such as mercury and PCBs (Endo et al. 2005; Graca et al. 2014). Therefore this project increases our knowledge of this emerging contaminant concern in the north, and allows us to better understand how plastics may be acting as vectors for chemical contaminants listed under the NCP's blueprints.

Activities in 2016-2017

All of the field work has been completed for this project. Northern fulmars were collected from Prince Leopold Island, Nunavut in 2013 as part of an NCP project led by Birgit Braune (Environment and Climate Change Canada). Additionally, northern fulmars were collected in 2015 by Stephanie Avery-Gomm (formerly of Environment and Climate Change Canada) in the Labrador Sea as part of a separate project.

Under NCP funding in 2016-2017 this project capitalized on this previous work supported by NCP and Marine Environmental Observation, Prediction and Response (MEOPAR) and focused on analyzing tissues from these same birds for plastic associated contaminants. First, we examined three tissues (breast muscle, fat, and brain) which will be analyzed for a suite of legacy and emerging contaminants known/suspected of being associated with plastics. The chemicals of focus will be OPEs, PBDE congeners, PFSAs (incl. PFOS)/PFCAs, as well as mercury. We analyzed 10 individuals from the low Arctic collections to look for OPEs, and PBDEs, and paired this with previous work supported under ECCC that examined individuals from our high Arctic birds for the same contaminants. Additionally, a subset of livers from the low Arctic location were screened for PFCAs (n=6 birds), and again compared with high Arctic samples from the same birds which had been analyzed under an ECCC project (K. Fernie and R. Letcher).

Second, we will ground truth a new technique that allows non-lethal sampling of a bird's preening oil as an indicator of plastic ingestion (Hardesty et al. 2015) using preening oil from the birds collected in the Labrador Sea. Preening gland oil from birds with known plastics ingestion will be tested for phthalates to evaluate if preening gland oil sampled non-lethally can be used as an indicator of the presence or absence of ingested plastics, and the level of plastic ingestion (i.e. abundance of ingested plastic pieces).

Third, we analyzed the plastics found in the stomachs of fulmars collected from the Labrador Sea and Prince Leopold Island to quantify the types of plastics (i.e. polyethylene, polypropylene, polyvinyl chloride, polyurethane etc.) that are available for ingestion to marine biota in eastern Arctic waters. These results will help assess what polymer types are present in Arctic waters, and help determine what chemical contaminants are most likely to be transferred to Arctic biota via ingestion, and thus impact what contaminants have the potential to bio-transfer to marine biota.

Capacity Building and Communications

Fulmars from the high and low Arctic sites have already been dissected as part of the Wildlife Contaminants Workshop with the Environmental Technology Program (ETP) students at the Nunavut Arctic College in 2014 and 2015 as supported by the NCP. All the tissues needed for this study were collected by the ETP students using chemically clean procedures as instructed by Guy Savard of Environment and Climate Change Canada's National Wildlife Research Centre's National Wildlife Specimen Bank (Provencher et al. 2013). Additionally, the gastrointestinal tracts of the birds have been quantified and described (Poon et al. 2016).

Results

While all analysis of the bird tissues for a variety of contaminants (OPEs, PBDE congeners, PFSAs (incl. PFOS)/PFCAs, mercury, phthalates etc.) are complete, the results have yet to be finalized and processed. These results will be examined in the coming months, and ultimately submitted for peer-review.

A total of 637 debris pieces have been analysed using FTIR. The following are summary results from 428 pieces for which initial detailed results are available (all from fulmars sampled near Nunatsiavut). A variety of polymer types were ingested by northern fulmars in the Labrador Sea (Figure 1). Polymer identification in some cases was very specific to a brand specific polymer type (e.g. Kraton G), but often we used more general identifications (e.g. nylon).

Using visual sorting methodologies (Provencher et al. 2017; van Franeker et al. 2011), 28 industrial pellets were identified among the debris pieces. When these were examined using FTIR, a wide variety of polymer types were identified within this one plastic category (Table 1).

Figure 1. Polymer types as determined by Fourier transform infrared spectroscopy (FTIR) of ingested plastics found in the stomachs of northern fulmars (*Fulmarus glacialis*) collected in the Labrador Sea near Nunatsiavut in 2015.

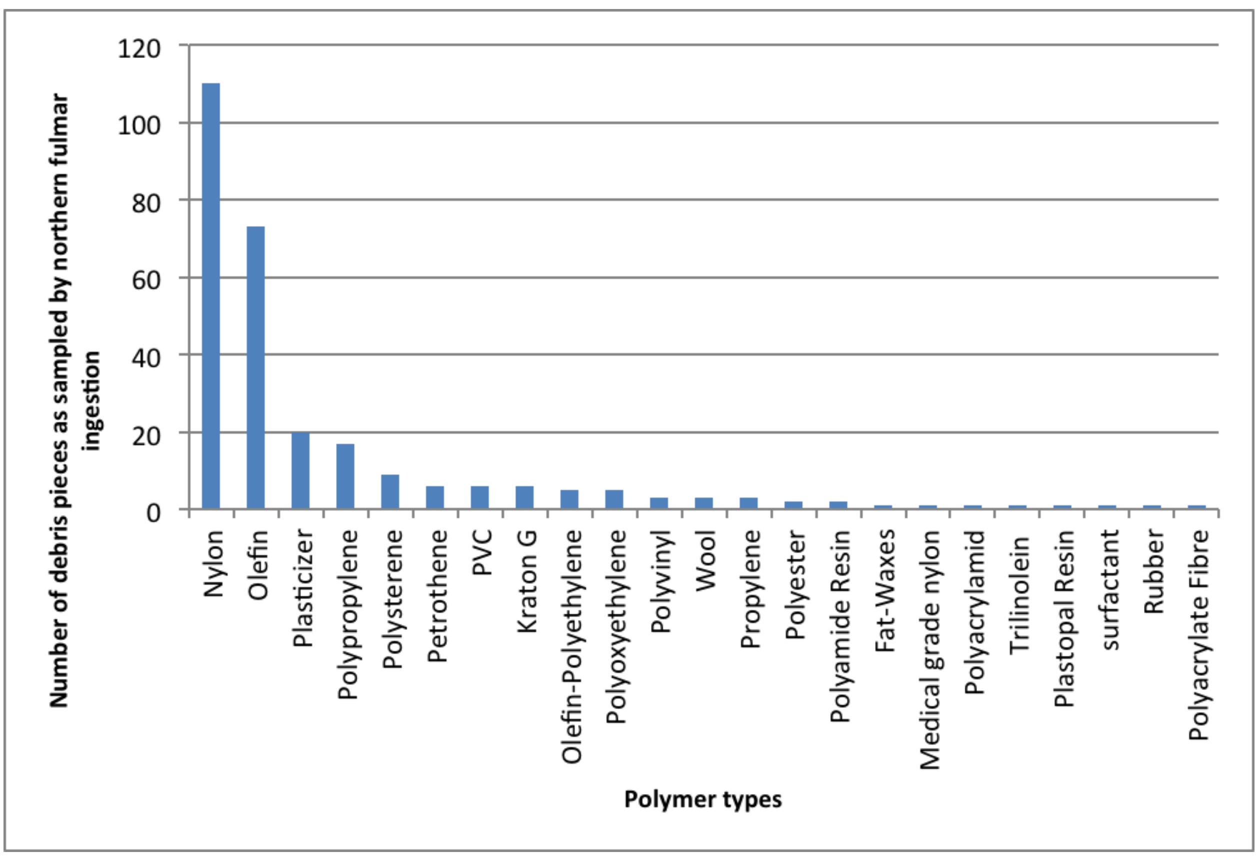

Table 1. Polymer types as determined by Fourier transform infrared spectroscopy (FTIR) of ingested plastics visually identified as industrial pellets (n=27) from the stomachs of northern fulmars (*Fulmarus glacialis*) collected in the Labrador Sea near Nunatsiavut in 2015.

Polymer type	Count
Polyethylene	6
Olefin Fibre	3
Polystyrene	2
Petrothene	2
High MW Polyethylene	2
Polyoxyethylene (polyamides)	1
Polyethylene Wax	1
Polyamide Resin	1
Petrothene (Polyethylene)	1
Nylon 6-9	1
Nylon 6	1
Nopalcol Br-13	1
Nopalcol (Plasticizer)	1
N4/Nylon Fibre	1
Minicel L-200 Polyethylene Foam	1
Kraton G (Strong plastic)	1
56% Cotton , 44% Nylon	1

Discussion and Conclusions

Over the past 30 years, plastic ingestion studies in Arctic seabirds in Canada, and other regions, has focused on documenting ingestion of debris in different species and in different regions (Day and Shaw 1987; Mallory 2008; Mallory et al. 2006; Poon et al. 2016; Provencher et al. 2010, 2009; Trevail et al. 2015). The efforts in the last 10 years been a part of a coordinated effort in assessing how seabirds are ingesting and accumulating plastic pollution throughout the northern hemisphere (Provencher et al. 2017). These studies have focused on identifying debris types through visual sorting methods.

This study aimed to take the examination of the plastic debris by Arctic seabirds using more advanced analytical techniques to better inform how plastic ingestion may affect marine biota. Our initial results suggest that northern fulmars in the Arctic are ingesting a variety of polymer types. As a result, fulmars may be being exposed to a high number of chemical compounds that are associated with the different polymer types. While environmental samples have shown that a variety of debris is entering the Arctic environment (Cózar et al. 2017), this is the first to show these different polymer types as sampled by Arctic wildlife.

While seabirds were the main focus of this research, our results suggest that all Arctic wildlife that are vulnerable to ingesting plastics may be exposed to these different polymers, and their associated chemical contaminants. Trophic transfer from seabirds to predators have been demonstrated (Hammer et al. 2016), suggesting that this may occur at several levels in Arctic food webs. Therefore, these same polymers found in northern fulmars, which are known to widely sample the marine environment for plastics (van Franeker et al. 2011), are likely being ingested by other animals in the region. This includes fish and marine mammals, which are increasingly found with ingested plastics globally (Provencher et al. 2017). This has wide implications for how plastics may be acting as vectors for a number of contaminants into the Arctic food web, and ultimately in food consumed by humans. Further work is needed to address questions relating to how plastics may be found in country foods specifically in Arctic Canada.

Expected Project Completion Date

All of the lab work is now complete, and currently the results are being analysed. Final analytical and statistical examination of the data is ongoing, and the results will be submitted for peer-reviewed publication in late 2017 to early 2018.

Acknowledgments

Many thanks to NCP for supporting this work. Thanks to the community of Resolute Bay, Nunavut who co-manage the Prince Leopold Island Migratory Bird Sanctuary with Environment and Climate Change Canada. Thanks to Stephanie Avery-Gomm (formerly of

Environment and Climate Change Canada) for collections in the Labrador Sea. Max Liboiron (Memorial University of Newfoundland) has also supported this work through funding from MEOPAR NCE. As always, thanks to the Nunavut Arctic College's Environmental Technology Program students and the Nunavut Research Institute for their work during the annual Wildlife Contaminants Workshop, as the annual Wildlife Contaminants workshop is a critical element to this research.

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Assessing persistent organic pollutants in Canadian air and water as an entry point into the Arctic food chain

Évaluer les polluants organiques persistants dans l'air et l'eau de l'Arctique canadien en tant que points d'entrée dans la chaîne alimentaire arctique

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Abstract

Organophosphate ester (OPEs) flame retardants and plasticizers are receiving increased attention due to their presence in remote locations including the Canadian Arctic. The widespread global distribution of OPEs is believed to arrive through various mechanisms including oceanic transport, and air transport in the gas phase and on fine particles. Air, water, sediment and zooplankton samples were collected between 2007-2016 in the Canadian Archipelago as part of ArcticNet and the Northern Contaminants Program. Samples were mainly taken from on board the CCGS Amundsen but also at Resolute Bay in the lower arctic and Alert in the high arctic. This coordinated sampling helps us understand how OPEs are introduced into the arctic food web. OPEs most frequently detected in the arctic environment were tri-

Résumé

Les produits ignifuges à base d'ester d'organophosphate (EOP) et les plastifiants retiennent de plus en plus l'attention en raison de leur présence dans les régions éloignées, y compris l'Arctique canadien. On croit que la présence généralisée des produits ignifuges à base d'EOP à l'échelle mondiale est causée par divers mécanismes, y compris par le transport atmosphérique et océanique de substances en phase gazeuse et sur des particules fines. Dans le cadre d'ArcticNet et du Programme de lutte contre les contaminants dans le Nord, on a procédé, de 2007 à 2016, au prélèvement d'échantillons d'air, d'eau, de sédiments et de zooplancton dans l'archipel canadien. Les échantillons ont principalement été prélevés à partir du NGCC Amundsen, mais également à Resolute Bay, dans le Bas-

phenyl phosphate (TPhP), tris(2-chloroethyl) phosphate (TCEP), tris(2-chloropropyl) phosphate (TCPP), tris(1,3-dichloro-2-isopropyl) phosphate (TDCiPP) and ethyl-hexyl diphenyl phosphate (EHDPP). Levels of OPEs were very high compared to other flame retardants including poly brominated biphenyl esters (PBDEs).

Arctique, et à Alert, dans l'Extrême-Arctique. Cet échantillonnage coordonné nous permet de comprendre comment les produits ignifuges à base d'EOP sont introduits dans le réseau trophique de l'Arctique. Les produits ignifuges à base d'EOP les plus souvent détectés dans l'environnement arctique sont le phosphate de triphényle (PTP), le phosphate de tris(2-chloroéthyle) (PTCE), le phosphate de tris(2-chloropropyle) (PTCP), le phosphate de tris(1,3-dichloro-2-isopropyle) (PTDIP) et le phosphate d'éthylhexyle diphényle (EHDPP). Les concentrations de produits ignifuges à base d'EOP étaient très élevées comparativement à d'autres produits ignifuges, y compris les polybromobiphénylesters (PBBE).

Key Messages

- Organophosphate esters are abundant in arctic air, water (dissolved and particulate), zooplankton, and sediment.
- OPEs arrive in the arctic through atmospheric and oceanic transport and end up on land, ocean and ice.
- Different environmental compartments have different proportions of the OPEs indicating different transport and deposition processes.
- It is difficult to assess atmospheric deposition processes (i.e. air water gas exchange and dry particle deposition of OPEs) due to issues with air sampling methods.

Messages clés

- Les esters d'organophosphate sont abondants dans l'air, l'eau (dissous ou en particules), le zooplancton et les sédiments arctiques.
- Les produits ignifuges à base d'EOP sont transportés jusque dans l'Arctique par des processus océaniques et atmosphériques et se retrouvent dans l'océan, les glaces et les sols.
- Les différents compartiments environnementaux renferment des proportions diverses de produits ignifuges à base d'EOP, indiquant des processus de transport et de dépôts variés.
- Il s'avère difficile d'évaluer les processus de dépôt atmosphérique (c.-à-d. les échanges gazeux air-eau et le dépôt de particules sèches d'EOP) en raison des problèmes liés aux méthodes d'échantillonnage de l'air.

Objectives

- To determine levels and trends of OPEs in the arctic air, water, sediment and zooplankton as an entry point into the arctic food chain.

Introduction

OPEs are high production volume chemicals and are increasingly used due to the ban of several bromine and chlorine containing flame retardants. OPEs are flame retardants but other uses include plasticizers, levelers in floor wax, and hydraulic fluids. This study targets all OPEs on the Canadian Chemical Management Plan (CMP) priority lists. Last year we expanded our target OPE list and were able to identify one new compound in the arctic environment, tris(2-isopropyl phenyl) phosphate (T2iPPP) was detected in both water and sediment samples.

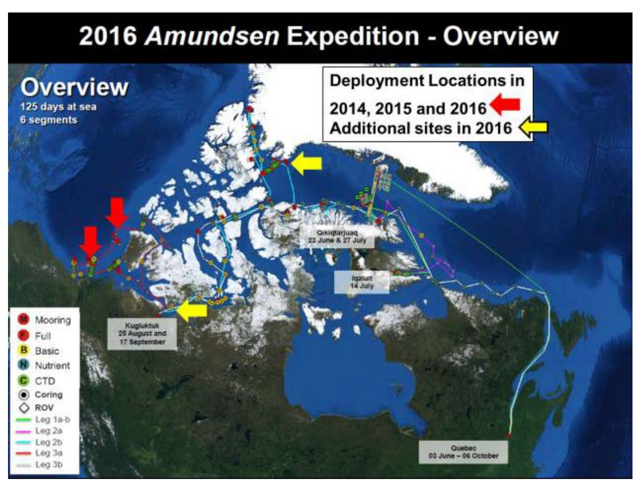
Activities in 2016-2017

During the summer of 2016 we secured two berths on the CCGS Amundsen as part of ArcticNet on Legs 3a-b. During this six week cruise focusing on the Beaufort Sea (but also including a transect across the Canadian Archipelago to Quebec City, see Figure 1) we collected, air, water (dissolved and particulate phases) and zooplankton samples. Passive water samples were also deployed in three locations and collected from the Beaufort Sea, see arrows on Figure 2. Sediment samples are collected in the odd years whereas zooplankton samples are collected in the even years.

Additional samples were collected for a proof of concept study for microplastics. This included sediments from the Mackenzie Delta and Frobisher Bay, near Iqaluit and filtered water in the Beaufort Sea.

Figure 1: Sampling locations in the summer of 2016.

Figure 2: Passive water sampling stations: red arrows indicate stations where samplers were deployed and/or retrieved in 2014, 2015, 2016, and will be again in 2017. The yellow arrows indicate where samplers were deployed in 2016 and will be again deployed in 2017.



Results

Air Samples

OPEs have been analyzed in air samples from 2007-2015. We have also been investigating the particle-gas distribution of these compounds in arctic air. The commonly found OPE compounds, tris(2-chloroethyl) phosphate (TCEP), tris(1-chloro-2-isopropyl) phosphate (TCiPP) and triphenyl phosphate (TPhP), are predominately found in the particle phase, although models based on physical chemical properties predict they should be ~100% in the gas phase. We have been investigating why there are conflicting results and have concluded that it is a sampling artifact. As the airborne OPEs pass through the filter, they sorbed onto the glass fibers or on a water film that forms on the filter especially in high humidity environments. The pore size of the filter also makes a difference as the smallest particles contain a higher proportion of the OPEs than the coarser particles. We conclude that the high-volume air sampling train that consists of a glass fiber filter followed by a PUF/XAD trap does not effectively separate the OPEs in gas phase from the particle phase so we are only able to report total OPEs.

We also investigated the transport and fate of OPEs by looking at the isomer ratios of TCPP, an abundant OPE in arctic air and water. TCPP has four possible isomers and two are routinely found in arctic air. As the ship moved away from source regions, the isomer ratio increased, indicating the dominate isomer (TCiPP) is more stable than the TCPP2 isomer, see Figure 3. This change in ratio can potentially be used to trace the sources and aging of TCPP in the environment.

Water samples

Water samples were collected between 2011-2015 in the Canadian Archipelago were analyzed for OPEs. Concentrations of the ΣOPEs in the water range from 7.1-36 ng•L^{-1}. These levels are very high and alternate sampling methods were employed in the summer of 2015/16 that confirm these measurements (averaging 16 ng•L^{-1}; see Figure 2).

Figure 3. Ratio of two isomers of TCPP (TCiPP/TCPP2) from Quebec City, along the east coast of Canada, along the north shore of Labrador and into Hudson Bay.

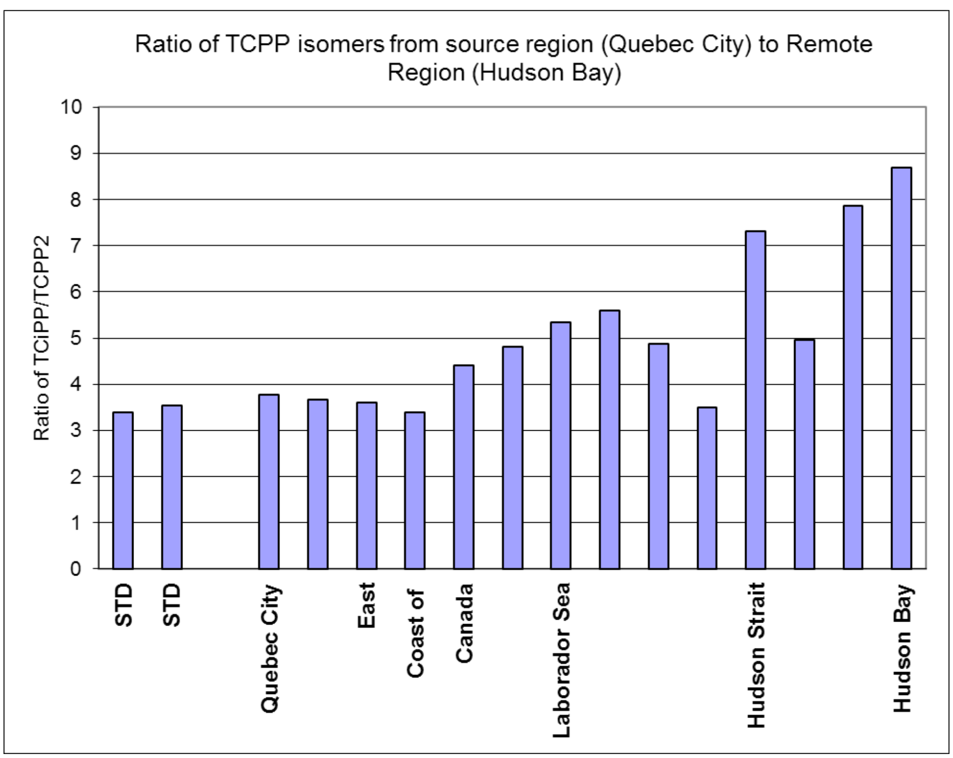
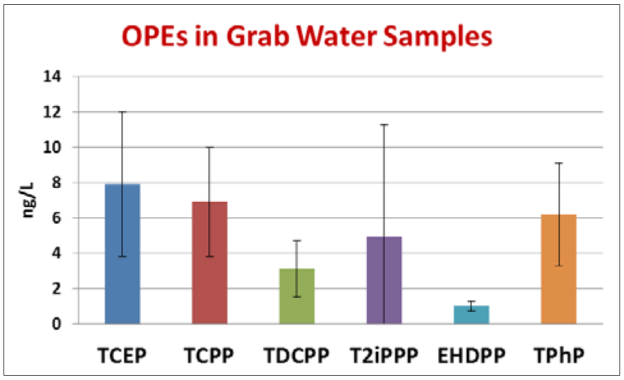


Figure 4. Grab surface water sample results from the Beaufort Sea in 2016.



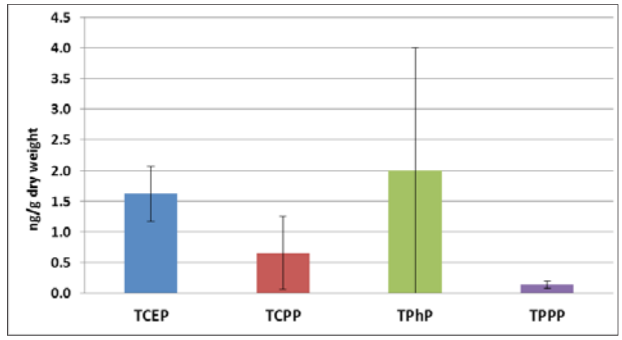
Passive water samples

All passive water samples were successfully retrieved from the moorings and more samplers were redeployed in the Beaufort Sea as proposed (Figure 4, red arrows). We were also able to deploy samplers in Northern Davis Straight and near Cambridge Bay (Figure 2, yellow arrows). Processing, cleaning up and QA/QC of these samples continue. Preliminary results indicate organochlorine and some current use pesticides, PBDEs, and PCBs are easily detected in the semi-permeable membrane devices (SPMDs). The types of passive water samplers are being changed from SPMDs to poly ethylene (PE) and silicon rubber (PDMS) type samples as the matrix is much easier to process and aligns this program with the AQUA-GAPS Network (Lohmann et al. 2016).

Sediment

OPEs were determined in arctic sediment samples from across the Canadian archipelago (Figure 4). They showed high variability with the highest concentrations in the Mackenzie Delta; this is not surprising as the Mackenzie River drainage basin is large and includes the northern half of Alberta, parts of British Columbia and Saskatchewan and most of the North West Territories. The lowest concentrations were found in mid-archipelago stations away from local or riverine inputs. In comparison to air and water, there was a relatively higher proportion of TPhP in sediments; this is consistent with its lower water solubility compared to TCEP and TCPP.

Figure 5. OPEs in arctic sediment from all regions of the Canadian Archipelago.



Discussion

OPE Composition in the Arctic

The relative amounts of OPEs were investigated in the different arctic media and are reported here. For comparison, air samples from Alert and snow samples from Resolute Bay were also included. Generally TCEP is the dominant OPE and this is likely due to its higher water solubility. The higher water solubility of TCEP allows for better transportation through ocean currents and its higher vapour pressure allows it to be better transported through air currents. The snow shows a very different composition compared to the air and water, this is probably due to preferential deposition of the higher vapour pressure compounds, TDCiPP and TPhP. At Alert there is a higher relative amount of TCPP than air from the cruises that take place further south, this is probably due to the influence of European air where TCEP has been banned in Europe and replaced with TCPP. In North America, generally the amount of TCEP>TCPP in air (Shoeib et al. 2014; Moller et al. 2012; Salamova et al. 2014a), whereas in Europe TCPP>TCEP (Moller et al. 2011; Salamova et al. 2014b). Zooplankton also shows a different composition than the other samples; it is the only media with a relatively high occurrence of EHDPP. EHDPP is also enriched in indoor dust compared to indoor air, indicating that it may be more lipophilic than the other OPEs and generally OPEs are more labile than organochlorine compounds (Pesticides and PCBs).

Figure 6. Percent composition of OPEs in Arctic Samples

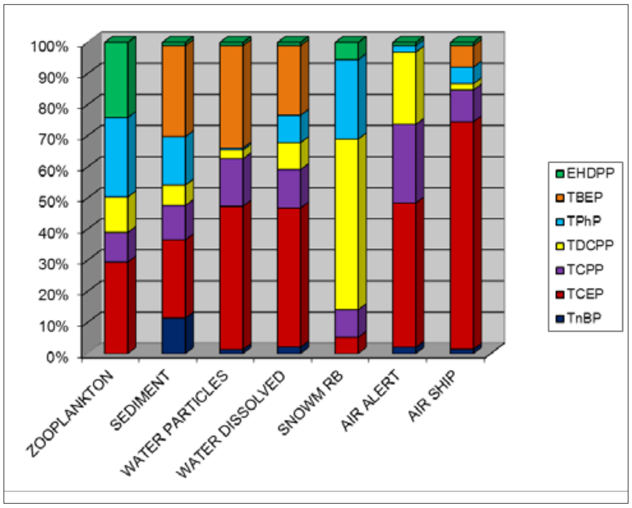
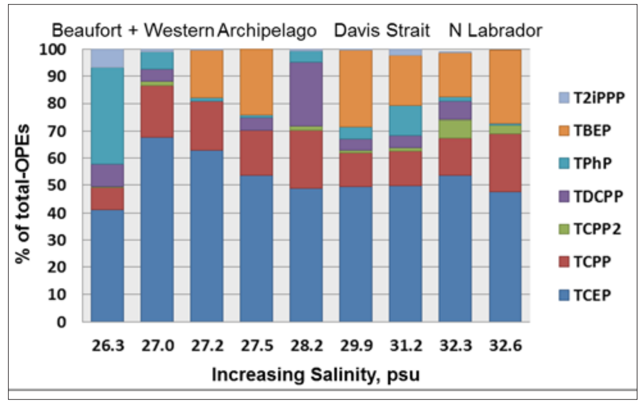


Figure 7. Percent composition of OPEs in water samples from different regions of the Canadian archipelago. Left to right is increasing salinity and decreasing longitude.



Water

The relative composition of the water samples are all similar and dominated by TCEP (Figure 7); on the Figure 7 graph, salinity increases and longitude decreases from left to right. For the more volatile compounds, TCEP and TCPP, there is a significant positive relationship with longitude but not latitude (although the span of latitude is narrow). This same trend is seen for α-hexachlorocyclohexane (a-HCH; Bidleman et al. 2007). There are differences in proportions of OPEs in the water samples, most notably is the absence of TBEP in three samples, this is probably because the detection limit if TBEP is quite high. The first sample has the highest proportion of TPhP and T2iPPP compared to all other samples. It is taken in the Beaufort Sea north of Banks Island and has the lowest salinity (i.e. the freshest water) and the coldest water temperature which indicates that it receives a large amount of melt water. This same higher proportion of TPhP has been seen in snow samples from Resolute Bay (Figure 6) further implying that this water sample is influenced by snow/glacier melt. The fifth bar is a sample that has a higher proportion of TDCPP; this sample may also be influenced by recent snow melt in the area since the salinity indicates it is relatively fresh and the snow melt samples from Resolute Bay (Figure 6) have a higher proportion of TDCPP compared to the dissolved water.

Conclusions

TCEP and TCPP are starting to be restricted for some uses in Canada. TCEP is banned from children's products and recent statements from CMP indicate that TCPP usage will be limited to 0.1% of products (such as mattresses and upholstered furniture) due to concerns over human health. CMP found TDCiPP and tris-cresyl phosphate do not pose a threat to Canadians but for TDCiPP "follow-up activities will be considered to inform prioritization and evaluation of future new or increased use of this substance." (Canada Gazette 2016). Other OPEs currently under evaluations include TEP, TBEP, TEHP and TDBPP. More OPE compounds are being detected in arctic air, such as EHDPP and TCP. EHDPP was first detected in zooplankton and was rarely found in air and water in previous years; however in 2016 it was detected in 100% of the air samples. As more analytical standards become available, a wider list of OPEs will be sought in arctic environment.

Expected Project Completion Date

The analysis of OPEs in these samples is complete except the passive water samples and zooplankton, and will be completed by the end of August 2017. Analysis of the additional target compounds is on-going and is expected to be completed by the end of December 2017.

Acknowledgments

We thank Environment and Climate Change Canada for their generous and on-going support. We also thank ArcticNet for the student stipend, ship time and sharing of complementary data. A special thanks to Alexis Burt, Jimmy Truong and Jasmin Schuster for help sampling and with deployment of passive samplers in 2016. Thanks to Hayley Hung and Cecilia Shin for the Alert air samples, and Gary Stern and Monika Pucko for the Resolute Bay snow samples.

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The effect of retrogressive thaw slumps on the delivery of high loads of toxic methylmercury to downstream freshwater systems in the Peel Plateau region, NT

Effets du glissement régressif dû au dégel dans la diffusion de charges élevées de méthylmercure toxique dans les réseaux d'eau douce en aval dans la région du plateau Peel, dans les Territoires du Nord-Ouest

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Abstract

On the Peel Plateau, retrogressive thaw slumps (RTS) are thermokarst disturbances that can cover areas up to multiple hectares, and mobilize thousands of cubic meters of permafrost-derived sediments over multiple decades. We are studying the effect of RTS activity on the concentrations of total (THg) and methyl (MeHg) mercury downstream of slumps. The potential mobilization of mercury (Hg) as a result of RTS activity is of interest because neurotoxic MeHg is known to bioaccumulate in organisms, and biomagnify as it makes its way up the food web. We find that slumping substantially increases both THg and MeHg downstream of slumps, with increases in THg as much as 600-fold and MeHg

Résumé

Dans la région du plateau Peel, les glissements régressifs de fonte sont des perturbations thermokarstiques qui peuvent couvrir un territoire de plusieurs hectares et mobiliser des milliers de mètres cubes de sédiments issus du pergélisol sur un grand nombre de décennies. Nous procédons à l'étude des répercussions des glissements régressifs de fonte sur les concentrations de méthylmercure et de mercure total en aval des glissements. La mobilisation possible du mercure à la suite de ces glissements présente un intérêt puisque le méthylmercure est neurotoxique et que l'on sait qu'il se bioaccumule dans les organismes et se bioamplifie à mesure qu'il circule vers les

as much as 4-fold, downstream of slumps when compared to pristine, upstream sites. We further find that this increase can persist for up to 3 km downstream. The concentrations of MeHg that we observe – as high as 3 ng•L^{-1} – are among the highest measured to date in uncontaminated sites in Canada. However, this increase in THg and MeHg that we observe is entirely particle associated; in filtered samples, both dissolved THg and MeHg decrease downstream of slumps, suggesting that the substantial particles released by slumping may provide an adsorptive surface that sequesters Hg. Thus, although slumping appears to enable the release of both THg and MeHg into contemporary biogeochemical cycles, or the production of MeHg in slumped materials, its particle association may mean that it is not readily available for uptake by organisms.

maillons supérieurs du réseau trophique. Nous avons constaté que les glissements augmentent considérablement les concentrations de méthylmercure et de mercure total en aval des glissements, avec des concentrations de mercure total pouvant être jusqu'à 600 fois plus élevées et de méthylmercure jusqu'à 4 fois plus élevées, en aval des glissements comparativement aux sites vierges en amont. Nous avons également noté que cette hausse peut persister jusqu'à trois kilomètres en aval. Les concentrations de méthylmercure que nous avons observées – pouvant atteindre 3 ng•L^{-1} – sont parmi les plus élevées mesurées à ce jour sur les sites non contaminés au Canada. Cependant, cette augmentation des concentrations de méthylmercure et de mercure total que nous avons observée est entièrement associée aux particules; dans les échantillons filtrés, les concentrations de méthylmercure et de mercure total dissous diminuent en aval des glissements, ce qui porte à croire que les quantités importantes de particules libérées par les glissements pourraient fournir une surface d'adsorption pour le mercure. Par conséquent, bien que les glissements semblent entraîner le rejet de méthylmercure et de mercure total dans les cycles biogéochimiques contemporains ou la production de méthylmercure dans les matériaux déposés par glissement, son association aux particules pourrait signifier qu'il n'est pas rapidement disponible pour absorption par les organismes.

Key Messages

- Permafrost slumping appears to significantly increase both THg and MeHg downstream of slumps on the Peel Plateau, NT.
- Increases are almost entirely associated with the particulate form. Downstream of slumps, Hg appears to be sequestered on particles, and dissolved Hg decreases downstream of slumps.
- Elevated levels of total (particulate + dissolved) THg and MeHg persist for up to 3 kilometers downstream.

Messages clés

- Le glissement du pergélisol semble augmenter de façon considérable les concentrations de méthylmercure et de mercure total en aval du glissement dans la région du plateau Peel, dans les Territoires du Nord-Ouest.
- Les augmentations sont presque totalement liées à la forme particulaire. Il semble que, en aval des glissements, il y ait séquestration du mercure par des particules et diminution du mercure dissous.

- The rise in THg and MeHg downstream of slumps occurs following the onset of slumping in the early summer, and continues throughout the thaw season.
- MeHg might be microbially produced in slumped environments.

- Les concentrations élevées de méthylmercure et de mercure total (dissous ou en particules) persistent jusqu'à trois kilomètres en aval.
- L'augmentation des concentrations de méthylmercure et de mercure total en aval des glissements se produit après le déclenchement des glissements au début de l'été et se poursuit tout au long de la période de fonte.
- ZIl est possible que le méthylmercure soit produit par voie microbienne dans les milieux touchés par des glissements.

Objectives

This project was intended as a short-term study to explore the effects of RTS features on the delivery of total mercury (THg; all forms of Hg in a sample) and MeHg (the toxic form of Hg) to downstream freshwater ecosystems in the Peel Plateau region, NT. It follows some exploratory (non-NCP funded) work that occurred during the summer of 2015, when spot measurements found significant increases in THg and MeHg downstream of slumps. Within this context, our 2016 objectives were to:

- Quantify THg and MeHg delivery from RTS features to Peel Plateau streams, and explore how this delivery varies with slump morphology;
- Determine how THg and MeHg concentrations downstream of slumps change with increasing distance from the site of disturbance, to better understand how slumping might affect stream water Hg at the landscape scale;
- Determine patterns in THg and MeHg concentrations throughout the thaw season; and
- Generate information about the relationship between slumping and Hg that is useful to local communities that use the Peel Plateau landscape, to enable community members to apply their land use decisions more confidently.

Introduction

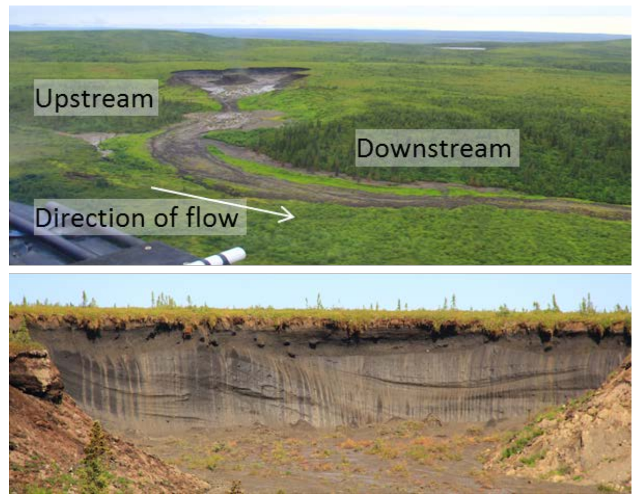
Low-Arctic landscapes continue to receive Hg generated by human activities, largely via atmospheric deposition following long-range transport from more southerly latitudes (Chételat and Braune 2012). During winter, atmospherically deposited Hg initially accumulates in snowpacks before being transferred to downstream water bodies during spring melt (St. Louis et al. 2007; K. St.Pierre, data in prep). However, meltwater and summer deposition (both wet and dry) can also cause Hg to be transferred to soils, where it can be archived for long periods if it subsequently becomes locked in permafrost. Understanding how the biogeochemical cycling of Hg is changing in northern regions as a result of global change is of particular interest because neurotoxic MeHg is known to bioaccumulate in organisms, and biomagnify as it makes its way up the food web. The resulting concentrations in upper trophic-level organisms can be high enough to be of concern to human health (e.g., Driscoll et al. 2013), an issue that is particularly pressing in the north, where consumption of upper trophic level organisms as country foods is common (Chan et al. 1995; Laird et al. 2013).

In the western Canadian Arctic, climate warming is intensifying the creation of RTS features, such as catastrophic thaw slumps that significantly increase the movement of permafrost-derived sediments from land to aquatic environments (e.g., Lantz and Kokelj 2008, Lacelle et al. 2010, Kokelj et al. 2013). RTS features are prevalent along a band that extends from the Arctic Ocean to near British Columbia's northern border, paralleling the maximum extent of the Laurentide Ice Sheet (Lacelle et al. 2004). These features occur in ice-rich, permafrost-affected regions, when massive ground ice degrades over sloping terrain. Under these conditions, ground ice thaw leads to slumping events that create a vertical headwall that can extend tens of meters in height, and an outwash plain that can cover an area of multiple hectares (Figure 1; Lacelle et al. 2010). The net result is the mobilization of up to thousands of cubic meters of permafrost-derived sediments over multiple decades, as a slurry that travels downslope towards valley-bottom streams (Kokelj et al. 2013; Lacelle et al. 2015).

We study the effects of RTS features on the Peel Plateau (Figure 2), where the considerable increase in slump activity has been tied to increasing sediment and ion loads in catchments as large as 1,100 km^2 (Stony Creek; Kokelj et al. 2013, Malone et al. 2013), and changing ionic composition within the downstream Peel River main stem (70,600 km^2 watershed area; Kokelj et al. 2013). Preliminary research in 2015 found that slumping leads to considerable increases in THg and MeHg downstream of slumps. Our work in 2016 sought to build upon these preliminary findings, by exploring temporal variation in THg and MeHg immediately downstream of slumps, and the degree to which the patterns we observe continue to persist downstream.

The Peel Plateau is within the traditional territory of the Tetlit Gwich'in (Fort McPherson). Waters of the 24,000 km^2 Plateau drain directly into the Peel River, which itself flows downstream to the Mackenzie Delta (Figure 2). The Peel Plateau region, the Peel River, and the Mackenzie Delta are all routinely used by residents of local communities for traditional hunting and fishing purposes. This includes use by several Gwitch'in communities, and downstream, residents of the Inuvialuit settlement region.

Figure 1: A typical slump on the Peel Plateau. Top panel: illustrates slump inflow to a Peel Plateau stream system, with upstream and downstream sampling sites indicated. Bottom panel: shows slump headwall detail, with the upper, Holocene-aged layer clearly visible. Both panels are from slump C.



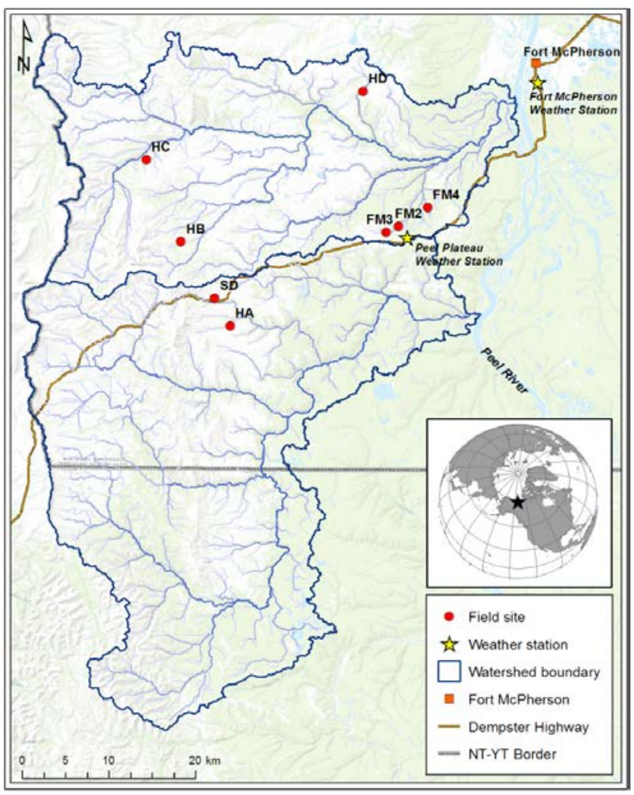
Activities in 2016-2017

During the summer of 2016, we collected time series and transect samples from a series of target slump features on the Peel Plateau. We also collected water chemistry samples to allow us to investigate biogeochemical drivers of the THg and MeHg patterns that we observed. Analyses for THg and MeHg are largely complete; water chemistry analyses are still underway. Our 2016-17 activities also incorporated the following components: capacity building, communications and traditional knowledge integration.

Capacity Building

Our research activities have allowed us to contribute to capacity building in northern communities, while also providing training opportunities for numerous southern students. Our work on the Peel Plateau always includes the involvement of local community members (see *Indigenous Knowledge*, below), which enables us to demonstrate sampling and preliminary processing techniques to the residents who join us in the field. Our work during the summer of 2016 also included the participation of three PhD students (Shakil and Zolkos, who are Peel Plateau specialists, and St. Pierre who is an Hg specialist), two undergraduate field research assistants (Guttmann and Stephen) and a laboratory assistant (Serbu) who assisted St. Pierre with THg and MeHg analyses at the University of Alberta.

Figure 2. Slump sites contained within the Stony and Vittrekwa watersheds of the Peel Plateau, NWT. During the summer of 2016, our work targeted slumps SC, SB, and SE.



Communications

As in past years, our group continues to take all available opportunities to communicate our research results to local community members. In part, this communication occurs through the involvement of community members as wildlife monitors and research assistants in our on-the-ground work. While a primary objective of wildlife monitor participation in our work is to guide our decisions about safe and respectful access to local Traditional Territory lands, having Fort McPherson residents directly involved in our field efforts provides an avenue through which our research results can be communicated back to the community, often in an informal way. Once we have completed the analysis of our results, we will also provide a formal report to Fort McPherson residents.

In addition, we have presented the results of our 2016 research efforts at two international conferences, including the *American Geophysical Union Fall Meeting* and *Arctic Frontiers Conference*.

Indigenous Knowledge Integration

As discussed above, members of the community of Fort McPherson form a critical component of our research team. It is typical that a Fort McPherson community member will join our field group for each of our sampling excursions. While community members primarily act as wildlife monitors, they also routinely provide advice on the execution of our field campaign. For example, we will often incorporate community members' knowledge of slump activity to best assess sampling locations. Local knowledge about changing slump activity has been useful in a more general way to aid with our interpretation of research results.

Results

As in 2015, we continue to find that slump activity leads to substantial increases in THg and MeHg downstream of slumps. At slump C (SC), where we were able to collect repeated samples over time, total (unfiltered) THg was as much as 600-fold greater, and MeHg was as much as 4-fold greater, downstream of the slump when compared to the upstream, unimpacted location (Figure 3). However, this increase occurred almost entirely as a result of increases in the particulate fraction. Dissolved THg and MeHg both decrease downstream of SC, suggesting that adsorption onto particles may sequester Hg in the particulate form immediately downstream of slumps. The substantial increase in unfiltered THg at SC initiates at some point after our late-June sample. This mirrors trends in total suspended sediments (TSS), which indicate a significant increase in slump activity between the first and second sampling dates, and as much as a 400-fold increase in TSS downstream of slump C when compared to paired measurements from the upstream location (Figure 4).

Figure 3. Concentrations of unfiltered (left panels) and filtered (right panels) THg and MeHg, measured over time at slump C. Samples taken upstream of the slump are shown in blue; samples taken immediately downstream of the slump (inflow to the valley bottom stream) are shown in orange. Points show means (n = 2) ± 1 SD. Note the change in scale for the THg panels.

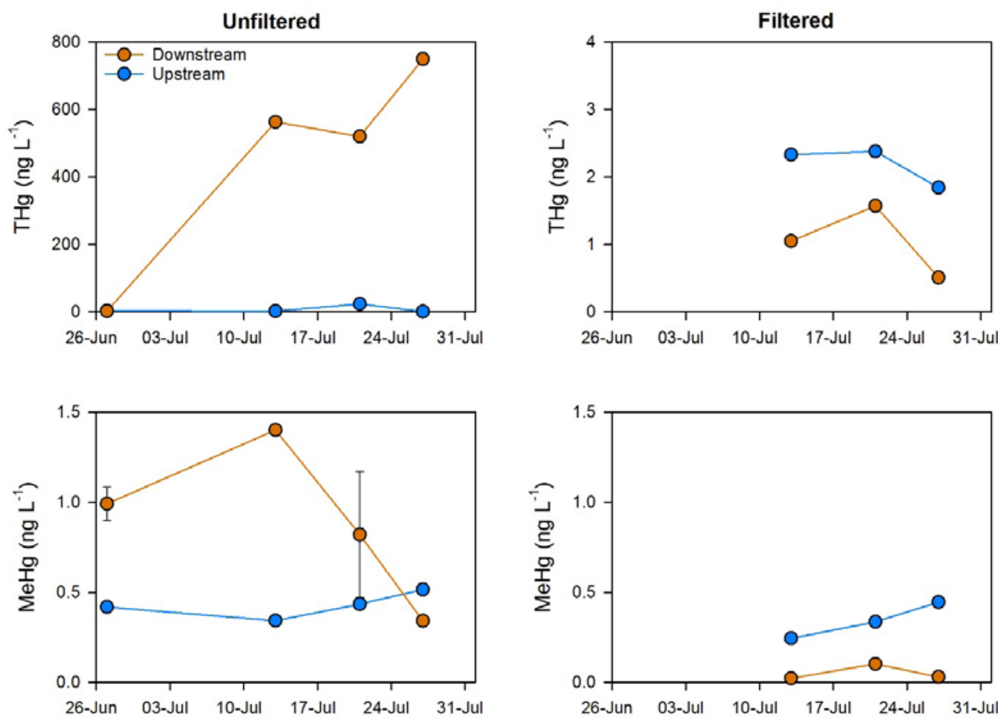
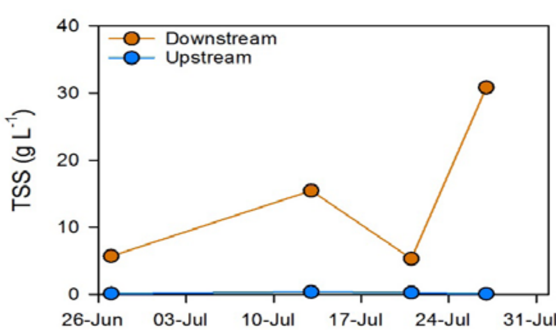


Figure 4. Concentrations of total suspended sediments (TSS) over time at slump C. Each point indicates a single measurement



We measured broader scape changes in Hg concentrations downstream of slumps B and E. These sites enable transects of several kilometers in length that are accessible by foot. At both sites, THg and MeHg were significantly elevated up to 3 km downstream of the slump. At Slump B, unfiltered THg and MeHg concentrations both continue to increase downstream, to the point of an inflow at ~2.65 km from the slump (Figure 5, top panel). Downstream of this inflow, unfiltered THg shows a clear dilution response, as expected from a concomitant decrease in TSS (data not shown). Unfiltered MeHg, however, increases from 1.5 to 15.5 ng•L^{-1}, suggesting that the catchment feeding this inflow stream is a site of active Hg methylation (e.g. contains a wetland). Similar to our findings from SC, both THg and MeHg occur overwhelmingly in the particulate phase throughout the below-slump portion of the SB transect, and show a clear sequestration response with dissolved THg and MeHg decreasing throughout the below-slump transect (Figure 5, bottom panel). Above the slump, 77% of THg and 33% of MeHg are found in the dissolved phase (calculated as filtered/unfiltered concentration). Below the slump, the dissolved phase never represents more than 3% of the unfiltered Hg measured.

At Slump E (SE) neither THg nor MeHg showed a strong response to the presence of the slump inflow during an early season (mid-June) survey (Figure 6). Slump activity was relatively modest at this time, as reflected by downstream concentrations of TSS (1.4 g•L^{-1}; data not shown). By mid-August, downstream TSS had increased to 46 g•L^{-1} (data not shown), following a significant increase in slump activity. The increase in slump activity was accompanied by substantially elevated concentrations of unfiltered THg and MeHg throughout the ~3 km downstream transect (Figure 6). Similar to other slumps, however, dissolved THg and MeHg concentrations were as much as 60% lower downstream of slumps than in the upstream location. Concentrations of THg and MeHg in streambed sediments (solid samples; Figure 6 bottom panel) were relatively consistent throughout the SE transect.

Figure 5. Concentrations of total (THg) and methyl (MeHg) upstream, and with consecutive distance downstream, of slump B. Top panel shows unfiltered concentrations; bottom panel shows filtered (dissolved) concentrations. Note the stream tributary inflow at 2.65 km downstream, as indicated on both panels. Samples were taken immediately upstream (2.64 km) and downstream (2.66 km) of this inflow point.

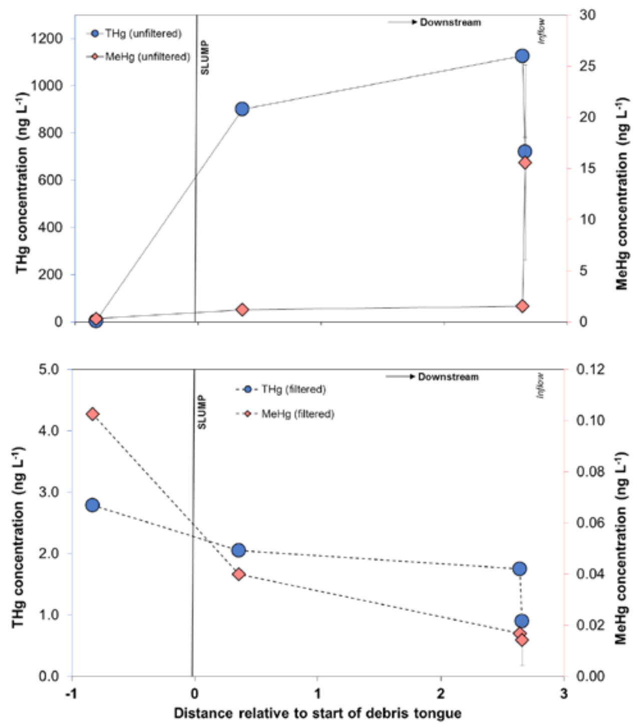
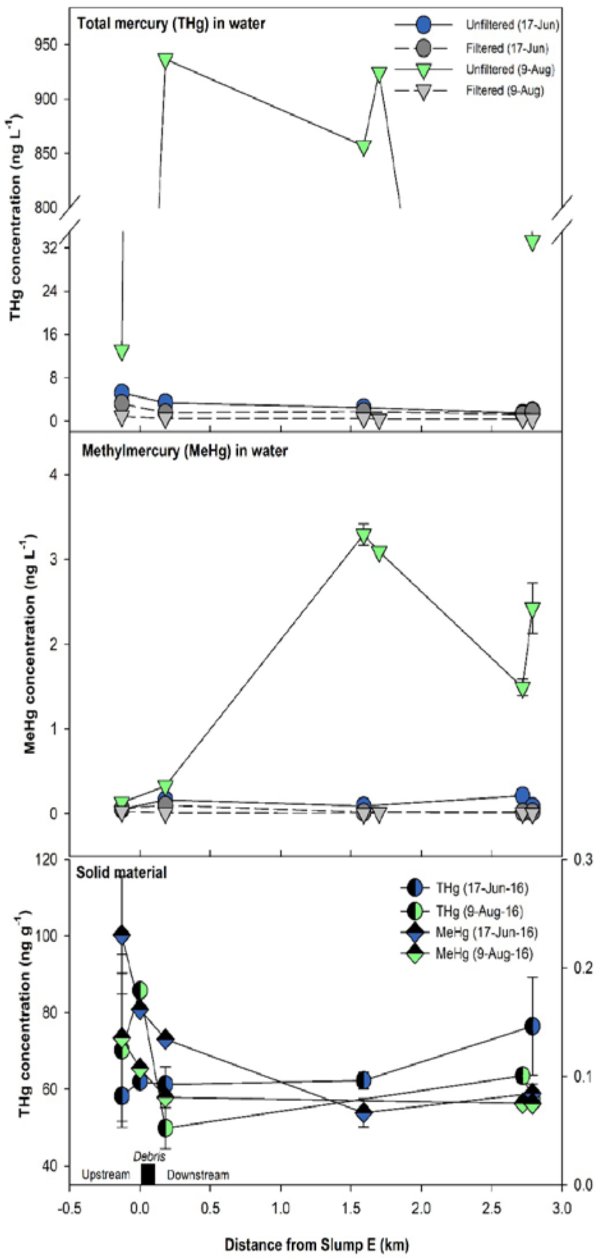


Figure 6. Concentrations of total (THg) and methyl (MeHg) mercury upstream, and with consecutive distance downstream, of slump E. Top panel shows unfiltered and filtered THg; middle panel shows filtered and unfiltered MeHg, bottom panel shows streambed concentrations.



Discussion and Conclusions

Concentrations of both THg and MeHg are substantially elevated downstream of slumps on the Peel Plateau. Although this effect can persist for several kilometres downstream, the increase in Hg is entirely due to Hg that is associated with particles. In the dissolved (filtered) fraction, both THg and toxic MeHg concentrations decline downstream of slumps. This suggests that the substantial mineral particles that are released by slumping facilitate THg and MeHg adsorption. Our results add to those seen for lakes in this region, where lakes with RTS features along their shorelines show increased inorganic sedimentation rates, which led to a dilution of THg and MeHg in lakebed sediments (Deison et al. 2012). On the Peel Plateau, although slumping is enabling THg and MeHg to become available for activity within contemporary biogeochemical cycles, it appears that much of this mercury may be unavailable – at least over the short term – for incorporation into food webs as a result of its particle-associated nature.

Expected Project Completion Date

We requested funding for one year only, and have not re-applied to NCP for the summer of 2017. We anticipate that results from this work will be published within 18 months of project completion. As discussed above in the *Activities* section, project results have already been presented at several conferences.

Acknowledgments

We will acknowledge NCP in a formal way in all presentations and other communications products (including papers) related to this work.

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Glacier and soil/permafrost thaw inputs of mercury and emerging organic contaminants to a pristine high Arctic watershed in Quttinirpaaq National Park, northern Ellesmere Island, Nunavut

Apports en mercure et en contaminants organiques émergents dus au dégel des glaciers, des sols et du pergélisol vers un bassin hydrographique vierge dans l'Extrême-Arctique, dans le parc national 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 concern. 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 Northern Contaminants Program funding has allowed us to quantify elevated winter atmospheric loadings and springtime runoff of total Hg (THg: all forms of Hg in a sample), methylmercury (MeHg: the toxic and bioaccumulating form of Hg) and PFASs to the pristine Lake Hazen high Arctic watershed in Quttinirpaaq National Park, Northern Ellesmere Island, Nunavut, as well as examine how that runoff changed concentrations of those contaminants in Lake Hazen during the important spring bloom of biological activity under the lake ice. Building off our work in summer 2015, we continued sampling glacier and soil/permafrost thaw inputs of Hg to this watershed in July-August 2016. 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 plus au sud et dans différents pays industrialisés dans le monde. Heureusement, la réglementation des émissions atmosphériques et les interdictions touchant l'utilisation de substances spécifiques ont permis de réduire les concentrations de certains contaminants hérités du passé dans l'Extrême-Arctique. Toutefois, bon nombre de contaminants comme le mercure et les polluants organiques persistants (POP) nouveaux, émergents et non encore réglementés, comme certains composés perfluoroalkyles et polyfluoroalkyles (PFAS), de même que 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, le devenir et la bioaccumulation des contaminants, comme le mercure et les POP, dans l'Arctique. Un récent financement du Programme de lutte contre les contaminants dans le Nord nous a permis de quantifier les charges atmosphériques élevées en hiver et le ruissellement printanier de mercure total (HgT : toutes les formes de mercure dans un échantillon), de méthylmercure (MeHg : les formes toxiques et bioaccumulables de mercure) et de PFAS vers le bassin hydrographique vierge du lac Hazen, dans l'Extrême-Arctique, dans le parc national du Canada Quttinirpaaq, au nord de l'île d'Ellesmere au Nunavut, ainsi que d'examiner la façon dont le ruissellement avait modifié les concentrations de ces contaminants dans le lac Hazen durant l'importante prolifération printanière d'activité biologique sous la glace du lac. Dans la foulée de nos travaux de l'été 2015, nous avons poursuivi notre échantillonnage des apports en mercure dus au dégel des glaciers, des sols et du pergélisol dans ce bassin hydrographique en juillet et août 2016. 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 à l'heure actuelle pour être en mesure de prévoir 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.

- Along a continuum that allowed us to quantify how soil/permafrost thaw water quality changes as it moves across the landscape prior to discharging into Lake Hazen, 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.

- MeHg concentrations were extremely low throughout the water column after the height of summer glacial melt and soil/permafrost thaw inputs, all of which were higher in MeHg concentration. THg concentrations throughout the upper water column after the height of summer glacial melt and soil/permafrost thaw inputs were also very low. However THg concentrations began to increase below 150 m depth in the lake, paralleling increases in turbidity, again suggesting that THg was of mineral origin and associated with particles transported by glacial rivers. Dense and turbid glacial runoff enters into Lake Hazen, and then plummets rapidly to the bottom of the lake.

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'eau de ruissellement des glaciers est fixée sur des particules ou d'origine minérale. Les concentrations de HgT et de MeHg comme telles ont augmenté avec la montée du débit des rivières et de l'intensité de l'érosion.

- Selon un continuum qui nous a permis de quantifier la façon dont la qualité de l'eau de fonte du pergélisol et des sols change à mesure que l'eau se déplace dans le paysage avant de se jeter dans le lac Hazen, nous avons constaté que les petits lacs et les 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 dans la phase dissoute et non fixée sur des particules, ce qui rend le MeHg beaucoup plus facilement biodisponible pour la bioaccumulation dans ces systèmes.

- Les concentrations de MeHg étaient extrêmement faibles partout dans la colonne d'eau après le pic des apports liés à la fonte estivale des glaces, des sols et du pergélisol, tous ayant des concentrations de méthylmercure plus élevées. Les concentrations de HgT étaient également extrêmement faibles partout dans la partie supérieure de la colonne d'eau après le pic des apports liés à la fonte estivale des glaces, des sols et du pergélisol. Cependant, les concentrations de HgT ont commencé à augmenter à plus de 150 m de profondeur dans le lac, parallèlement à l'augmentation de la turbidité, ce qui laisse supposer, encore une fois, que le HgT était d'origine minérale et associé à des particules transportées par les rivières glaciaires. Les eaux de ruissellement des glaciers denses et troubles se déverse dans le lac Hazen, pour ensuite descendre rapidement au fond du lac.

Objectives

The objectives of our 2016/17 project were four-fold:

- Quantify concentrations and loads of THg (all forms of Hg in a sample) and MeHg (the toxic and bioaccumulating form of Hg) in glacial runoff in a pristine high Arctic watershed;
- Quantify concentrations and loads of THg and MeHg in soil/permafrost thaw runoff in a pristine high Arctic watershed;
- Quantify THg and MeHg concentrations in a pristine high Arctic lake during the height of summer glacial melt and soil/permafrost thaw runoff into the lake;
- Quantify concentrations of THg, MeHg, emerging poly- and perfluorinated alkyl substances (PFASs) and organophosphorus flame retardants (OPFRs) priority contaminants into the base of the foodweb (zooplankton and midges) during the height of summer glacial melt and soil/permafrost thaw runoff into a pristine high Arctic lake, as well as the height of lake productivity.

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 (Chételat and Braune 2012; Muir et al. 2013). 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 (Chételat and Braune 2012; Muir et al. 2013). 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 (Chételat and Braune 2012; Muir et al. 2013). However, contaminants such as Hg, as well as new, emerging and yet unregulated PFASs, as well as OPFRs, continue to be of priority concern.

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 (Chételat and Braune 2012; Muir et al. 2013). Human-induced climate change is altering polar watersheds at unprecedented rates (Hassol 2004, Dicks, et al. 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 (Parry et al. 2007; Stocker et al. 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 (Parry et al. 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.

NCP funding in 2013 and 2014 permitted us to quantify winter atmospheric loadings and springtime runoff of THg, MeHg and 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. NCP funding in 2015 and 2016 has subsequently allowed us to quantify glacier and soil/permafrost thaw inputs of THg, MeHg, PFASs and OPFRs into a pristine high Arctic lake, and their impacts on lake water quality itself. We are currently integrating the results of these NCP projects (2013-2016) to construct annual watershed-scale mass balance budgets of THg, MeHg, PFASs, and OPFRs, and to better understand the impacts of climate change on contaminant cycling in High Arctic watersheds.

- Since 2013, we have used the Lake Hazen watershed, located within Quttinirpaaq National Park, northern Ellesmere Island, Nunavut, as a model research system. Studying the Lake Hazen watershed is ideal because:
- 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;
- 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 Derek Muir); this project will therefore provide added value to help interpret results from the char monitoring program;
- 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 records changes being imparted to an otherwise pristine environment that has been identified as part of our Canadian heritage.

The overall objectives of our most recent 2015-2017 research program were to examine the complex linkages between the deposition and biogeochemical cycling of contaminants (THg, MeHg, PFASs, and OPFRs) on glaciers and/or frozen soils and climate change in the high Arctic.

Activities in 2016-2017

We are currently integrating the results of the 2013-2016 NCP projects to construct annual watershed-scale mass balance budgets of THg, MeHg, PFASs, and OPFRs; and to better understand the impacts of climate change on contaminant cycling in High Arctic watersheds. Two manuscripts describing these results are currently in preparation for submission to peer-reviewed journals.

Research

We are pleased to report that we have made significant progress on all of the four specific objectives outlined for the 2016-2017 year. We were at the Lake Hazen basecamp, Quttinirpaaq

National Park, between 29 June and 11 August 2016. During this time, we conducted weekly samplings of two glacial rivers and a small permafrost-fed freshwater continuum within walking distance of the basecamp to assess temporal variation within these systems. We sampled six additional rivers twice (11-13 July and 1-2 August) by helicopter. Extending from our 2015 results, we also conducted Hg methylation/demethylation experiments in water samples and sediment cores from Skeleton Lake and the downstream wetland complexes, which we previously hypothesized were areas of active Hg methylation and demethylation. Unsafe ice conditions prevented us from being able to complete a full water column profile or zooplankton sampling in 2016; however, we were able to sample 3 depths within the water column (0, 25, 250 m) to corroborate with our results obtained in 2015. In the results section below, we describe the specifics of the summer sampling program and discuss our initial interpretations of our exciting results.

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 six 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 we actively engaged with Adam Ferguson and Cynthia Pialaq (seasonal employee, Parks Canada, Quttinirpaaq National Park) about 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 northern scientific project. Adam was raised in Pond Inlet and currently resides in Thunder Bay, where he is attending Lakehead University. Cynthia currently resides in Iqaluit, where she is a student at Nunavut Arctic College.
- On April 4th 2016, St. Pierre and Aukes delivered a one-day field training session in chemical and physical limnology (including contaminant sampling) in collaboration with Jamal Shirley (Nunavut Research Institute) for 2nd year students at Nunavut Arctic College's Environmental Technology Program in Iqaluit. St. Pierre and Aukes later met with Jamal Shirley and Daniel Martin (Nunavut Arctic College) about the analytical requirements of developing a community-based freshwater quality monitoring program around Iqaluit. Samples students collected during the field session were analyzed at the University of Alberta's Biogeochemical Analytical Service Laboratory (BASL). Chemistry results have been forwarded to the Nunavut Research Institute (NRI) and Arctic College for use in subsequent course teaching and/or possible monitoring program development.

Communications

- A Parks Canada field research report was completed (including translation into Inuktitut) in October 2016.
- De Silva (2015 proposal) presented a poster presentation on PFA concentrations in the Lake Hazen watershed at the SETAC World Congress in November 2016 in Orlando, Florida, USA.
- Lehnherr and Varty presented the results of the Skeleton Lake/pond methylation experiments in a poster presentation at the 12th ArcticNet Annual Scientific Meeting in December 2016 in Winnipeg, MB.
- St.Louis presented the Lake Hazen climate change story, which included sediment Hg fluxes, at the American Geophysical Union (AGU) conference in December 2016 in San Francisco, California.
- St. Pierre presented Hg results from the glacial rivers and Lake Hazen at the Arctic Frontiers Conference in January 2017 in Tromsø, Norway.

- St. Louis, Lehnherr, St. Pierre, and Varty have submitted abstracts for presentations at the International Conference on Mercury as a Global Pollutant, scheduled for July 2017 in Providence, Rhode Island, USA.

Traditional Knowledge Integration

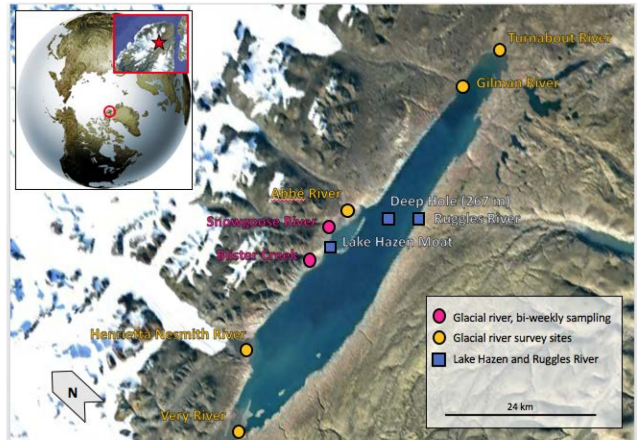
Parks Canada utilizes the TK of members of the Joint Parks Management Committee to guide their decisions and practices in northern National Parks. Also, with a goal of 80% Inuit employees, Parks Canada hopes that TK is shared amongst staff, and that their actions are reflected in this. Our activities 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 and MeHg in glacial runoff in a pristine high Arctic watershed

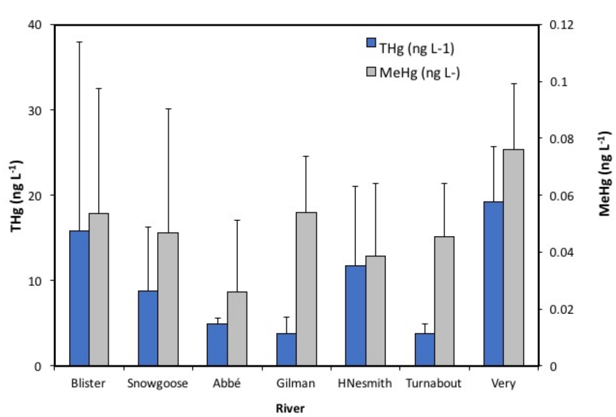
Glacial runoff in the Lake Hazen watershed from late June to August represents the dominant annual hydrological event. Approximately 16 sub-catchments have been historically identified in the watershed that drains into Lake Hazen. Weekly from 2 July to 10 August, we sampled two rivers within walking distance of the Lake Hazen base camp (Blister Creek and the Snowgoose River; Figure 1). We sampled an additional 5 glacial rivers (Very, Abbe, Turnabout, Gilman, Henrietta Nesmith), as well as the Ruggles River outflow by helicopter twice during the summer. Three-site transects, extending from the glacier to the river delta, were completed on the Gilman and Snowgoose Rivers. Three sites along the Ruggles River, extending from Lake Hazen to Chandler Fjord, were also sampled to quantify Ruggles River exports to the nearshore marine environment. On 11-13 July, this effort was coordinated with Parks Canada staff who concurrently sampled the Very, Abbe, and Turnabout as part of their annual survey. All sites were sampled again on 1-2 August to assess temporal variability in chemistry in each of these rivers.

Figure 1. The major glacial melt rivers flowing into Lake Hazen that we sampled. The Ruggles River is the lake outflow.



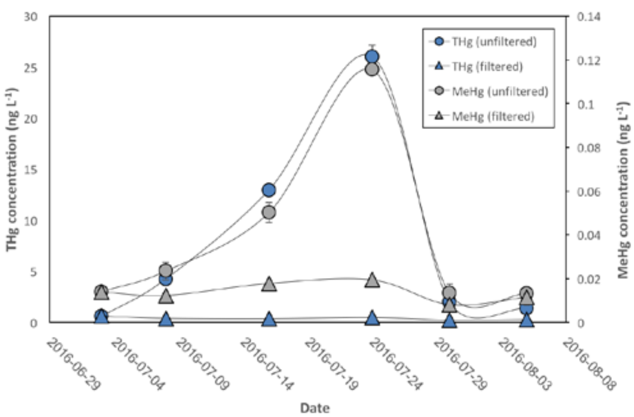
We found that average unfiltered MeHg concentrations ranged from 0.026 ng•L^{-1} in the Abbe River to 0.076 ng•L^{-1} in the Very River (Figure 2), whereas average unfiltered THg concentrations ranged between 3.8 ng•L^{-1} in the Gilman River to 19 ng•L^{-1} in the Very River (Figure 3). Filtered (dissolved) MeHg concentrations were much lower and fairly consistent among the different rivers (< 0.007-0.016 ng•L^{-1}), suggesting that a significant portion of the MeHg in glacial runoff is particle bound. Similarly, filtered THg concentrations were much lower and fairly consistent among the different rivers (0.33-0.50 ng•L^{-1}), suggesting that the majority of the THg in glacial runoff is mineral in origin.

Figure 2. Unfiltered concentrations of THg and MeHg in glacier-fed rivers (mean for 2015-2016 ± 1 SD).



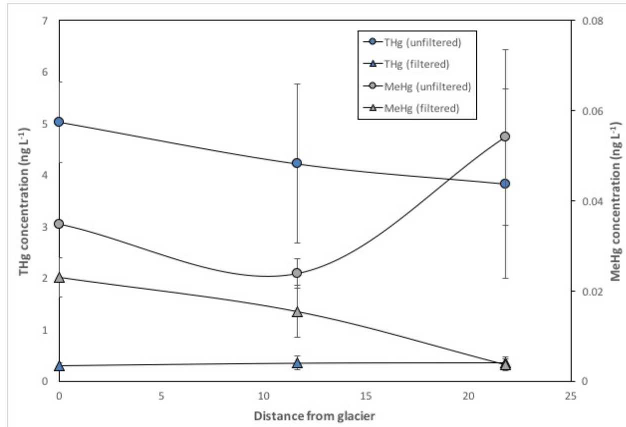
The Snowgoose River and Blister Creek River were sampled six times during the summer of 2016 to examine changes in contaminant concentrations with changing river flows. In 2016, we arrived earlier (29 June) and stayed later (10 August) than in 2015 to better capture variability throughout the melt season. These two rivers are representative of larger and smaller glacially-fed inflow rivers, respectively. In the Snowgoose River for example, unfiltered MeHg concentrations increased from ~0.014 ng•·L^{-1} to ~0.115 ng•L^{-1} at the height of glacial river runoff, but then declined to concentrations of ~0.013 ng•L^{-1} as air temperatures cooled off and river flow decreased (Figure 3). Filtered MeHg concentrations were consistently low at ~0.010 ng•L^{-1} in both rivers (Figure 3), suggesting that a large portion of the MeHg in the rivers was particle bound.

Figure 3. Unfiltered and filtered THg and MeHg concentrations in the Snowgoose River delta throughout summer 2016.



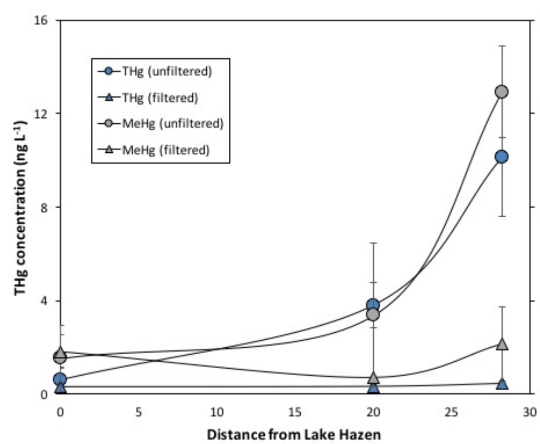
To determine whether the Hg entering Lake Hazen was from the glaciers themselves or from the proglacial area, we completed transects by helicopter on the Snowgoose River and Gilman River. For simplicity, only the results from the transects along the Gilman River are shown (Figure 4). In both rivers, neither THg nor MeHg concentrations changed significantly with increasing distance from the glacier, suggesting that most of the Hg originated from the glacier itself. Partitioning between the bulk and dissolved phases of THg did not change over space; however, MeHg became increasingly particulate-bound downstream, possibly reflecting adsorption of dissolved MeHg onto fine sediments.

Figure 4. Unfiltered and filtered THg and MeHg concentrations along the Gilman River (means of 2 samplings shown).



Both unfiltered and filtered concentrations of MeHg (0.01 ng•L^{-1} and <0.007 ng•L^{-1}) and THg (0.60 ng•L^{-1} and 0.29 ng•L^{-1}) at the Lake Hazen outflow to the Ruggles River were lower than any of the concentrations in the inflow rivers, suggesting that a combination of sedimentation, dilution and photoreduction is occurring within the lake. Concentrations of both THg and MeHg increase downstream of Lake Hazen (Figure 5), likely reflecting erosional inputs.

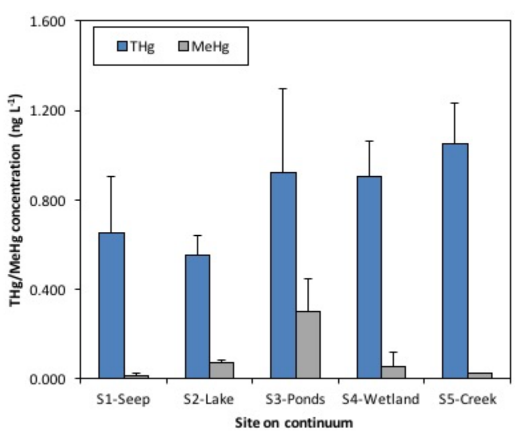
Figure 5. Unfiltered and filtered THg and MeHg concentrations along the Ruggles River (means of 2 samplings shown).



Objective 2. Quantify concentrations and loads of THg and MeHg in soil/permafrost thaw runoff in a pristine high Arctic 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: (i) distinct thaw seepage sites, (ii) through Skeleton Lake, (iii) two smaller ponds, (iv) *Carex* grass dominated wetlands, and (v) 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 (Figure 6). Unfiltered MeHg concentrations increased as water moved through Skeleton Lake (0.072 ng•L^{-1}) and two downstream ponds (0.303 ng•L^{-1}) (Figure 6), indicating active microbial Hg methylation occurred in both these sites. 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 ~0.025 ng•L^{-1} (Figure 6), suggesting that MeHg was either sequestered or demethylated in these latter sites of the landscape continuum.

Figure 6. 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 (means from 2015, 2016 shown).

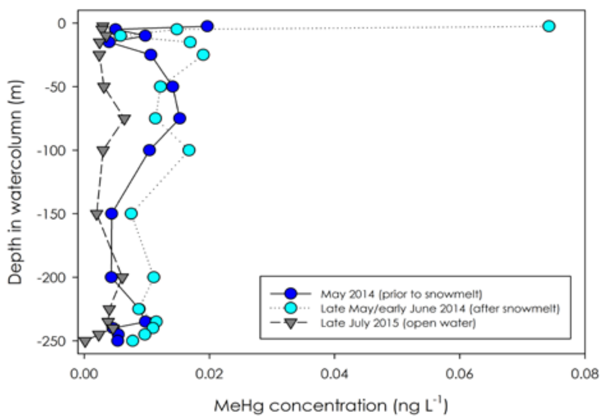


We further investigated the methylation and demethylation potentials of Skeleton Lake, the downstream ponds and the wetland by conducting tracer experiments using Hg standards enriched in stable isotope of Hg (Hg^{198} as methylation tracer and $Me^{199}Hg$ as demethylation tracer). Results from these experiments are still being processed.

Objective 3. Quantify THg and MeHg concentrations in a pristine high Arctic lake during the height of summer glacial melt and soil/permafrost thaw runoff into the lake

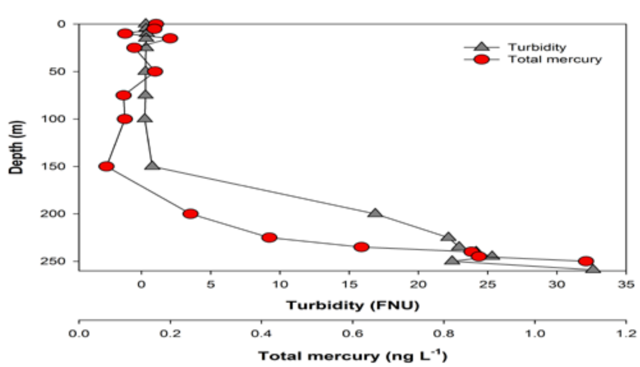
To determine the impact of glacial and soil/permafrost thaw runoff on contaminant loadings to Lake Hazen, we strategically sampled the ice-free Lake Hazen water column, building off of results from 2013-2015 (Figure 7). Due to sustained periods of inclement weather, we were unable to resample the whole water column as per our original plan, so 3 depths (0 m, 15 m – the chlorophyll maximum, 250 m) were strategically selected. 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 7). As in 2015, MeHg concentrations were extremely low (<0.007 ng•L^{-1}) throughout the water column after the height of summer glacial melt and soil/permafrost thaw inputs. Furthermore, these inputs all had higher MeHg concentrations than those found in the Lake Hazen water column.

Figure 7. 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 7). However, THg concentrations began to increase below 150 m, reaching concentrations of 0.648 ng•L^{-1} (1.1 ng•L^{-1} in 2015, a higher melt year) near the bottom (Figure 8). Increases in THg concentrations paralleled increases in turbidity, again strongly suggesting that THg was of mineral origin. Dense and turbid glacial runoff enters the shorelines of Lake Hazen, and then plummets rapidly to the bottom of the lake.

Figure 8: Unfiltered concentrations of THg and turbidity throughout the water column of Lake Hazen during the mostly open water period after the height of summer glacial melt and soil/permafrost thaw (late July 2015).



Objective 4. Quantify concentrations of THg, MeHg, emerging poly- and perfluorinated alkyl substances (PFASs) and organophosphorus flame retardants (OPFRs) priority contaminants into the base of the foodweb (zooplankton and midges) during the height of summer glacial melt and soil/permafrost thaw runoff into a pristine high Arctic lake, as well as the height of lake productivity

Zooplankton samples collected in 2015 were analyzed for MeHg in 2016. Unlike in 2015, there was no substantial midge emergence around Lake Hazen, which precluded our ability to sample them.

Discussion and Conclusions

In 2015, several questions arose from our sampling campaign further to our main objectives, which we investigated in 2016:

a. The summer of 2015 was exceptionally warm at Lake Hazen, resulting in elevated watershed runoff into the lake. *What would contaminant concentrations be in glacial melt and soil/permafrost thaw runoff in either a cooler or even warmer summer?*

   Despite the summer of 2016 being the warmest summer on record, glacial melt in the Lake Hazen watershed was approximately one third of the total in 2015 (0.281 Gt vs. 0.948 Gt). Overall, pooled concentrations of THg and MeHg did not vary substantially between 2015 and 2016; however, the effect of the years varied depending on the system. Although the concentrations overall did not change, the meltwater volume-dependent fluxes of THg and MeHg did, with substantially more THg (15 Gt vs. 3.4 Gt) and MeHg (0.38 Gt vs. 0.11 Gt) input to the lake in 2015 than in 2016.

b. As we left Lake Hazen in early August 2015, 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? What are contaminant concentrations in early season glacial melt and soil/permafrost thaw runoff when recent deposition dominates their melt water source?*

In 2016, we arrived earlier (first sampling 2 July) and stayed later (10 August) than in 2015. In 2016, we were therefore able to capture much lower concentrations of Hg at the start and end of the melt season, than in 2015. We confirmed that Hg concentrations in glacier-fed rivers reach their peak at the height of glacial run-off in mid to late July. This, combined with the fact that THg/MeHg concentrations varied little over the length of the glacial rivers (see *Results*), suggests that Hg inputs seem to reflect the volume of meltwater coming off the glaciers, rather than the age of the glacial deposits melting. Concentrations of THg and MeHg varied little over the summer along the permafrost thaw continuum.

c. *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?*

   There was little variation in THg or MeHg in the Abbé and Turnabout Rivers either between 2015 and 2016, or between the July and August samplings in 2016. In contrast, Very River THg concentrations fluctuated between 12 $ng•L^{-1}$ and 22 $ng•L^{-1}$ in July and August 2016, respectively. Equally dramatic were the fluctuations in THg at the Henrietta Nesmith River: 21 $ng•L^{-1}$ in 2015 to 11 $ng•L^{-1}$ in July 2016 and 2.9 $ng•L^{-1}$ in August 2016. Using other data collected during these surveys, we are currently investigating the physical and chemical controls on THg and MeHg in the various glacial subwatersheds.

d. 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?*

   In 2016, we were able to isolate enough suspended sediments from water samples in 7 glacial river samples to analyze for THg, and in 2 river samples to analyze for MeHg. Sediment THg concentrations ranged between 11 $ng•g^{-1}$ (Blister Creek) and 100 $ng•g^{-1}$ (Very River), while MeHg concentrations ranged between 0.042 and 0.11 $ng•g^{-1}$ in the Snowgoose River and the Gilman River, respectively. We have subsequently conducted carbon stable isotope analyses on these particles to discern their origin and as expected, the sediments within the rivers, are largely mineral. We also opportunistically sampled other forms of solid materials in the rivers, including a complex foam matrix found floating on Lake Hazen and in the Gilman River, as well as coal deposits along Blister Creek and the Gilman River. THg and MeHg concentrations in the partially organic foam were very high: 431-517 $ng•g^{-1}$ and 0.68-1.9 $ng•g^{-1}$, respectively. Due to low volumes, we believe this foam to constitute a very minor source of Hg to Lake Hazen. Concentrations of THg and MeHg in coal samples ranged from 7.1-94 $ng•g^{-1}$, and 0.016-0.036 $ng•g^{-1}$, respectively.

e. 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?*

   We conducted Hg stable isotope tracer experiments on water and core samples collected from various locations along the Skeleton Continuum. Results from these experiments are still being processed.

As described above, 2016 was an incredibly productive year. We are currently synthesizing the data collected as part of NCP-funded projects from 2013-2016 and hope to have two manuscripts submitted for publication in peer-reviewed journals by the end of 2017. By combining the data from 2013-2016, we will construct mass balance budgets for THg and MeHg, and organic contaminants (2013-2015), for the Lake Hazen watershed. We hope that this will shed some light on the impacts of climate change on contaminant cycles in high arctic freshwater environments.

Expected Project Completion Date

We expect to fully complete this project by December 2017.

Project website

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.

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Sources of methylmercury, perfluoroalkyl substances, and polychlorinated biphenyls to ringed seal food webs of Lake Melville, Northern Labrador

Sources de méthylmercure, de substances perfluoroalkyliques et de biphényles polychlorés des réseaux trophiques du phoque annelé du lac Melville dans le nord du Labrador

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Abstract

People living on Lake Melville are concerned about contaminant levels in country foods they harvest, especially methylmercury (MeHg: the toxic form of mercury that biomagnifies through food webs), and projected increases in methylmercury resulting from hydroelectric power development on the Churchill River. Lake Melville is also a unique Arctic site to study because it is affected by both river and ocean water and it has a history of polychlorinated

Résumé

Les riverains du lac Melville se préoccupent des concentrations de contaminants dans les aliments qu'ils récoltent dans la nature, en particulier du méthylmercure (MeHg : la forme toxique du mercure qui se bioamplifie à travers les réseaux trophiques) et des augmentations prévues de méthylmercure résultant des activités de développement hydroélectrique sur le fleuve Churchill. En outre, le lac Melville est un lieu d'étude unique de l'Arctique parce

biphenyl (PCB) contamination from local sources, such as the Goose Bay air base. We are utilizing combined analyses of mercury, methylmercury, carbon and nitrogen stable isotopes with perfluorinated alkyl substance (PFAS) and PCB congener analyses, to identify the relative importance of local versus regional and terrestrial versus marine contaminant sources to Lake Melville ringed seal food webs prior to hydroelectric development and further climate-induced alterations.

71 seal samples were collected during harvests by local hunters during 2013-2016 and were analyzed for mercury, methylmercury and mercury stable isotopes. A subset of these samples was analyzed for PFASs and PCBs. Average MeHg concentrations in the liver and muscle of Lake Melville seals were 150 ± 205 and 119 ± 145 ng•g^{-1} wet weight (ww), respectively, with 14 of 71 liver samples and 10 of 71 muscle samples surpassing the Canadian frequent consumer guideline of 200 ng•g^{-1} ww. Average Hg concentrations in Lake Melville ringed seals are lower than those recently reported for 14 communities across the Canadian Arctic, likely because seals sampled to date are mostly pups. Hg concentrations are comparable to those recently reported in pups at other Labrador locations. Results from Hg stable isotope analyses demonstrate that Lake Melville seals obtain food from both inland and marine sources. PFAS concentrations in Lake Melville pups are higher than those in Greenland and PFAS show an annual increasing trend from 2013 to 2016 in contrast to PFAS temporal trends in marine mammals from other areas of the Canadian Arctic. We are continuing this project in 2017-2018 so that adult seals can be sampled and analyzed for the full suite of contaminants, as well as seal health markers, which will strengthen the baseline dataset. Results will be used to assess the impacts of the hydroelectric power developments on wildlife used for food by people of the region and to predict the impacts of the 22 hydro-electric power developments planned across Canada.

qu'il est touché à la fois par les eaux fluviales et océaniques et parce qu'il a un historique de contamination aux BPC à partir de sources locales, comme la base aérienne de Goose Bay. Nous nous servons des analyses combinées des isotopes stables du carbone et de l'azote, du mercure, du méthylmercure et des analyses des substances perfluoroalkyliques (PFAS) et des congénères de BPC, afin de déterminer l'importance relative des sources de contaminants locales par rapport aux sources régionales et des sources terrestres par rapport au sources marines pour les réseaux trophiques du phoque annelé du lac Melville avant les activités de développement hydroélectrique et autres changements d'origine climatique.

Soixante-et-onze échantillons ont été prélevés chez les phoques par les chasseurs locaux de 2013 à 2016, et ils ont été analysés en vue de détecter du mercure, du méthylmercure et des isotopes stables de mercure. Un sous-ensemble de ces échantillons a été analysé en vue de détecter des PFAS et des BPC. Les concentrations moyennes de méthylmercure dans le foie et les muscles des phoques du lac Melville étaient de 150 ± 205 et 119 ± 145 ng•g^{-1} (poids humide), respectivement, dans 14 des 71 échantillons de foie et dans 10 des 71 échantillons de muscles, dépassant les directives canadiennes en matière de fréquence de consommation de 200 ng•g^{-1} (poids humide). Les concentrations moyennes de mercure chez le phoque annelé du lac Melville sont inférieures à celles signalées récemment pour 14 collectivités dans l'ensemble de l'Arctique canadien, très probablement parce que les phoques échantillonnés à ce jour sont pour la plupart des nouveau-nés. Les concentrations de mercure sont comparables à celles récemment signalées chez les nouveau-nés à d'autres emplacements au Labrador. Les résultats des analyses des isotopes stables de mercure démontrent que les phoques du lac Melville obtiennent leur nourriture à partir de sources intérieures et marines. Les concentrations de PFAS chez les nouveau-nés du lac Melville sont supérieures à celles relevées au Groenland. De plus, les concentrations de PFAS affichent une tendance annuelle à la hausse de 2013 à 2016, contrairement aux tendances temporelles de concentrations de PFAS chez les mammifères marins d'autres régions de l'Arctique canadien. Nous poursuivons ce projet en 2017-2018 afin de prélever des échantillons chez les phoques adultes et de les analyser en vue de détecter une gamme complète de contaminants, ainsi que des marqueurs de l'état de santé des phoques, ce qui renforcera les ensembles de données de référence. Les résultats serviront à évaluer les répercussions des activités de développement hydroélectrique sur la faune utilisée à des fins alimentaires par les habitants de la région et à prévoir les incidences des 22 projets d'aménagements hydroélectriques prévus dans l'ensemble du Canada.

Key Messages

- People living on Lake Melville are concerned about contaminant levels in country foods, such as ringed seals, that they harvest. They are particularly concerned about methylmercury and predicted increases in methylmercury resulting from hydroelectric power development on the Churchill River.
- This project analyzes mercury, methylmercury, carbon and nitrogen stable isotopes, perfluorinated alkyl substances, and polychlorinated biphenyl in the Lake Melville food web, including ringed seals.
- Information from the project allows the researchers to determine the relative importance of local versus regional, and terrestrial versus marine contaminant sources to Lake Melville ringed seal food webs prior to hydroelectric development and further climate-induced alterations.
- Average methylmercury concentrations in the liver and muscle of Lake Melville seals (mostly pups <1 year in age) were 150 ± 205 and 119 ± 145 ng•g^{-1} wet weight, respectively, and are comparable to those recently reported in pups at other Labrador locations.
- PFAS concentrations in Lake Melville pups are higher than those in Greenland. In addition PFAS show an annual increasing

Messages clés

- Les riverains du lac Melville se préoccupent des concentrations de contaminants dans les aliments qu'ils récoltent dans la nature, tels que le phoque annulé. Ils s'inquiètent plus particulièrement du méthylmercure et des augmentations prévues de méthylmercure résultant des activités de développement hydroélectrique sur le fleuve Churchill.
- Le présent projet mène des analyses des isotopes stables du carbone et de l'azote, du mercure, du méthylmercure, des substances perfluoroalkyliques et des BPC dans le réseau trophique du lac Melville, y compris chez le phoque annelé.
- Les résultats du projet permettent aux chercheurs de déterminer l'importance relative des sources de contaminants locales par rapport aux sources régionales et des sources terrestres par rapport aux sources marines pour les réseaux trophiques du phoque annelé du lac Melville avant les activités de développement hydroélectrique et autres changements d'origine climatique.
- Les concentrations moyennes de méthylmercure dans le foie et les muscles des phoques du lac Melville (principalement des petits de moins d'un an) étaient de 150 ± 205 et 119 ± 145 ng•g^{-1} (poids humide), respectivement, et sont comparables à celles récemment

trend from 2013 to 2016 in contrast to PFAS temporal trends in marine mammals from other areas of the Canadian Arctic.

- Results from this project will be used to assess the impacts of the hydroelectric power developments on wildlife used for food by people of the region.

signalées chez des nouveau-nés à d'autres emplacements au Labrador.

- Les concentrations de PFAS chez les nouveau-nés du lac Melville sont supérieures à celles relevées au Groenland. De plus, les concentrations de PFAS affichent une tendance annuelle à la hausse de 2013 à 2016, contrairement aux tendances temporelles des concentrations de PFAS chez les mammifères marins d'autres régions de l'Arctique canadien.

- Les résultats issus de ce projet serviront à évaluer les répercussions des activités de développement hydroélectrique sur la faune utilisée à des fins alimentaires par les habitants de la région

Objectives

- Differentiate among global versus local and terrestrial versus marine sources of methylmercury, perfluoroalkyl substances (PFASs) and polychlorinated biphenyls (PCBs) to ringed seals using analyses of carbon, nitrogen, mercury stable isotopes, and PFASs and PCBs congeners in ringed seal tissues.

- Determine concentrations of methylmercury, PFASs and PCBs in ringed seals of Lake Melville, Northern Labrador before further climate-induced changes and reservoir creation for hydroelectric power development take place in the region.

- Examine the bioaccumulation and biomagnification of PFASs in the Lake Melville ringed seal food web by analyzing water, plankton, fish, and other food web samples.

- Communicate results to each participating community, the Nunatsiavut Health and Environment Research Committee, and to the NCP project on "Lake Melville and Labrador Inuit: Understanding and Projecting Human Health Implications of Exposure to Local and Long-Range Mercury Sources".

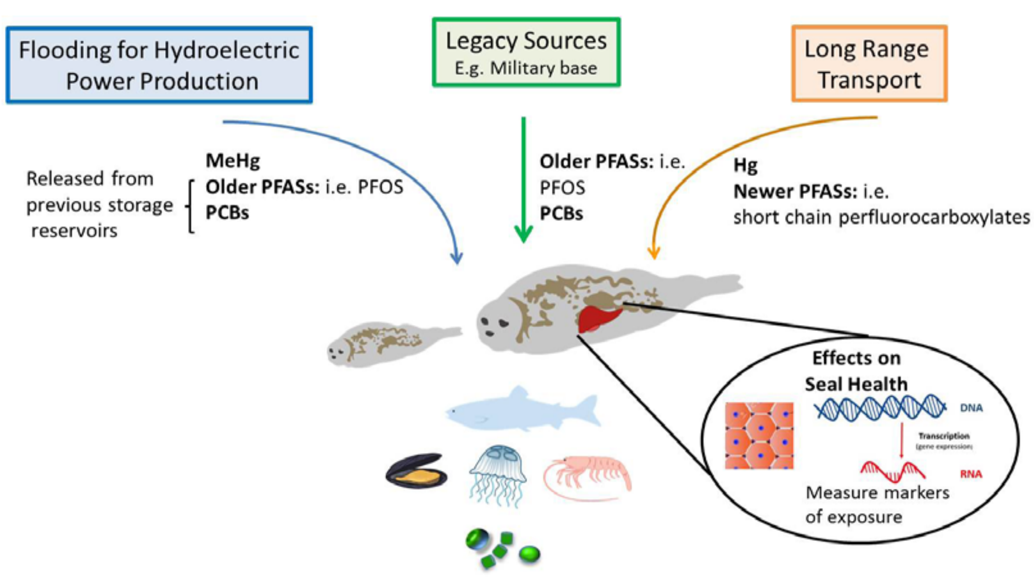
Introduction

Lake Melville in Northern Labrador is an estuarine fjord and is an important source of country foods, such as fishes and ringed seals, to the numerous communities along its shoreline, including Rigolet, North West River, Happy Valley-Goose Bay, and Mud Lake. People living on Lake Melville are concerned about contaminant levels in country foods they harvest, particularly methylmercury (MeHg), and the projected increases in MeHg originating from past and future hydroelectric power development on the Churchill River. In addition to mercury (Hg) and MeHg, other contaminants of potential concern in the region include "new" synthetic chemicals such as perfluoroalkyl substances (PFASs) and legacy contaminants, such as polychlorinated biphenyls (PCBs), which could be re-mobilized from flooding for hydroelectric power production.

In addition to local environmental changes from hydroelectric power production, Lake Melville is also experiencing regional environmental changes due to climate change including temperature increases and changing ice conditions including later freeze up, earlier melt, and decreased ice thickness. Climate induced changes can alter contaminant cycling as well as feeding and reproduction behaviors, which can impact trophic position and thus contaminant levels in top predators. Lake Melville is an ecosystem at the crossroads of numerous environmental stressors and is an ideal site to track contaminants with differing local versus global sources, transport pathways, and biomagnification processes in a key traditional food species.

In this project, we are utilizing combined analyses of Hg, MeHg, carbon and nitrogen stable isotopes with PFAS and PCB congener analyses, to identify the relative importance of local versus regional and terrestrial versus marine contaminant sources to Lake Melville ringed seal food webs prior to hydro-electric power development and further climate-induced alterations to contaminant cycling in this region (Figure 1). Contaminants can be found at high enough concentrations in Canadian Arctic wildlife to impact biological pathways, which can be examined using genomic tools. We are therefore utilizing relationships between liver levels of MeHg, PFAS, and PCB of Lake Melville ringed seals and selected genomic and cellular responses related to biological pathways of interest (e.g., immunity, stress responses). We have recently secured funding for 2017-18 to continue this project, which we aim to continue over the long-term, as this site presents a rare opportunity to obtain high quality pre- and post-impact data in a region affected by multiple environmental stressors. In fact, we hypothesize that the source signatures of MeHg, PFASs, and PCBs in Lake Melville ringed seal food webs will dramatically change after flooding for hydro-development. Findings from this project

Figure 1. Overview of the project. Contaminants with varying sources and chemical properties (Hg, PFASs, and PCBs) are being quantified in Lake Melville ringed seals and the impact of contaminant exposure on ringed seal health is being assessed. Hg, carbon, and nitrogen stable isotopes and PFAS and PCB congener analyses are being used to determine the relative contribution of potentially important sources (reservoir creation for hydroelectric power development, legacy sources, and long range atmospheric and oceanic transport) to ringed seal contaminant burdens. The complete Lake Melville food web is also being analyzed for PFASs because the potential biomagnification of these chemicals through a complete Arctic food web has never been examined which represents a gap in our understanding of the potential health impact of these chemicals on Arctic organisms.



will be useful for predicting the impacts of the 22 Canadian planned hydro-electric power developments on food web organisms used for food by Northern peoples at other locations.

Activities in 2016-2017

As part of this project and earlier work by Sheldon and collaborators, sampling of the Lake Melville ringed seal population was carried out by local harvesters with support from Nunatsiavut Government staff during 2013-2016. Muscle, liver, blubber, kidney, stomach, and jaws were sampled from 71 individuals (n=15-20 per year) following protocols developed by the NCP Core Monitoring project on "Temporal trends of persistent organic pollutants and metals in ringed seals from the Canadian Arctic". Information on biological data was recorded, including length, axial and maximum girth, gender, and blubber thickness. All 71 seal liver and muscles have now been analyzed for total Hg (THg; all forms of Hg in a sample), MeHg, and Hg stable isotopes. 40 seals were selected and analyzed for PFASs; 20 of these 40 samples were selected for PCB analyses and blubber sub-samples were analyzed by ALS Global. Samples from all 71 seals have also been analyzed for aging (canine tooth), and carbon and nitrogen stable isotopes (freeze dried muscle sub-sample).

As part of 2013-2015 work focusing on Hg, some of which has been presented in Schartup et al. 2015, Li et al. 2016, and Calder et al. 2016, key fish species (cod, Northern pike, and Arctic Char) and some food web samples were also collected. A subset of fish samples have now been analyzed for PFASs in the Sunderland lab at Harvard and a subset of samples is being selected for further analyses. Previous plankton collections were not large enough to analyze Hg, carbon and nitrogen stable isotopes and PFASs. In August 2016, we therefore sampled the base of the food web (i.e., plankton) at 6 Lake Melville sites and analyzed it for THg, MeHg, Hg isotopes and PFASs as well as carbon and nitrogen isotopes so that food web δ^{15}N values can be baseline corrected. This information will also allow comparison of Hg, PFASs, and PCBs concentrations in ringed seals from Lake Melville to those from Nain and other Arctic locations. In addition, the δ^{15}N in plankton will allow us to assign seals to a trophic level as was recently done in Brown et al. (2016). We attempted to collect different size fractions of plankton (>500, 153-500, and 64-153 μm) from sites spanning the freshwater-marine gradient so that the variation in plankton δ^{15}N throughout Lake Melville could be assessed. However, due to confirmation of NCP funding coming in late, sampling could not be conducted until early August when Lake Melville productivity was already declining. Thus, we did not obtain the spatial coverage of different size fractions we would have liked. Traditional knowledge on productive zones of Lake Melville from field team members Liz Pijogge, Kevin Gear (Northwest River resident), and Martin Shiwak (Rigolet resident) was important for this sampling trip and allowed the unplanned collection of lower food web organisms, krill, scallops and jellyfish at 1-2 sites.

To track the bioaccumulation and potential biomagnification of new and old PFASs through the Lake Melville food web (from water to plankton, lower food web organisms, fishes, and ringed seals), we also collected water from 6 sites for PFAS analyses which is also underway at the De Silva/Muir lab. Water was also collected for basic water chemistry parameters to help interpretation of contaminant data.

Capacity Building

All seal collections for this project were carried out by hunters from Upper Lake Melville and Rigolet during traditional harvesting seal hunts. Payment and training of all hunters involved was coordinated by the Nunatsiavut Government. Training on seal collections for contaminants analyses was provided, including dissections (collection of blubber, liver, jaw, muscle, stomach, kidney samples), preservation methods (immediate freezing of tissue samples), as well as recording of morphometric data (length, weight, blubber thickness, age, gender and status of tissues). In August 2016, Amber Gleason (ECCC), Liz Pijogge (Nunatsiavut Government), Kevin Gear (Northwest River resident), and Martin Shiwak (Rigolet resident) carried out a field season to collect plankton and water from Lake Melville. Gleason provided training on clean techniques to avoid sample contamination (i.e. wearing supplied powder free gloves, double bagging samples), as well as use of plankton nets and plankton sieves for plankton size fractionation to the other team members. This training increased exposure to several specialized sampling techniques needed for evaluating contaminants in traditional country food species.

Communications

Project team members from the Environment Division of the Nunatsiavut Government coordinated communications with the communities involved in the project. Highlights of results to date are being uploaded to the Nain Research Centre Website (http://nainresearchcentre.com/). Poster presentations will also be made at the NCP results workshop and SETAC North America 2017 in fall 2017.

Indigenous Knowledge Integration

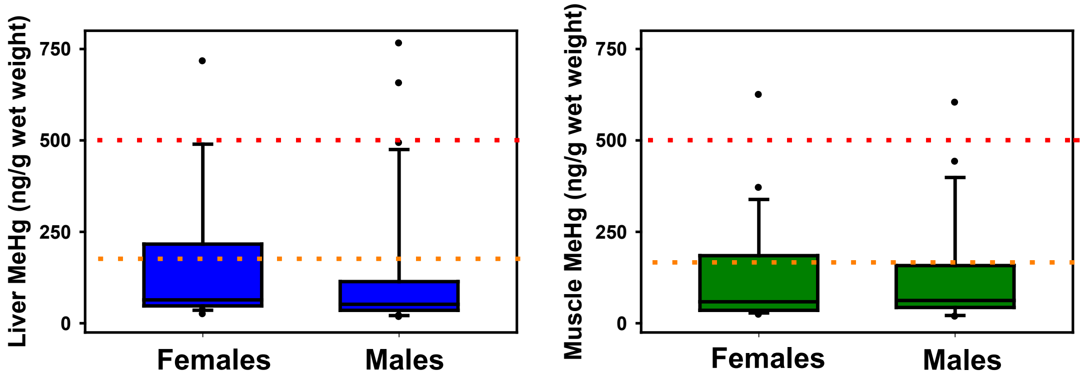
All seal collections are carried out during traditional harvesting activities and therefore completely rely on traditional knowledge, including knowledge of when and where to collect samples and any potential changes in ringed seal populations and/or habitat. The success rate of the hunter based collections at Lake Melville was high in 2013-2016 (n=71 samples collected) with excellent morphometric data, information on age and gender, and kill location recorded. We also relied on traditional knowledge of field team members Liz Pijogge, Kevin Gear of Northwest River and Martin Shiwak of Rigolet during our August 2016 collections of water and plankton. Kevin Gear and Martin Shiwak were hired to provide boats, and knowledge on how to travel safely on Lake Melville and of productive zones for sampling plankton. Traditional knowledge of locations where scallops, krill and jellyfish are plentiful also allowed for the unexpected collection of these lower food web organisms at a couple of sites.

Discussion and Results

Average MeHg concentrations in the liver and muscle of Lake Melville seals were 150 ± 205 and 119 ± 145 $ng{\bullet}g^{-1}$ wet weight (ww), respectively, with 14 of 71 liver samples and 10 of 71 muscle samples surpassing the Canadian frequent consumer guideline of 200 $ng{\bullet}g^{-1}$ ww (Figure 2). As has been observed in ringed seals of numerous other regions (Dehn et al. 2005), there was a positive, near one-to-one relationship (r^2=0.99, p<0.01) between THg and MeHg in ringed seal muscle, demonstrating that THg can be used as a surrogate for MeHg concentrations in seals of this region. As has also been observed in other regions, concentrations of liver THg were higher than liver MeHg in a subset of individuals, likely due to toxin storage in the liver (Dehn et al. 2005). Thus, future liver samples will be analyzed for both THg and MeHg concentrations so that MeHg exposure to human consumers and the impacts of Hg exposure on ringed seal health can be assessed.

Average Hg concentrations in Lake Melville ringed seals are on the lower end of those recently reported for 14 communities across the Canadian high and sub-Arctic (average muscle THg concentrations between 2007-2011 were 107-1070 $ng{\bullet}g^{-1}$) (Brown et al. 2016). This is likely because seals sampled to date are predominantly young. Muscle THg concentrations are comparable to those recently reported in sub-adults of other Labrador locations, including Nachvak Fjord, Saglek Fjord, Okak Bay, and Anaktalak Bay (Brown et al. 2016).

Figure 2. MeHg concentrations (wet weight; ww) in Lake Melville ringed seal liver and muscle sampled between 2012-2016 (n=71). The Canadian frequent consumer guideline of 200 ng•g-1 ww and the Canadian fish commercial sale limit of 500 ng•g-1 ww are shown by the orange and red dashed lines, respectively.



Results from Hg stable isotope analyses of ringed seal liver and muscle samples demonstrate that $\Delta^{199}Hg$ values of seal muscle samples generally fall between marine and freshwater fish from the same region (Li et al. 2016; Figure 3), which is consistent with their wide range of diets from both inland and marine ecosystems. The more enriched $\delta^{202}Hg$ in the seal muscle relative to that observed in fish is indicative of in vivo demethylation of MeHg in seals after ingesting food. A similar phenomenon is observed in some human studies. Seal muscle is consistently more enriched in $\delta^{202}Hg$ than liver tissue for all the ringed seals analyzed (Figure 4), indicating that during in vivo degradation of MeHg, lighter Hg isotopes are preferentially demethylated to inorganic Hg in liver, thus leaving residual MeHg, as demonstrated in muscle, with a higher proportion of the heavier Hg isotopes. The $\delta^{202}Hg$ offsets generally increases as seals grow older, indicating that the capability of demethylation in the liver improves with growth/age.

Figure 3. Stable Hg isotope composition of fish and ringed seals from Lake Melville collected 2012-2015.

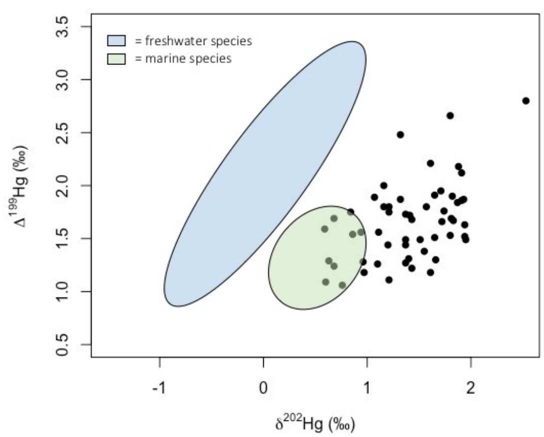
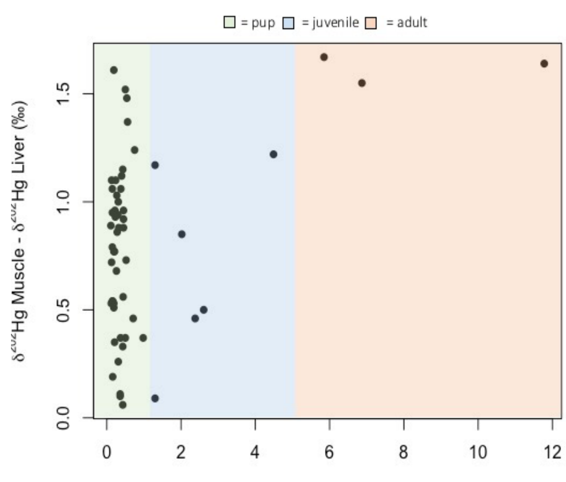


Figure 4. The difference in the $\delta^{202}Hg$ offset between Lake Melville seal liver and muscle collected between 2012-2015.



Seventeen different perfluoroalkyl substances (PFAS) were measured in seal liver. Liver and blood are the tissues in which PFAS accumulate. Between 2013 and 2016, the sum of PFAS (ΣPFAS) ranged from 43 to 342 ng•g^{-1} ww. In general, PFAS are increasing in seals during the sampling period (Figure 5). This is in contrast to PFAS trends reported in other Arctic wildlife which show a marked decline in PFOS concentrations in recent years. For example, Riget et al. (2016) noted a decline in PFOS in ringed seal livers from East (Ittoqqortoormiit) and West (Qeqertarsuaq) Greenland from 2006 to 2010. In that study, Riget et al. reported 2010 ringed seal liver concentrations corresponding to 16.3 ± 10 ng•g^{-1} ww PFOS in West Greenland (aged 0.2 years) and 112 ng•g^{-1} ww PFOS in East Greenland (aged 3 years). More recently in 2012-2013, Gebbink et al. (2016) measured further declining PFOS concentrations of 93 ± 5 ng•g^{-1} ww in East Greenland ringed seal livers. In our study, the Melville ringed seals correspond to 75 ± 39 (2013), 60 ± 27 (2014), 105 ± 22 (2015), and 122 ± 48 (2016) ng•g^{-1} ww PFOS for seals that were all generally <1 year old. The summed PFAS levels in Melville seals (Figure 5) are generally higher than East Greenland ringed seals (in 2013 sampling campaign reported 138 ± 7 ng•g^{-1} ww ΣPFAS).

Another interesting feature in Melville ringed seal are the PFAS congener profiles themselves. Most PFAS profiles in ringed seals from other regions of the Arctic are known to consist predominantly of PFOS. For example, Gebbink et al. (2016) observed ringed seal PFAS composition to consist of 70% PFOS. However in this study, PFOS comprised ~40-50% of total PFAS (Figure 6), suggesting a more diverse pattern of PFAS in ringed seals from the Lake Melville area.

One important parameter that should be considered is the age of the sampled seals. Many studies have reported that PFAS undergo maternal transfer in marine mammals through milk and also placental transfer. This can result in higher concentrations in pups compared to mother mammal. For example, GrØnnestad et al. (2017) detected 66 ng•g^{-1} ww PFAS in the plasma of hooded seal pups compared to 36 ng•g^{-1} ww PFAS in the plasma of the nursing mother in East Greenland. In the current study, juvenile seals were sampled which may present elevated PFAS in liver compared to adult seals. Future work will target adult seals in the region to improve our understanding of PFAS in Lake Melville compared to seals from other Arctic locations.

Figure 5. Total PFAS Concentration in Lake Melville ringed seal liver, 2013-2016. Bars represent average and standard deviation wet weight liver concentration.

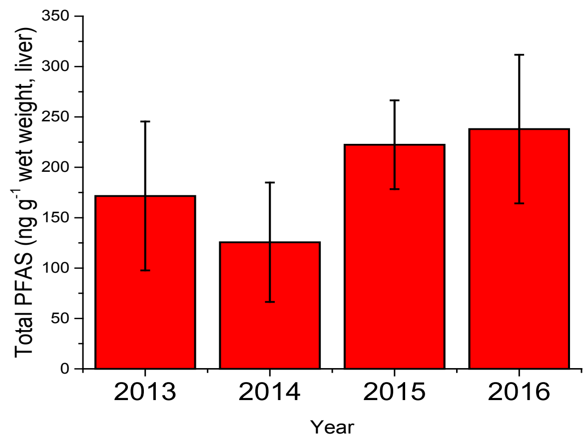
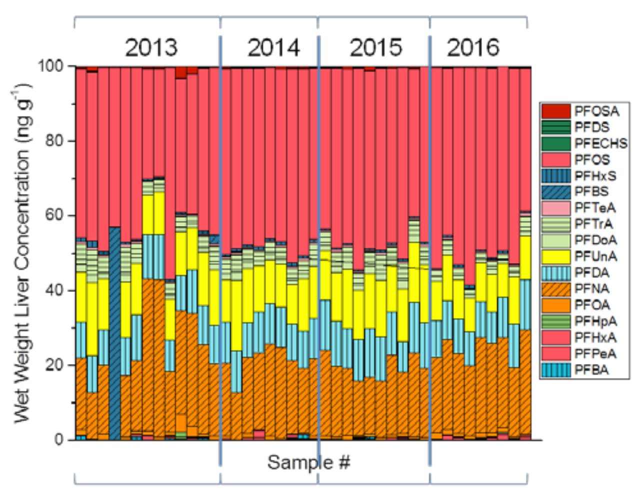


Figure 6. Composition of PFASs in seal livers from 2013-2016. Throughout the sampling period, the dominant PFAS was PFOS (46 ± 6), followed by PFNA (21 ± 6), PFUnA (13 ± 2), and PFDA (11 ± 1).



Expected Project Completion Date

Results from 2016-17 funding will be complete within 6 months; however we plan to carry out this research over the long-term (5-10 years) to track the impact of flooding for hydroelectric power production and climate change on Lake Melville food webs.

Acknowledgments

We are grateful to the hunters in the communities of Northwest River and Rigolet for their participation in this project. We would like to acknowledge the Northern Contaminants Program, Environment and Climate Change Canada, Harvard University, and the Nunatsiavut Government for the funding to produce the data within this report. We finally acknowledge Ron MacLeod and Whitney Davis at ALS Global (Burlington) for conducting PCBs analysis and providing detailed data reports.

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Metabolomic consequences of elevated PCB exposure in ringed seals (*Pusa hispida*) in Labrador: an expanded toxicological repertoire to characterize health impacts

Conséquences métabolomiques de l'exposition élevée aux BPC chez le phoque annelé (*Pusa hispida*) au Labrador : répertoire toxicologique élargi pour caractériser les répercussions sur la santé

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Abstract

Causal evidence linking PCBs to adverse health effects in free-ranging marine mammals is generally confounded by the highly complex contaminant mixtures to which they are exposed. A local PCB "hotspot" on the Labrador coast provided a rare opportunity to evaluate the effects of PCBs on the health of a marine mammal as this chemical dominated their persistent organic pollutant (POP) burdens. The release of approximately 260 kg of PCBs by a military radar facility over a 30 year period (1970-2000) contaminated some local marine biota, including 60% of the ringed seals (*Pusa hispida*) along the coast. A select suite of genes measured in ringed seals from Labrador

Résumé

Les indications probantes du lien causal entre les concentrations de BPC et les effets néfastes sur la santé des mammifères marins sauvages sont généralement brouillées par les mélanges de contaminants hautement complexes auxquels ils sont exposés. Une source de BPC locale sur la côte du Labrador offrait une occasion inestimable d'examiner les effets des BPC sur la santé d'une population de mammifères marins, puisque ce produit chimique dominait leurs charges de polluants organiques persistants (POP). Le rejet d'environ 260 kg de BPC par une installation radar militaire sur une période de 30 ans (1970-2000) a contaminé une partie du biote marin local, y compris 60 % des phoques annelés (*Pusa hispida*)

revealed a strong relationship between the profiles of gene transcripts that play a role in animal health and PCB concentrations, suggesting that some adverse effects have been caused by this local PCB source. Threshold values were calculated for these genes, with the most conservative value being 1370 ng•g^{-1} (lipid weight). Approximately 14% of the seals in the region exceeded this threshold. In the present study, we examined 254 metabolites to add further insight to the consequences of PCBs on ringed seal health. These included 18 energy metabolism metabolites, 18 endogenous steroid metabolites, 21 amino acids, 22 biogenic amines, 40 acylcarnitines, 89 phosphatidylcholines, 15 sphingomyelins, Σhexose, 13 bile acids, and 18 fatty acids in liver, plasma, and serum samples collected from 43 ringed seals in the affected area. Preliminary metabolomics results suggest that variability between metabolites is explained by PCB concentrations and the year of collection. Those sampled during 2010, an unfavourable ice condition year, differed from the other sampling years. The dominance of PCBs in the seals studied enabled an assessment of the effects of this chemical on metabolites involved in regulating the health of a highly mobile predator, something that is rarely possible in the world of complex mixtures. Our findings add mechanistic insight into the nature of PCB toxicity in seals, and additional evidence for a widespread impact associated with the release of PCBs from the Labrador radar facility.

le long de la côte. L'analyse d'un ensemble choisi de gènes chez les phoques annelés du Labrador a révélé un lien très étroit entre les profils des transcrits de gènes jouant un rôle dans la santé animale et les concentrations de BPC, suggérant que certains effets néfastes sur la santé avaient été causés par cette source locale de BPC. On a calculé les valeurs de seuil de ces gènes, la valeur la plus conservatrice étant 1 370 ng•g^{-1} (poids lipidique). Environ 14 % des phoques de la région dépassaient ce seuil. Dans la présente étude, nous avons examiné 254 métabolites afin d'avoir un meilleur aperçu des conséquences des BPC sur la santé des phoques annelés. Il s'agissait, entre autres, de 18 métabolites du métabolisme énergétique, 18 métabolites de stéroïdes endogènes, 21 acides aminés, 22 amines biogènes, 40 acylcarnitines, 89 phosphatidylcholines, 15 sphingomyélines, Σhexose, 13 acides biliaires et 18 acides gras dans des échantillons de foie, de plasma et de sérum prélevés sur 43 phoques annelés dans la région touchée. Selon les résultats préliminaires des analyses métabolomiques, la variabilité entre les métabolites s'explique par les concentrations de BPC et l'année de prélèvement des échantillons. Ceux prélevés en 2010, une année où les conditions de la glace étaient défavorables, différaient de ceux des autres années d'échantillonnage. La dominance des BPC chez les phoques étudiés a permis d'évaluer les effets de ce produit chimique sur les métabolites contribuant à régulariser la santé d'un prédateur très mobile, ce qui est rarement possible dans un monde où existent les mélanges complexes. Nos constatations ajoutent une perspective mécaniste à la nature de la toxicité des BPC chez les phoques, de même qu'une preuve supplémentaire des conséquences à grande échelle associées au rejet de BPC par l'installation radar du Labrador.

Key Messages

- 42 liver samples, 39 plasma samples, and 10 serum samples were analyzed for concentration levels of 236 metabolites in 42 ringed seals that were collected along the northern Labrador coast in the summers of 2009 to 2011.

Messages clés

- On a procédé à l'analyse de 42 échantillons de foie, 39 de plasma et 10 de sérum afin d'obtenir les niveaux de concentration de 236 métabolites chez 42 phoques annelés; ces échantillons ont été prélevés le long de la côte nord du Labrador au cours des étés 2009 à 2011.

- Ringed seal metabolomics results suggest that variability between metabolites is attributed to year of collection with those collected during 2010, an unfavourable ice condition year, differing from the other years.
- Fatty acid metabolites in ringed seals in 2010 are lower relative to other sample years, suggesting possible changes in feeding ecology of seals in 2010.
- Adult male ringed seal metabolomics results suggest that variability between metabolites is attributed to PCB concentrations.
- Energy metabolism, amino acid and bile acid metabolites were altered in ringed seals exposed to increasing concentrations of PCBs.

- Selon les résultats préliminaires des analyses métabolomiques pour le phoque annelé, la variabilité entre les métabolites est attribuable à l'année de prélèvement des échantillons, dont ceux prélevés en 2010, une année où les conditions de la glace étaient défavorables, différaient de ceux des autres années d'échantillonnage.
- En 2010, les métabolites d'acides gras chez le phoque annelé étaient moindres par rapport à ceux d'autres années d'échantillonnage, laissant supposer des changements possibles dans l'écologie d'alimentation du phoque cette année-là.
- Selon les résultats des analyses métabolomiques pour le phoque annelé mâle adulte, la variabilité entre les métabolites est attribuable aux concentrations de BPC.
- Les métabolites du métabolisme énergétique, d'acides aminés et d'acides biliaires ont été modifiés chez les phoques annelés exposés à des concentrations de BPC à la hausse.

Objectives

- Assess the health of ringed seals in Northern Labrador using a targeted metabolomic platform.
- Develop / adapt and validate techniques to measure the health of ringed seals using metabolomic methods established in other species.
- Measure a total of 254 metabolites, including 18 energy metabolism metabolites, 18 endogenous steroid metabolites, 21 amino acids, 22 biogenic amines, 40 acylcarnitines, 89 phosphatidylcholines, 15 sphingomyelins, Σhexose, 13 bile acids, and 18 fatty acids in ringed seal liver (tissue specific metabolomics).
- Report on the associations found between these new metabolic profiles and PCBs, and any relationships with previously reported gene expression (n=8) endpoints.
- Measure the 254 metabolites in serum (integrated systemic metabolomics) in a subset of ringed seals (n=10) and report on the associations found between the metabolomics profiles observed in plasma and in liver.
- Publish in the international scientific literature and at conferences.
- Communicate our results to the communities of Nunatsiavut through several avenues, including regular updates and reports to the Nunatsiavut Government.

Introduction

Concerns regarding food safety with respect to ringed seals (*Pusa hispida*) and the general health of ringed seals in Nunatsiavut arose following reports of elevated PCB concentrations in some seals from the north Labrador coast. Ringed seals are an important country food for Inuit in Nunatsiavut, and play an integral role in community diet and culture. They feed opportunistically on a variety of fish and crustaceans and are important prey of polar bears and arctic foxes (Wolkers et al. 1998; Wolkers et al. 2008). As a result, these seals play a critical role in the dynamics of arctic marine ecosystems. High trophic level ringed seals are particularly vulnerable to persistent organic pollutants such as PCBs (Muir et al. 2000). Examples of negative effects associated with PCBs in ringed seals include impaired reproduction, endocrine disruption, bone lesions, reduced immune function, and tumour incidence (Helle et al. 1976; Nyman et al. 2003; Olsson et al. 1994; Sormo et al. 2005; Routti et al. 2010; Brown et al. 2014a).

Saglek, a former Pole Vault radar station, has contaminated the local marine environment, and up to 60% of ringed seals studied in the region (Brown et al. 2009; Brown et al. 2014b). Recent findings show that average PCB concentrations in adult male ringed seals exceeded a 1,300 ng•g^{-1} (lipid wt; blubber, Mos et al. 2010) threshold for endocrine and immunotoxic effects derived for harbour seals (*Phoca vitulina*) (Brown et al. 2014b). Further, an examination of hepatic gene expression profiles in ringed seals from the Labrador coast revealed a strong relationship between ringed seal PCB burden and profiles of gene transcripts which encode proteins that play an important role in animal health with respect to chemical detoxification, the immune and endocrine systems, and the regulation of growth, development, and metabolism (Brown et al. 2014a).

To add further insight to the consequences of PCBs on ringed seal health, we examined 254 metabolites. These included 18 energy metabolism metabolites, 18 endogenous steroid metabolites, 21 amino acids, 22 biogenic amines, 40 acylcarnitines, 89 phosphatidylcholines, 15 sphingomyelins, Σhexose, 13 bile acids, and 18 fatty acids in liver, plasma, and serum samples collected from 42 ringed seals in the affected area. This study allows us to determine which metabolic systems were affected in the highly exposed ringed seals and adds an additional layer of insight into a valuable sample set. The inclusion of multi-metabolomic measurements in the same individuals will allow for comparisons between tissue-specific (hepatic) and systemic (plasma and serum) measured metabolic responses and provide insight into the relative value of each sampling approach in assessing ringed seal health. Combining transcriptomic and metabolomic profiles for the same individual ringed seal samples will allow us to capture a comprehensive picture at a given moment in time. We know of no other case of a marine mammal population that has been solely exposed to a PCB point source, thus this study affords us an invaluable opportunity to evaluate the effects of PCBs on the health of a wild marine mammal.

Activities in 2016-2017

42 liver samples, 39 plasma samples, and 10 serum samples were analyzed for concentration levels of 236 metabolites in 42 ringed seals that were collected along the northern Labrador coast in the summer of 2009 to 2011. The following metabolites were included in the analysis: 18 energy metabolism metabolites, 21 amino acids, 22 biogenic amines, 40 acylcarnitines, 89 phosphatidylcholines, 15 sphingomyelins, Σhexose, 13 bile acids, and 18 fatty acids. The remaining 18 endogenous steroid metabolites will be analyzed in liver, plasma, and serum samples in June 2017.

Results

Metabolites that were present in 70% or more of the samples were included in the data analysis (Table 1). Any metabolites less than the detection limit were replaced with a random number between the detection limit and zero. Relationships were evaluated using Principal Component Analysis (PCA) (Pirouette, Infometrix, Bothell, WA, USA) and ANOVA. Metabolite values were autoscaled (scaled to variable mean and standard deviation) prior to PCA analysis. This analysis showed similarities and differences among ringed seal metabolite profiles, which can be used to provide insight into what variables (e.g., type of matrix analyzed, sea ice condition, and PCB concentration) explain these differences and similarities.

Plasma vs serum vs liver

We compared 10 matched plasma, serum and liver samples collected from the same seals to assess the detection rate and performance similarity for metabolomics analysis. Metabolites were more detectable in the liver than in the serum and plasma (Table 1). Serum and plasma metabolite concentration values performed similarly and did not differ from one another (Figure 1 (left)). In contrast, liver differed from both plasma and serum (Figure 1 (right)), which could be due to variation in tissue type and/or processing batch.

Our 2009 liver samples appeared to have inexplicably degraded between the date of collection and the date of testing, thereby precluding data analysis of these samples. Thus, all further analyses for the purpose of this report are done using the plasma metabolomics results. We will further investigate the 2009 liver sample data to confirm our initial observations.

Metabolomic changes during the year

The first principal component (p1: 30.3%) clearly differentiates ringed seals sampled in 2010 from seals sampled in 2009 and 2011 (Figure 2). The most notable change between 2010 and the other years involved the fatty acid (FA) metabolites. FA metabolites analyzed included three saturated FAs: myristic acid, palmitic acid, and stearic acid; and six poly/monounsaturated FAs: oleic acid, linoleic acid, arachidonic acid, eicosapentaenoic acid, docosapentaenoic acid, and docosahexaenoic acid. Concentrations of all FA metabolites analyzed were lower ($p < 0.05$) in the 2010 seals compared with the other years. None of the other biological variables (age, sex, weight, length, girth, blubber thickness) or ∑PCBs correlated with the sample scores of the first or second principal component (t1 or t2) ($p > 0.05$) from Figure 2.

Table 1. Number of metabolites detected in 70% of the samples for each sample type.

	Liver	Plasma	Serum
# samples	42	39	10
# of metabolites assayed	236	236	236
# detected in 70% of the samples	212	172	173
% detected in 70% of the samples	90	73	73

Figure 1. Plasma and serum metabolite profiles were similar (left). In contrast, liver metabolite profiles differed from both plasma and serum (right), as evidenced by the tight clustering by liver samples compared with plasma and serum samples.

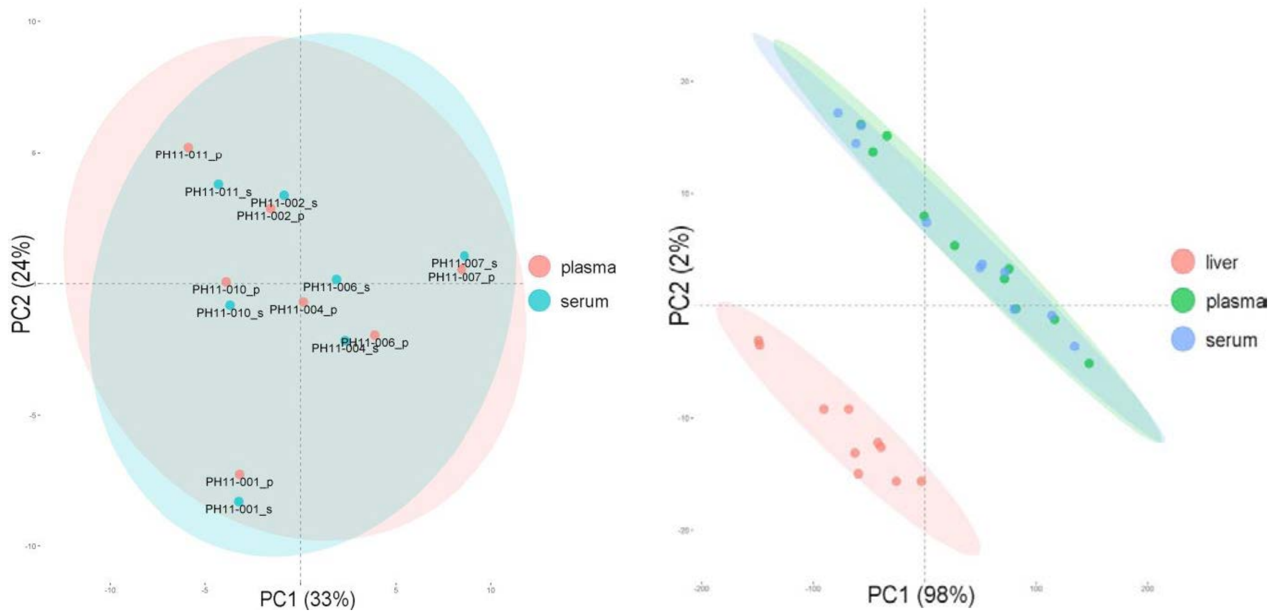


Figure 2. (a) Principal components analysis (PCA) revealed that variability between metabolites in ringed seal plasma (n=39) can be attributed to year of collection, with samples collected during 2010, an unfavourable ice condition year, differing from the other years. Each circle on the scores plot represents a plasma sample from a seal. (b) 172 metabolites were included in the PCA. Colours identify the different metabolic systems; a divergence between the 18 fatty acid metabolites was observed along the variable loadings of the first principal component (p1).

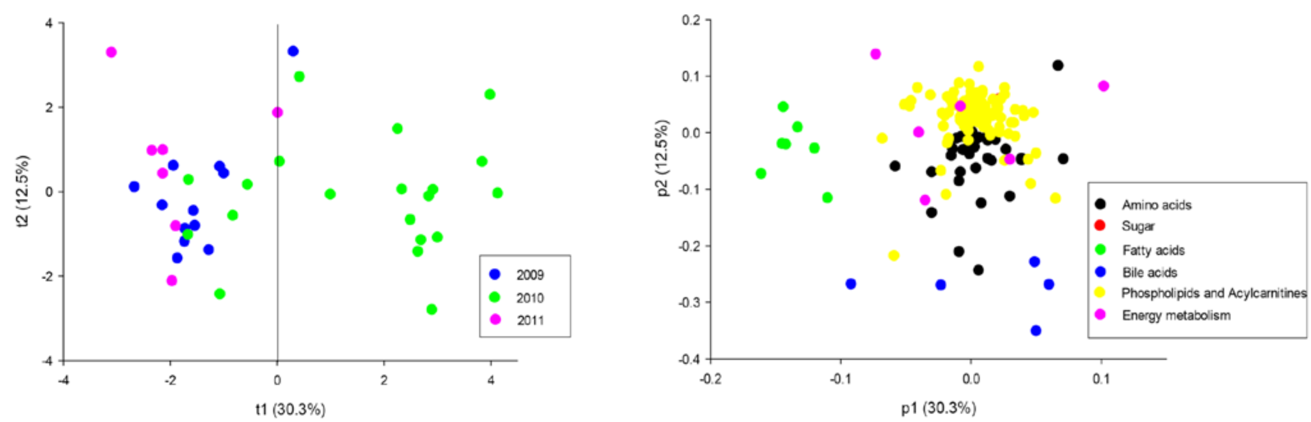
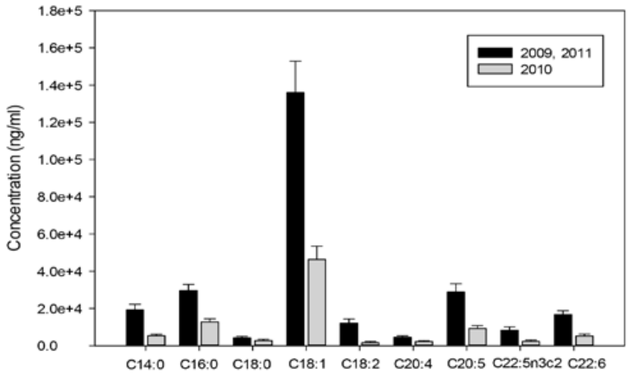


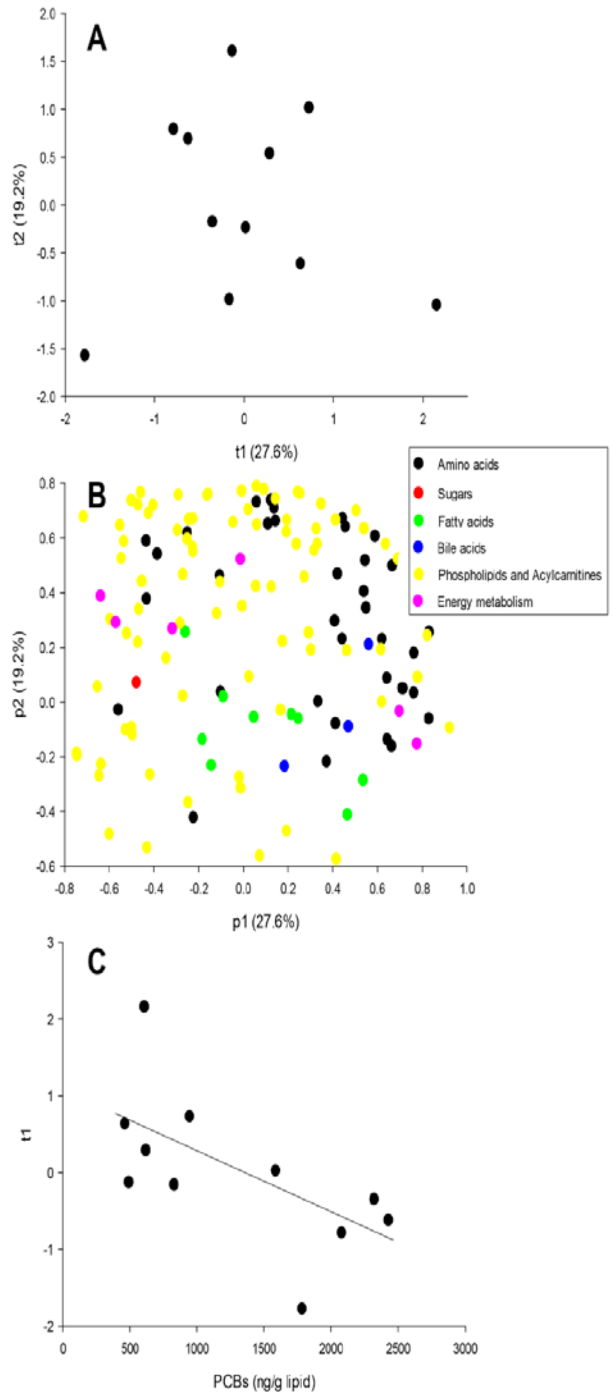
Figure 3. Concentrations of fatty acids were lower ($p < 0.05$) in 2010 ringed seals compared to the other sampling years (2009 and 2011).



PCB changes in adult males

PCA analysis of just the adult males showed that 28% of the variation in metabolite patterns was explained by the first factor (Figure 4A). None of the other biological variables or year correlated with t1 or t2 ($p > 0.05$). Many of the energy metabolism, amino acid and bile acid metabolites varied significantly in the more PCB contaminated seals compared with the less contaminated adult males (Figure 4B). The females in the present study were far less contaminated than the adult males, which can be attributed to the transfer of PCBs through the placenta and nursing to their young. In this way, our findings that the females and sub-adults exhibited no relationship ($p > 0.05$) with PCBs (results not shown), while the adult males did (r^2=0.40, p=0.02) (Figure 4C) demonstrates the way in which the PCB concentrations in our study population straddle the effects threshold for seals.

Figure 4. (A) Principal components analysis (PCA) of plasma metabolite levels in adult male Labrador ringed seals (n = 11). Each circle on the scores plot represents an adult male seal. (B) 164 metabolites were included in the PCA; a divergence between a number of the energy metabolism, amino acid, and bile acid metabolites was observed along the variable loadings of the first principal component (p1) (C) Sample score of the first principal component (t1) was correlated with ∑PCBs.



Discussion and Conclusions

Preliminary results suggest that metabolite levels are explained largely by PCB concentrations and year of collection. Our study therefore indicates that exposure to an industrial chemical (PCBs), combined with changes in feeding ecology as a result of a poor ice year, are conspiring to have detectable physiological effects on ringed seals in Labrador.

The altered metabolic profile in 2010 ringed seals is consistent with lower $\delta^{15}N$ levels from that year which we previously attributed to changes in their feeding ecology associated with changes in ice condition (Brown et al. 2015). The altered metabolic profile in adult male seals with increasing PCB concentrations adds mechanistic evidence of PCB-associated toxicity to our previously reported altered mRNA transcript levels in the same adult males (Brown et al. 2014b). Further, the altered energy metabolism metabolites in the more PCB contaminated adult male seals compared with the less contaminated adult males is consistent with a recent study of ours which showed an indication of energy metabolism imbalance in PCB contaminated ringed seals (Brown et al. 2017). We are currently completing the steroid metabolite measurements on all samples (2009, 2010 and 2011). By the fall of 2017, interpretation of all the data will be completed and a manuscript will be submitted for publication.

The combination of long-range 'background' and a local PCB 'hotspot' on the Labrador coast afforded us an invaluable opportunity to examine the effects of a relatively unweathered commercial grade PCB mixture on the health of a marine mammal population. This project will deepen our understanding of PCB-related health effects in marine mammals by building on our earlier NCP-supported genomics study. Results from this proposed study provide additional insight into the health of the ringed seal population in Labrador, as well as those community members that rely on this species as important country food.

Expected Project Completion Date

Fall of 2017 we will complete steroid metabolite measurements on all samples (2009, 2010 and 2011) and interpretation of the data. A manuscript will then be submitted for publication.

Acknowledgments

Funding and support were provided by, the Northern Contaminants Program of Crown-Indigenous Relations and Northern Affairs Canada, Fisheries and Oceans Canada, the Torngat Joint Fisheries Board, the Director General Environment of the Department of National Defence, Raincoast Conservation Foundation, National Sciences and Engineering Research Council of Canada (NSERC) (awards to T.M.B.) and the ArcticNet Canadian Network of Centres of Excellence, ArcticNet (Project ArcticNet Nunatsiavut Nuluak). Finally, we gratefully acknowledge Joey Angnatok and the crew of the Motor Vessel (MV) "*Whats Happening*" for their steadfast support, expertise, and active participation in the field.

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Communications, Capacity Building and Outreach

Communications, renforcement des capacités et sensibilisation

Yukon Contaminants Committee (YCC)

Comité des contaminants du Yukon (CCY)

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Abstract

Since 1991, the Yukon Contaminants Committee (YCC) has and continues to keep the Yukon people informed of the Northern Contaminants Program's (NCP) initiatives. Over the past 24 years, the YCC has communicated the results of the Northern Contaminants Program to the people of Yukon and contributed to national and international publications. The YCC is considered to be the point of contact for contaminant issues in the Yukon.

In addition to their ongoing role as the point of contact between the residents of the Yukon and the NCP, the YCC is responsible for reviewing all regional proposals for socio-cultural merit. The YCC also assists with fiscal co-ordination of projects funded within the Yukon and works with researchers to create communications strategies for research results within the Yukon.

This year the YCC hosted a two-day workshop in March 2017 in Whitehorse, Yukon to raise the profile of the NCP and YCC. Past and

Résumé

Depuis 1991, le Comité des contaminants du Yukon (CCY) a informé et continue d'informer les peuples du Yukon sur les initiatives du Programme de lutte contre les contaminants dans le Nord (PLCN). Durant les 24 dernières années le CCY a communiqué les résultats du programme de lutte contre contaminants dans le Nord au peuple du Yukon et a contribué aux publications nationales et internationales. Le CCY est considéré comme le point de contact pour les questions sur les contaminants au Yukon.

En plus de leur rôle permanent en tant que point de contact entre les résidents du Yukon et le PLCN, le YCC est chargé d'examiner toutes les propositions régionales pour le mérite socio-culturel. Le YCC aide également à coordonner les projets financés au Yukon et collabore avec les chercheurs afin de créer des stratégies de communication pour les résultats de la recherche au Yukon.

present research projects were highlighted with a number of researchers attending to showcase their work and provide information to Yukon residents. Communities also had the opportunity to become members of the YCC and strategize the YCC's direction for the coming years.

Cette année, le CCY a organisé un atelier de deux jours en mars 2017 à Whitehorse, au Yukon, afin de relever le profil du PLCN et du CCY. Des projets de recherche passés et en cours ont été mis en évidence avec un certain nombre de chercheurs présents pour présenter leurs travaux et fournir de l'information aux résidants du Yukon. Les communautés ont également eu l'occasion de devenir membres du CCY et d'élaborer des stratégies pour orienter la direction du CCY pour les années à venir.

Key Messages

- Over the past 24 years, the YCC has communicated the results of the Northern Contaminants Program to the people of Yukon and contributed to national and international publications.
- The YCC is considered to be the point of contact for contaminant issues in the Yukon.

Messages clés

- Durant les 24 dernières années le CCY a communiqué les résultats du programme de lutte contre contaminants dans le Nord au peuple du Yukon et a contribué aux publications nationales et internationales.
- Le CCY est considéré comme le point de contact pour les problèmes de contaminants au Yukon.

Northwest Territories Regional Contaminants Committee (NWTRCC)

Comité régional des contaminants des Territoires du Nord-Ouest (CRCTNO)

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Abstract

The Northwest Territories Regional Contaminants Committee (NWTRCC) represents the Northern Contaminants Program (NCP) in the Northwest Territories (NT) ensuring that northern and Indigenous interests are being served by scientific research conducted in the Northwest Territories, and to serve as a resource for long-range contaminants information in the Northwest Territories.

NWTRCC was represented by Tim Heron, Emma Pike, Carmon Bessette, Linna O'Hara, Brett Elkin, as well as a Dene Nation

Résumé

Le CRCTNO représente le Programme de lutte contre les contaminants dans le Nord (PLCN) aux Territoires du Nord-Ouest et s'assure que les intérêts des résidents du Nord et des Autochtones sont pris en compte dans les recherches scientifiques menées aux Territoires du Nord-Ouest. Il se veut en outre une ressource pour l'obtention de renseignements sur les contaminants transportés sur de grandes distances aux Territoires du Nord-Ouest.

Le CRCTNO était représenté par Tim Heron, Emma Pike, Carmon Bessette, Linna O'Hara,

Representative, when attending the NCP Management Committee (MC) meetings in April and/or October 2016. NWTRCC hosted a productive social-cultural review of NCP proposals on February 14-15, 2017 in Yellowknife. A total of 15 people (including two via conference call) participated in the face-to-face meeting and 24 NT-based proposals were reviewed.

NWTRCC had representation at the NCP human health and risk communication workshop held in Ottawa November 22 and 23, 2016. Emma Pike, Linna O'Hara, Andrea Corriveau, Eric Loring and Shannon O'Hara attended.

NWTRCC provided feedback to NCP researchers on communications (i.e., summary reports, posters, and information pamphlets) intended for community dissemination. In addition, the NWTRCC met face-to-face with NCP-funded researchers to discuss their respective proposals/projects and how they were progressing throughout the year.

Brett Elkin et un représentant de la Nation dénée aux réunions d'avril et d'octobre 2016 du Comité de gestion du PLCN. Le CRCTNO a également dirigé un examen socioculturel productif des propositions du PLCN les 14 et 15 février 2017 à Yellowknife. Au total, 15 personnes (dont deux par conférence téléphonique) ont participé à la réunion en personne, au cours de laquelle 24 propositions concernant les Territoires du Nord-Ouest ont été examinées.

Des représentants du CRCTNO ont assisté à l'atelier sur la santé humaine et la communication des risques du PLCN qui a eu lieu les 22 et 23 novembre 2016 à Ottawa. Emma Pike, Linna O'Hara, Andrea Corriveau, Eric Loring et Shannon O'Hara y ont assisté.

Le CRCTNO a présenté des commentaires aux chercheurs du PLCN au sujet des produits de communication (rapports sommaires, affiches et brochures d'information) destinés aux collectivités. Enfin, le CRCTNO a rencontré en personne des chercheurs financés dans le cadre du PLCN pour discuter de leurs propositions et projets respectifs ainsi que de leurs progrès tout au long de l'année.

Key Messages

- Through its social-cultural review of all NT-based NCP proposals, the NWTRCC ensures northern and Indigenous interests are being served by scientific research conducted in the Northwest Territories, and results of these studies are shared with communities.
- The NWTRCC aims to serve as a resource to NT residents for long-range contaminants information in the Northwest Territories.

Messages clés

- Grâce à son examen socioculturel de toutes les propositions pour le PLCN concernant les Territoires du Nord-Ouest, le CRCTNO s'assure que les intérêts du Nord et des Autochtones sont pris en compte dans les recherches scientifiques menées aux Territoires du Nord-Ouest. Les résultats de ces études sont transmis aux collectivités.
- De plus, le CRCTNO se veut une ressource pour les résidents des Territoires du Nord-Ouest, afin qu'ils puissent obtenir des renseignements sur les contaminants transportés sur de grandes distances que l'on trouve aux Territoires du Nord-Ouest.

Objectives

- Through its social-cultural review of all NT-based NCP proposals, the NWTRCC ensures the interests of NT residents are being addressed during research activities, including:
  - Local or northern training and capacity building opportunities are pursued by Principal Investigators (PI) whenever possible;
  - Youth are included and incorporated into the study designs and process when possible;
  - Research results are appropriately communicated back to participating or nearby communities; and
  - Meaningful community consultation is achieved.
- Assist researchers with conversion of NCP-funded contaminant research results into plain language that is understood by all residents.
- Assist and advise NCP-funded researchers, as well as prospective researchers, on the relevant methods and distribution of communication materials to communities.
- By way of GNWT-Department of Health & Social Services (DOH) representatives on the committee, provide relevant NCP-funded contaminant research results to the Chief Medical Officer of Health (CMOH).
- Work in partnership with communities, researchers, governments, GNWT-DOH, and various organizations with an interest in the projects when undertaking community outreach related to communicating NCP research results.
- When requested by the GNWT, provide support to the CMOH who will work in collaboration with NWTRCC on the development, implementation and follow up of nutrition recommendations, food policies, and public health messages resulting from NCP funded contaminants research.
- 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 NCP Secretariat, which funds long-range contaminants research in the north. The NWTRCC fosters partnerships among interested stakeholders when developing and delivering public messages concerning contaminants in relation to human health and the environment. The NWTRCC was started nearly 25 years ago and since its inception, the annual social-cultural review of NCP proposals has been the committee's primary focus. Through its review of all NT-based proposals, the committee ensures Northern and Inuit interests are being served by scientific research conducted in the Northwest Territories.

Activities in 2016-2017

The following activities were undertaken by the NWTRCC in 2016-2017:

- April 12-14, 2016 – Tim Heron/Chair, Carmon Bessette, Brett Elkin, Roland Pangowish, and GNWT-DOH Representative attended the NCP Management Committee meeting in Ottawa, ON.
- July 26, 2016 – Teleconference regarding Biomonitoring with Brian Liard, Mylene Ratelle, Jeremy (GNWT-DOH), Sarah Kalhok, Emma Pike, Carmon Bessette, Linna O'Hara, Kelley Skinner, and Meredith Kerr (Health Canada, Ottawa).

- August 5, 2016 – In person meeting with Mylene Ratelle, Emma Pike, and Carmon Bessette to discuss progress on the biomonitoring project.
- September 8, 2016 – NWTRCC teleconference call with Tim Heron, Emma Pike, Carmon Bessette, Brett Elkin, Catrina Owens, Linna O'Hara, Shannon O'Hara, Eric Loring, Shin Shiga, and Cindy Gilday where mid-year reporting, and how we would distribute and give comments regarding progress of projects was discussed.
- September 12, 2016 – NWTRCC teleconference meeting about mid-year review preparation with Tim Heron, Emma Pike, Carmon Bessette, Brett Elkin, Catrina Owens, Linna O'Hara, Shannon O'Hara, Eric Loring, Shin Shiga, and Cindy Gilday.
- September 26, 2016 – Mid-year review of reporting discussion attended by Shannon O'Hara, Sjoerd Van der Wielen, Linna O'Hara, Diane Giroux, Dakota Erutse, Tim Heron, Catarina Owens, Eric Loring, and Dahti Tsetso.
- October 4-6, 2016 – Emma Pike, Carmon Bessette, Tim Heron, and Roland Pangowish attended the Fall NCP Management Committee meeting in Whitehorse, YK.
- October 17, 2016 – Biomonitoring meeting attended by Brian Laird, Mylene Ratelle, Kelley Skinner, Jeremy (GNWT-DOH), Carmon Bessette, Emma Pike. Discussions centred on bringing back results and messaging, looking ahead to other interested communities and their concerns.
- November 22-23, 2016 – NCP Health Workshop attended by Emma Pike, Linna O'Hara, Andre Corriveau.
- November 30, 2016 – NWTRCC conference call attended by Eric Loring, Erika Hillie, Linna O'hara, Simon Smith, Emma Pike, Carmon Bessette, Tas-Tsi Catholique, Tim Heron, Shin Shiga, Cindy Gilday, Dahti Tsetso, Tyanna Steinwand, and Diane Giroux.
- December 9, 2016 – NWTRCC conference call attended by Tim Heron, Emma Pike, Carmon Bessette, Sharon Hopf, Shin Shigs, Dakota, Diane Giroux, and Erika Hillie. Discussions centered on Dene Nation submitting a proposal for a Pan-Territorial meeting in conjunction with the NCP results workshop planned for September in Yellowknife.
- January 5, 2017 – Scheduled conference call with Catarina Owens, Carmon Bessette, Emma Pike, and Tsa-Tsi Catholique. This meeting was cancelled due to poor attendance.
- February 2, 2017 – Conference call with Emma Pike, Carmon Bessette, Simon Smith, and Sarah Kalhok discussing preparations for the social-cultural review.
- February 14-15, 2017 – NWTRCC Social-Cultural Review attended by Tim Heron, Diane Giroux, Cindy Gilday, Adrian Derit (representing Shin Shiga), Dahti Tsetso, Tyanna Steinwand, Trevor Teed, Shannon O'Hara, Erika Hille, Linna O'Hara, Simon Smith, Emma Pike, Carmon Bessette. Attendees via phone: Tsa-Tsi Catholique, Eric Loring; Absent: Brett Elkin
- February 22, 2017 – Meeting with Brian Laird, Emma Pike, Carmon Bessette to update on the progress of the Biomonitoring project and the look ahead for fiscal year 2017/18 as well as 2018/19.
- March 2017 – preparation for the early April NCP Management Committee meeting.

Throughout the year the NWTRCC Secretariat's function has involved organizing and facilitating the regional calls as needed. The regional secretariat also administered, tracked and ensured funding for eighteen Contribution Agreements through the NCP program. This work has become more involved with requiring approval of general assessments, and coordinating review of final reports along with financial report reviews.

Discussion and Conclusions

The work of NWTRCC is on-going and will continue into 2017-2018. The NWTRCC saw some minor changes to our membership this fiscal year but overall had a very busy successful year. NWTRCC plans to maintain the very good lines of communication which we have with a number of our researchers while continuing to build those connections with many others.

By building on these contacts made with NCP researchers and Northern institutions we hope to enhance collaborative efforts that will foster more opportunities for capacity building and training for NT residents, and more effective communications between NCP researchers and communities. NWTRCC is committed to assisting PIs with communicating research back to their partnering communities and encourages researchers to contact NWTRCC before they embark on any community consultations or communications.

In terms of the upcoming work plan for 2017-2018, the NWTRCC is aiming to do more networking with PI's. NWTRCC will continue with its regular annual activities, including reviewing mid-year reports and requests for additional funding; conducting a detailed social-cultural review of 2018-2019 NCP proposals; helping coordinate researcher presentations within the NT; and providing feedback to PIs on presentations and communication products intended for community dissemination.

Expected Project Completion Date

Work is on-going.

Nunavut Environmental Contaminants Committee (NECC)

Comité sur les contaminants environnementaux du Nunavut (CCEN)

Project Leaders/Chefs de projet

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Abstract

The NECC represents the Northern Contaminants Program (NCP) in Nunavut (NU) to ensure that northern and Inuit interests are being served by scientific research conducted in Nunavut, and to serve as a resource to Nunavummiut for long-range contaminants information in Nunavut.

NECC attended the NCP Management Committee meetings in April and October 2016. NECC hosted a productive social-cultural review of NCP proposals on February 22-24, 2017 in Iqaluit. A total of sixteen people (including three community members) participated in the face-to-face meeting and thirty-two Nunavut-based proposals were reviewed. A total of eight Environmental

Résumé

Le CCEN représente le Programme de lutte contre les contaminants dans le Nord (PLCN) au Nunavut et s'assure que les intérêts des résidents du Nord et des Inuits sont pris en compte dans les recherches scientifiques menées au Nunavut. Il se veut en outre une ressource pour les Nunavummiuts dans l'obtention des renseignements sur les contaminants transportés sur de grandes distances que l'on trouve au Nunavut.

Le CCEN a assisté aux réunions d'avril et d'octobre 2016 du Comité de gestion du PLCN. Le CCEN a également dirigé un examen socioculturel productif des propositions du PLCN du 22 au 24 février 2017 à Iqaluit. Au total, 16 personnes (dont trois membres de

Technology Program (ETP) students were able to participate on a rotational basis.

NECC participated in the annual Wildlife Contaminants Workshop at the Nunavut Arctic College (NAC) in September 2017; supported travel for an ETP student to go to Resolute Bay to attend the seal health workshop (C-12) in October 2016; and attended the NCP human health and risk communication workshop in November 2016.

NECC provided feedback to NCP researchers on communications (i.e., summary reports, posters) intended for community dissemination, met face-to-face with NCP-funded researchers to discuss their respective proposals/projects, and attended seminars/workshop held by NCP researchers.

la collectivité) ont participé à la réunion en personne, et 32 propositions concernant le Nunavut ont été examinées. En tout, huit étudiants inscrits au programme de technologie écologique ont pu y participer à tour de rôle.

Le CCEN a participé à l'atelier annuel sur les contaminants de la faune en septembre 2017 au Collège de l'Arctique du Nunavut; a payé les frais de voyage d'un étudiant inscrit au programme de technologie écologique afin qu'il puisse assister à l'atelier sur la santé du phoque (C-12), qui a eu lieu à Resolute Bay en octobre 2016; et a participé à l'atelier sur la santé humaine et la communication des risques du PLCN de novembre 2016.

Le CCEN a présenté des commentaires aux chercheurs du PLCN au sujet des produits de communication (rapports sommaires et affiches) destinés aux collectivités, il a rencontré en personne des chercheurs financés dans le cadre du PLCN pour discuter de leurs propositions et projets respectifs, et il a assisté à des séminaires et à un atelier organisés par des chercheurs du PLCN.

Key Messages

- Through its social-cultural review of all Nunavut-based NCP proposals, the 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

- Grâce à son examen socioculturel de toutes les propositions pour le PLCN concernant le Nunavut, le CCEN s'assure que les intérêts du Nord et des Inuits sont pris en compte dans les recherches scientifiques menées au Nunavut.
- Le CCEN se veut une ressource pour les Nunavummiuts afin qu'ils puissent obtenir des renseignements sur les contaminants transportés sur de grandes distances que l'on trouve au Nunavut.

Objectives

- Through its social-cultural review of all NU-based NCP proposals, the NECC ensures the interests of Nunavummiut are being addressed during research activities, by making certain that:
  - Local or northern training and capacity building opportunities are pursued by Principal Investigators (PI) whenever possible;
  - Inuit Qaujimajatugangit (IQ) is incorporated into the study design and process;
  - Research results are appropriately communicated back to participating or nearby communities; and
  - Meaningful community consultation is achieved.
- Assist researchers with conversion of NCP-funded contaminant research results into plain language that is understood by Nunavummiut.
- Assist and advise NCP-funded researchers on the relevant methods and distribution of communication materials to communities.
- By way of Government of Nunavut Department of Health (GN-DOH) representatives on the committee, provide relevant NCP-funded contaminant research results to the Chief Medical Officer of Health (CMOH).
- Work in partnership with communities, researchers, governments, and Inuit organizations when undertaking community outreach related to communicating NCP research results.
- When requested by the GN, provide support to the CMOH who will work in collaboration with Nunavut Tunngavik Inc.(NTI) on the development, implementation, and follow up of nutrition recommendations, food policies, and public health messages resulting from NCP funded contaminants research
- 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 NCP Secretariat, which funds long-range contaminants research in the north. 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 the committee's primary focus. Through its review of all NU-based proposals, the committee ensures northern and Inuit interests are being served by scientific research conducted in Nunavut.

Activities in 2016-2017

The following activities were undertaken by the NECC in 2016-2017:

- Attended the NCP Management Committee meeting in Ottawa, ON in April 2016 (NTI co-chair and a Government of Nunavut Department of Environment (GN-DOE) representative).
- Attended the NCP Management Committee meeting in Whitehorse, YK in October 2017 (CIRNAC and NTI co-chairs and a GN-DOE representative).
- Hosted face-to-face NECC social-cultural review meeting February 22-24, 2017 in Iqaluit (16 people participated in the review of 32 NCP proposals and co-chairs provided detailed feedback in a summary report to the NCP Secretariat).

- Hosted a face-to-face NECC meeting/ teleconference on September 21, 2016 to review mid-year reports, review NCP blueprints, and to discuss NECC matters (terms of reference, state of knowledge report, Indigenous knowledge working group, etc.).
- Participated in the Wildlife Contaminants Workshop at NAC in September 26-30, 2016 (NECC committee members gave presentations on the NCP and best practices for communicating results).
- Supported one NAC ETP student's travel to Resolute Bay to participate in a NCP-funded seal health workshop (C-12) in October 2016.
- Attended the human health and risk communication workshop in Ottawa, ON in November 2016 (CIRNAC co-chair and 3 GN-DOH representatives).
- Attended the ArcticNet Scientific Meeting in Winnipeg, MB in December 2016 (CIRNAC and NTI co-chairs).
- Participated in a teleconference in December 2016, organized by the NCP and GN-DOH to discuss mercury in beluga in Nunavut.
- NECC participated in a meeting on September 30, 2016 with Mary Gamberg, regarding her project on Arctic caribou monitoring (M-14).
- NECC members (CIRNAC, Nunavut Research Institute (NRI), GN-DOE, GN-DOH) met with Hayley Hung, Alexandra Steffen, and Liisa Jantunen on February 20, 2017 in Iqaluit to discuss community outreach plans for their respective proposals (i.e. M-01, M-02, M-03, M-22) and NECC was invited to the seminar/workshop they gave at the NAC on February 21, 2017.
- Attended a presentation and met with Tanner Liang to discuss community outreach plans for their research on terrestrial moss as bioindicators (M-23).
- Provided feedback on plain language summary reports prepared by PIs for community dissemination (see Appendix 1 for a complete list of NECC reviews).

Results

The NECC provided feedback to researchers on communications (i.e., plain language summaries, reports, posters). The NECC also completed the 2016-2017 NECC Mid-Year Report Review Summary Report and 2017-2018 NECC Social-Cultural Review Summary Report.

Discussion and Conclusions

The work of the NECC is on-going and will continue into 2017-2018. The NECC saw many changes (Nunavut no longer has an Inuit Research Advisor and there were a total of three CIRNAC co-chairs over the course of the year) but overall, had a successful year. NECC plans to continue building on the contacts 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 assisting Principal Investigators with communicating research back to their partnering communities and encourages researchers to contact NECC before they embark on any community consultations or communications.

In terms of the upcoming work plan, NECC aims to increase regional representation on our committee by soliciting new members from each of Nunavut's regions: Qikiqtani, Kivalliq, and Kitikmeot. NECC will continue with its regular annual activities including reviewing mid-year reports and requests for additional funding; conducting a detailed social-cultural review of 2018-2019 NCP proposals; helping coordinate researcher presentations in Nunavut; and providing feedback to PIs on presentations and communication products intended for community dissemination.

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 (NNHC), originally named the PCB Resource Committee, was established in 1989 to deal with issues related to food, contaminants, the environment, and health in Nunavik. Since its inception, the committee has broadened its perspective to take a more holistic approach to environment and health issues inclusive of both benefits and risks. Today, the committee acts as the 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

Résumé

Le Comité de la nutrition et de la santé du Nunavik (qui s'est d'abord appelé Comité des ressources sur les BPC) a été mis sur pied en 1989 pour étudier les questions liées aux aliments, aux contaminants, à l'environnement et à la santé au Nunavik. Depuis sa création, le Comité a élargi son champ d'action et a ainsi adopté une approche plus globale quant aux questions touchant l'environnement et la santé, qui tient compte des avantages aussi bien que des risques. Aujourd'hui, le Comité fait office d'organe consultatif et d'examen autorisé pour les questions de santé et de nutrition de la région, et comprend des représentants d'un grand nombre des organismes qui s'intéressent

liaison for researchers and agencies, from both inside and outside the region; directs work on priority issues; communicates with, and educates the public on health and environment topics and research projects; and represents Nunavik interests at the national and international levels. All activities are conducted with the goal of protecting and promoting public health in Nunavik, through more informed personal decision-making.

à ces questions ainsi que de ceux qui effectuent des recherches à ce sujet. Le Comité donne une orientation et assure la liaison pour les chercheurs et les organismes de la région et de l'extérieur, dirige les travaux qui portent sur les questions prioritaires, transmet des renseignements au public et éduque celui-ci au sujet de l'environnement et de la santé ainsi que des projets de recherche, et représente les intérêts du Nunavik sur les scènes nationale et internationale. Toutes les activités sont réalisées dans le but de protéger et de promouvoir la santé publique au Nunavik par la prise de décisions personnelles éclairées.

Key Messages

- The Nunavik Nutrition and Health Committee is the key regional committee for health and environment issues in Nunavik.
- The committee advises the Nunavik Public Health Director about educating the public on food and health issues, including benefits and risks associated with contaminants and country foods.
- 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 conseille le directeur de la santé publique du Nunavik à propos des activités d'information et d'éducation concernant la nutrition et la santé, y compris les bienfaits et les risques associés aux contaminants et aux aliments locaux.
- 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 liaise with Nunavik communities, and provide information necessary for the public to understand 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 the objectives and results of environmental health, nutrition, and contaminants research;
- To compile elements of public concern that have not been addressed to date, and to steer and support research activities towards providing the data needed to address these concerns;
- To undertake public communications of environmental health data, including results of northern contaminants-research projects, and help develop regional communications and evaluation strategies for this information;
- To facilitate NCP-funded research and other research on environmental contaminants, nutrition and health including research on risk communications and risk-perception issues;
- To support partnerships in various research and intervention activities related to country food, nutrition, and health;
- To prepare and disseminate information on nutrition, contaminants, and health;
- To define topics related to human health and contaminants to be monitored under the NCP which includes the indicators to be monitored through *Qanuilirpitaa 2017*;
- To contribute to the development of a regional food-security policy that will incorporate the issue of contaminants in country food;
- To support training programs for young Inuit researchers, such as the one funded by the Kativik School Board and linked to *Qanuilirpitaa 2017*.

Introduction

In Nunavik, a group of representatives from different regional organizations concerned with health, the environment, and nutritional issues formed to address these issues and communicate with and educate the public so that the public can make more informed decisions on these issues. The group, the Nunavik Nutrition and Health Committee, evolved from the PCB Committee, created in 1989 (later renamed the Food, Contaminants and Health Committee). The name has changed over the years as the group has learned of the importance to not only focus on negative impacts of contaminants, but also to address the need for a more holistic approach to nutrition, health and the environment, including benefits. On an ongoing basis, the committee addresses a number of issues relating to food, contaminants, nutrition and health, and the relationship to the environment. The committee is the recognized and authorized body for the region on nutrition, health and environment issues. Its mandate addresses the full range of nutritional issues that may affect the health of *Nunavimmiut* in the region. The key priorities are:

- To identify and make available to *Nunavimmiut* easy-to-understand information on food and health issues;
- To promote wise decisions by individuals and organizations in the region on these subjects;
- To advise the Public Health Director and other organizations on the development of nutritional aspects of regional health programs and on research regarding nutrition and health;
- To review and guide the evaluation of health and nutrition research projects and programs so that they meet *Nunavimmiut* needs and expectations;
- To facilitate exchanges between Nunavik organizations on nutrition and health activities;
- To support communications between Nunavik organizations and outside organizations/agencies on these topics.

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 a regional contaminants committee. This report represents a synopsis of the committee's activities for the 2016-2017 year.

Activities in 2016-2017

Meetings and workshops

In 2016-2017, the committee will have met in person twice and conducted three teleconference meetings in addition to a number of regular exchanges through emails.

The first meeting took place in Québec City on June 15, 2016. This spring meeting was held in Québec City to allow the committee to attend the Northern Health Forum (June 16, 2016) at Laval University. It was a one-day meeting to discuss regular topics linked to nutrition, contaminants, and *Nunavimmiut* health. Various subjects and research projects were addressed during this meeting including the biomonitoring and the related communication-evaluation project led by M. Lemire, the regional lead-reduction strategy, the *Qanuilirpitaa 2017 Health Survey* (*INSPQ*-NRBHSS) as well as the Food Security Project under ArcticNet. On the following day, the committee members attended the Northern Health Forum. This forum included four different themes: (i) Major health issues from a northern perspective, (ii) Population health, (iii) Nutrition and food systems and (iv) Social and environmental determinants of health. The forum presentations were very interesting and informative. This event was also a great opportunity for the committee members to connect with researchers working in the north.

Unfortunately, during the fall, it was not possible to meet in person. Nevertheless, the committee held three teleconference meetings (November 7, December 1 and December 20, 2016). During these meetings, we once again addressed and followed up different topics linked to nutrition, contaminants and *Nunavimmiut* health. Updates and information were shared about the NCP Management Committee meeting discussions and the recent Risk Communication Workshop held in November. Results on *Toxoplasma gondii* in country foods were also presented and discussed with the researchers. The regional lead-reduction strategy has also been an important topic. Through a summer project, the current situation in terms of availability of lead and lead-free ammunition as well as related hunting practices have been documented. Moreover, we discussed writing an open letter to acknowledge Nunavimmiut contribution to contaminants research and help the recruitment for the biomonitoring project funded by the NCP. The contaminant component of the *Qanuilirpitaa 2017 Health Survey* has also been a key topic discussed at these teleconference meetings. Finally, we discussed our priorities and upcoming work for 2017-2018.

Three members of the NNHC, Elena Labranche (former NNHC Chairperson), Dr. Françoise Bouchard (Director of Public Health), and Eric Loring (ITK representative for NNHC) participated in the Risk Communication Workshop held in Ottawa on November 22 and 23, 2016.

The last meeting of 2016-2017 was held in February 2017 in Kuujjuaq. It focussed mainly on the review of the 2017-2018 NCP proposals for the region. Moreover, the committee invited the researchers who submitted proposals to the NCP to join by teleconference during this meeting so that questions raised during the proposal review could be clarified with the researchers themselves. The committee has been functioning this way for a few years now and feels that it is very efficient and helpful to meet researchers during the review process. At the meeting, the committee also addressed other topics, namely the *Qanuilirpitaa 2017 Health Survey* including its training program for youths, preliminary results of metals in Arctic char of Deception Bay by the Nunavik Research Centre, the BRIGHT (*Bridging Global change, Inuit Health and the Transforming Arctic Ocean*) project under Sentinel North and zoonosis testing by the Laval University research team.

Mercury guidelines for health practitioners

In 2016-2017, the development of comprehensive regional mercury guidelines for health practitioners was pursued. This initiative is made possible through close collaboration between researchers and the Public Health Department. The content of these guidelines is greatly informed by past and present NCP funded projects, namely by the "Exposure to food chain contaminants in Nunavik: evaluating spatial and time trends among pregnant women & implementing effective health communication for healthy pregnancies and children" project.

Lead reduction efforts

In the summer of 2016, Claudel Pétrin-Desrosiers a medical student for the Public Health Department conducted a study on the availability of lead-based ammunitions and some related hunting practices in Nunavik. The results of her work have been presented to the Nunavik Hunting Fishing Trapping Association (NHFTA) annual general meeting in November 2016. The presentation was very well received and the NHFTA adopted a resolution to support the reestablishment of a regional ban of lead-ammunitions in the region. In 2017-2018, efforts will be pursued to promote a lead-free environment in Nunavik.

Committee visibility

The committee reviewed and reissued its presentation pamphlet. In August 2016, the NRBHSS launched its new website. Under the Public Health section of the website, information on the NNHC mandates and membership is presented. The updated committee presentation pamphlet is also available online. All content of the website is available in Inuktitut, French and English.

Discussion and Conclusions

We believe that there is a great need to pursue the interorganizational collaboration and communication through the committee's work on the important issues of food, contaminants, nutrition, and health.

Members of the committee will continue working on various files related to food, contaminants, nutrition, and health including the planning and realization of the *Qanuilirpitaa 2017 Health Survey*, the elaboration of a regional lead exposure-reduction strategy, the development of a regional food-security policy as well as the completion of regional mercury guidelines for health practitioners.

Furthermore, collaboration and communication between the committee and the NCP projects researchers will be maintained. The NNHC also wishes to see and reinforce the emergence of meaninful community-based and community-led projects in the region.

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.

Appendix 1

Nunavik Nutrition Health Committee presentation pamphlet 2016.

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/Chef de projet

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Project Team/Équipe de projet

Rodd Laing, Environment Division, Nunatsiavut Government; Elizabeth Pijogge, Northern Contaminants Researcher, Nunatsiavut Government

Abstract

The Inuit Research Advisor (IRA) for Nunatsiavut continues to serve as the first step in a more coordinated approach to community involvement and coordination of Arctic science and represents a new way of knowledge sharing and engagement of Inuit in Arctic science. The Nunatsiavut Government (NG) encourages researchers to consult with Inuit Community Governments in the five Nunatsiavut communities, Rigolet, Makkovik, Postville, Hopedale and Nain, as well as NG departments in developing more community based research proposals. Comprehensive reviews of proposals are initiated involving appropriate NG departments, 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

Résumé

La conseillère en recherche inuite (CRI) du Nunatsiavut poursuit son mandat, qui constitue la première étape d'une approche coordonnée en matière de participation et de coordination communautaires dans le domaine des sciences de l'Arctique. Elle propose un nouveau moyen de diffuser les connaissances et de mobiliser les Inuits en ce qui concerne les sciences de l'Arctique. Le gouvernement du Nunatsiavut incite les chercheurs à consulter les gouvernements des cinq collectivités inuites du Nunatsiavut (Rigolet, Makkovik, Postville, Hopedale et Nain) ainsi que ses ministères en vue d'élaborer de nouvelles propositions de recherche communautaire. L'examen complet 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 CRI du Nunatsiavut

the region. In addition to NCP support, the program is co-funded by ArcticNet and the Nunatsiavut Government.

s'efforce de promouvoir une nouvelle façon de diffuser les connaissances et de mobiliser les Inuits en ce qui concerne les sciences de l'Arctique dans la région. Le financement des activités est conjointement assuré par le Programme de lutte contre les contaminants dans le Nord (PLCN), ArcticNet et le gouvernement du Nunatsiavut.

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 52 researchers from April 1st, 2016 to March 31st, 2017. 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.

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. Elle a communiqué avec plus de 52 chercheurs pendant la période du 1er avril 2016 au 31 mars 2017. Cette année, elle a présidé 12 réunions du Comité consultatif de la recherche du Nunatsiavut. L'une d'elles était une réunion en personne tenue à Nain.
- La CRI a aussi joué le rôle d'agent de liaison, de contact et d'assistant pour ce qui est des projets de recherche menés au Nunatsiavut. Entre autres, elle a mis les chercheurs en contact 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 autres 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 (i.e. the 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 the 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 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 2016-2017:

- 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 as well as one face to face meeting in Ottawa.
- Participated in numerous teleconferences as a member of the Inuit Qaujisarvingat National Committee and attended one face to face meeting in Ottawa.
- 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 ArcticNet's annual scientific meeting in Winnipeg and presented/co-presented during ArcticNet's student day activities as well as during the conference.

- 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.

Discussion and Conclusions

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 projects 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

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Abstract

In 2016/17, the Inuit Research Advisor (IRA) position went through a departmental transition within Inuvialuit Regional Corporation (IRC) with the recent establishment of a new Research Division within our organization. From January 2016 to the end of February 2017, the IRA position continued to be housed in the Community Development Division under the supervision of Evelyn Storr and Jiri Raska. Then from March 2017 until present, the Research Division was moved to the 2nd floor of the Inuvialuit Corporate Center and is now being led by Jenn Parrott, Research Manager of the Research and Community Support Division. This new office location is ideal due to its close proximity to the Joint Secretariat and Inuvialuit Game Council offices as our three offices are each involved with NCP research. Within this time frame, the Inuit Research Advisor has continued to conduct the activities as outlined in IRC's annual proposal submission to NCP.

Résumé

En 2016-2017, le poste de conseiller en recherche inuite (CRI) a fait l'objet d'une transition ministérielle à la Société régionale inuvialuite en raison de la mise en place récente d'une nouvelle division axée sur la recherche au sein de l'organisation. Pendant la période de janvier 2016 à la fin de février 2017, le poste continuait d'être abrité à la Division du développement communautaire, sous la supervision d'Evelyn Storr et de Jiri Raska. Puis, en mars 2017, la Division de la recherche a déménagé au deuxième étage du Inuvialuit Corporate Centre et est maintenant dirigée par Jenn Parrott, gestionnaire de recherche de la Division de la recherche et du soutien communautaire. Le nouvel emplacement des locaux est idéal en raison de la proximité avec les bureaux du Secrétariat commun et du Conseil de gestion du gibier, puisque ces bureaux participent tous les trois aux travaux de recherche du PLCN. Au cours de cette période, la CRI a continué de réaliser les activités énoncées dans la proposition

In 2016-17, the IRA completed the following activities:

- Attended and participated in the social and cultural proposal review of proposals in Yellowknife in February 2017. At this meeting, Shannon O'Hara was re-nominated and accepted the role of Vice Chair of the Northwest Territories Regional Contaminants Committee (NWTRCC).
- Attended and participated in NCP's risk management communications workshop held in Ottawa in November 2016 to learn about the NCP initiatives in place across the north in risk management by listening to presentations and participating in group break-out sessions.
- Developed an NCP specific Power Point presentation for use during communication and outreach activities and presented this to the NWT RCC during the February 2017 meeting. There was good feedback and suggestions to improve it were given. Overall, the presentation was very well received by the Committee, which led to regional reps requesting that the NCP include more metrics in results given to communities in regards to funding social-cultural deliverables.
- Provided continued support and assistance to researchers who have funded NCP projects, specifically those outlined in the proposal (i.e. Trevor Lantz, Laurie Chan, Hayley Hung, Derek Muir).

annuelle soumise par la Société régionale inuvialuite dans le cadre du PLCN.

En 2016-2017, la CRI a exécuté les activités suivantes :

- Assister et participer à l'examen des propositions sociales et culturelles en février 2017 à Yellowknife. Lors de cette rencontre, Shannon O'Hara a été reconduite dans ses fonctions et a accepté d'agir en qualité de vice-présidente du Comité régional des contaminants des Territoires du Nord-Ouest (CRCTNO);
- Assister et participer à l'atelier de communication en gestion des risques du PLCN qui a eu lieu en novembre 2016 à Ottawa afin de mieux connaître les initiatives de gestion des risques du PLCN en place dans le Nord en assistant aux présentations et en participant aux séances en ateliers du groupe;
- Concevoir un exposé en PowerPoint sur le PLCN destiné aux activités de communication et de sensibilisation, et le présenter au CRCTNO à la réunion de février 2017. Il y a eu des commentaires positifs, et des suggestions d'amélioration. Dans l'ensemble, la présentation a reçu un accueil très favorable de la part du Comité, ce qui a incité les représentants régionaux à demander à ce que le PLCN intègre plus de paramètres dans les résultats transmis aux collectivités au chapitre du financement des livrables sociaux et culturels;
- Assurer une aide et un soutien continus aux chercheurs travaillant à des projets financés dans le cadre du PLCN, particulièrement ceux nommés dans la proposition (Trevor Lantz, Laurie Chan, Hayley Hung et Derek Muir).

Key Messages

- The IRA is now well integrated into the research landscape within the ISR through the transition into a new Research Division that has taken place and has continued conducting duties as outlined in appendix

Messages clés

- Le poste de CRI fait maintenant partie intégrante de la recherche dans la région désignée des Inuvialuit grâce à la transition vers une nouvelle division de la recherche, et son titulaire continue d'exercer les fonctions

1, 2 and 3 of annual proposal submitted to NCP.

- The IRA continues to participate and serve as a representative of the IRC in key NCP activities. (i.e. NWT Regional Contaminants Committee teleconferences and in person meetings, mid-year reviews, and other events such as this year's risk management workshop.
- The IRA continues to deliver on funded projects, and has successfully completed the new NCP specific PowerPoint presentation which was presented to the NWTRCC in February 2017.
- The IRA has not had the opportunity to deliver any regional communication products or in person presentations to our six communities in a couple years and would like to be able to go through an evaluation process in order to continue to offer this information to the region again. Any specific direction and advice that could be offered from any members of the NWTRCC or the Management Committee would be appreciated.

énoncées aux annexes 1, 2 et 3 de la proposition annuelle soumise dans le cadre du PLCN.

- La CRI continue de participer aux principales activités du PLCN et d'agir en qualité de représentante de la Société régionale inuvialuite (téléconférences et réunions en personne du CRCTNO, examens semestriels, et autres événements comme l'atelier sur la gestion des risques de cette année).
- La CRI continue de réaliser des projets financés et elle a créé une nouvelle présentation en PowerPoint sur le PLCN, qu'elle a présenté au CRCTNO en février 2017.
- Au cours des dernières années, la CRI n'a pas eu l'occasion d'offrir des produits régionaux de communication ou de faire des présentations en personne dans les six collectivités, et elle aimerait être en mesure d'exécuter un processus d'évaluation afin de pouvoir offrir de nouveau ce service d'information dans la région. Les membres du CRCTNO ou du Comité de gestion qui auraient des conseils ou des directives spécifiques à donner à ce sujet sont invités à le faire.

Objectives

- Continue to conduct IRA duties as outlined in appendix 1, 2, and 3 of the IRC proposal to NCP.
- Attend NWTRCC Social-Cultural Review and other Committee related communication.
- Development of a new NCP specific PowerPoint presentation.
- Continued involvement and communication with NCP funded project leaders and project teams in the ISR.

Introduction

The Inuit Research Advisor for the Inuvialuit Settlement Region has been working with the NCP for ten years (2007-2017). Previous NCP funded positions within IRC include the Health and Environment Research Coordinator (HERC) from 2007-2010 and Regional Contaminants Coordinator (RRC) that dates back to the 1970's-1990's when the position was is in its transition to what it is now in Inuit regions. The IRA position was initially developed as part of a co-funding agreement made between arctic research organizations ArcticNet and Nasivvik, and invited NCP to also contribute to and help develop this new position. Now, ten years later, the IRA position is a nationally recognized role that is ideally placed in Inuit regions in Canada, where research has increased exponentially since the International Polar Year in 2007-2008. This movement in research sparked a need to create a position situated in the north to help bridge the communication between researchers and communities. In past years (2007-2015), the NCP funded the IRA in the ISR to conduct regional community tours and the development of a regionally focused research newsletter that brought the results and current news on research to residents in the ISR. From 2015 to present the IRA has a reduced workload that only includes IRA and NCP specific duties, moving away from the tri-organization focus that was developed with the other two funders of research. With Nasivvik no longer in operation and ArcticNet preparing to sunset as well in 2018, it is now time for northern organizations and the NCP to plan a path forward in monitoring contaminants in the north. This path forward must not lose the relationships and capacity that has been built and must utilize what has been established for the mutual benefit of northern communities and the NCP. There is a need to re-visit the partnership and discuss with northern regions and NCP what monitoring for contaminants in Canada's north will look like in the next twenty years to come.

Activities in 2016-2017

Capacity Building

As per training funding provided by ArcticNet, IRAs received group course training at the ITK office in Ottawa in May 2016 by an accredited instructor from University of Ottawa, titled: "Moving from Research into Policy". This training was the second part of training done in the previous year.

It was outlined through developing the NCP PowerPoint presentation that more than 50% of NCP funded research in the NWT is in the Inuvialuit Settlement Region, and that dedicated funding should be provided to regions in the NWT (Dene, Metis, Tlicho, Gwich'in, and Inuvialuit) to develop stronger social and cultural review capabilities. Additionally these regions should receive more support to start building capacity at the local level with the goal of replicating a similar model to the "Regional Contaminants Coordinator". This would build capacity and increase the number of Inuit and other Indigenous communities actively engaging in NCP programs. This new model would take lessons learned and assist regions to standardize the position across the north.

In a new project funded by the NWT Anti-Poverty Fund, the IRA conducted a regional consultation survey, through hiring a total of twelve local surveyors to conduct a baseline survey around a proposed regional country foods exchange program. This consultation aims to revive a country foods sharing network that would have existed long ago. This project successfully built capacity and provided an income for people in each Inuvialuit community and will provide IRC with the detailed information required to develop an anti-poverty program that will work for the ISR.

Communications

In May 2016, IRA's attended two events in Ottawa. Annual IRA training as was alluded to in the Capacity Building sections above, but the IRAs also attended an ArcticNet, Inuit Advisory Committee, Inuit evaluation meeting/workshop which was facilitated by the same instructor at the University of Ottawa. The group brainstormed a mission and a vision for the Legacy of Research and tried to develop priorities that could be accomplished to help Inuit benefit from research in the arctic.

In November 2016, the IRA for ISR attended the NCP Risk Management Workshop in Ottawa to learn about risk communication and contribute to break out sessions.

During the ArcticNet Annual Scientific Meeting (ASM) in Winnipeg in December 2016, IRA's Carla Pamak and Shannon O'Hara did a co-presentation on engaging and delivering research results to Inuit communities. This presentation was well received and there were many follow up conversations with students and others afterwards.

Also at the ASM, IRA's and other members of the Inuit Advisory Committee of ArcticNet, provided a presentation on the Inuit Research Legacy Project. There were on the go and facilitated break-out sessions to gather feedback on the Inuit Research Legacy Project from conference attendees who were other Inuit, researchers, educators, students and other northerners. Their feedback will help guide our content.

In November 2016, the IRA for ISR attended the NCP Risk Management Workshop in Ottawa to learn about risk communication and contribute to break out sessions.

In February 2017, the IRA for ISR presented a NCP specific PowerPoint This presentation was made to the NWT Regional Contaminants Committee during the Social and Cultural review meeting in Yellowknife.

Indigenous Knowledge Integration

As per IRA membership on the Inuit Advisory Committee of ArcticNet and the National Inuit Committee on Research (IQ) at ITK, IRA's have had the opportunity to be part of two important initiatives that will help bring more Indigenous knowledge integration to research in the north including:

- The development of an IRA Legacy Document and the conduct of an Inuit specific evaluation of ArcticNet.
- The development of a national Inuit Research Committee that is working on issues such as traditional knowledge integration, ethics, Indigenous Knowledge, and other issues of importance to Inuit at the national level.

IRAs also are involved and sit on the National Inuit Climate Change Committee (NICC) at ITK and have the opportunity to be involved in national level document reviews as well as the development of policies that will impact climate change adaptation in the north.

Results

All 2016-17 deliverables were completed by the IRA without any delays as per this report and the proposed timeline.

In terms of the ending of the IRA program, there is a need for a new model for NCP and Indigenous organizations across the north in how they will work together on contaminants issues as the current model is not consistent across the north. There are a few areas that should be addressed or considered within the upcoming fiscal year in regards to addressing the underlying issue of capacity building within the north, which from lessons learned can only be addressed through meaningful jobs and positions that offer a person an incentive to continue to work as a Regional Contaminants Coordinator or IRA. This discussion must take place at the regional level with the organizations that are partners with the NCP so that Indigenous people and organizations can help guide this new model in a way that is regionally specific and culturally appropriate.

Discussion and Conclusions

With the IRA Program sun setting and in its final year of co-funding by the NCP and ArcticNet, it is time for the NCP to look at a new way forward on how to maintain the relationship between Inuit and other Indigenous regions that are covered by the program. There is need to develop a new, updated model of Indigenous integration into the NCP that best serves northern communities and the northern Indigenous partners which have a long standing relationship with NCP. There is a need to re-define what communication, capacity and outreach looks like at NCP in this new era of research communication. With capacity built with the previous Regional Contaminants Coordinators (RCC's) and the IRA Program, there is now a new model for other Indigenous regions to emulate that is grounded in partnerships between Land Claims organizations, which worked well for both parties. The NCP and these groups need to discuss what this new model could look like and try to improve overall partnerships by addressing areas that need improvement in regions that need more capacity to fully participate in NCP call for proposals, meetings, and events.

Expected Project Completion Date

This project is ongoing.

Project website (if applicable)

www.inuvialuit.com (new)

Acknowledgments

None at this time.

Nunavik Inuit Research Advisor: Building health and environment- Research Capacity in the Nunavik Region

Conseiller en recherche inuite au Nunavik : établissement d'une capacité de recherche sur la santé et l'environnement dans la région du Nunavik

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Project Team/Équipe de projet

Nunavik Nutrition and Health Committee (NNHC), Makivik Corporation, Inuit Tapiriit Kanatami, ArcticNet

Abstract

The Nunavik Inuit Research Advisor (IRA) continues to serve as the first step in a more coordinated approach to community involvement and coordination of Arctic science in Nunavik. The IRA position is housed within the Renewable Resources Department of the Kativik Regional Government and works closely with the Nunavik Nutrition and Health Committee, the Nunavik Board of Health and Social Services, and the Makivik Research Center. The objective of the IRA position is to help facilitate research, at the program level, by assisting researchers from the Northern Contaminants Program (NCP) and ArcticNet, and by updating communities in advance of research. Together, with IRAs in the other Inuit regions of Canada, the Nunavik IRA works towards achieving a new way of knowledge sharing and engagement of Inuit in Arctic science and research. In addition to NCP

Résumé

Le poste de conseiller en recherche inuite au Nunavik (CRI) est toujours la première étape d'une approche plus concertée en matière de participation communautaire et de coordination des sciences arctiques au Nunavik. Le CRI travaille à l'Administration régionale Kativik (Ressources renouvelables, Environnement et Aménagement des terres) et collabore étroitement avec le Comité de la nutrition et de la santé du Nunavik (CNSN), la Régie régionale de la santé et des services sociaux du Nunavik, et le Centre de recherche de Makivik. Il est chargé de faciliter les recherches dans le cadre du programme en aidant les chercheurs du Programme de lutte contre les contaminants dans le Nord (PLCN) et d'ArcticNet, ainsi qu'en préparant les collectivités aux recherches. Avec les CRI d'autres régions inuites du Canada, le CRI du Nunavik cherche un nouveau moyen de mettre en commun les connaissances et de faire

support, the Nunavik IRA position is co-funded by ArcticNet.

participer les Inuits aux activités scientifiques et aux recherches dans l'Arctique. En plus de l'appui du PLCN, le poste de CRI au Nunavik est cofinancé par ArcticNet.

Objectives

The broad objectives are to:

- make research more specific to the needs and interests of Nunavimmiut.
- provide input and direction from a Nunavummiut perspective on proposals and research to the NCP.
- help researchers and Nunavik communities coordinate and share information.
- To be (along with the NNHC) one of the first points of contact for NCP researchers working in Nunavik.
- To provide a voice in the NCP proposal process and communication of NCP health information to Nunavik communities and sit on the Nunavik Nutrition and Health Committee.
- To continue to meet and advise community governments and members as well as researchers to ensure research needs are being met.

The IRA undertakes a number of diverse tasks for the KRG ranging from attending workshops, meetings, and focus groups to collaborating and networking with researchers. The Nunavik IRA is also currently a member of the Kativik Environmental Advisory Committee which was created by virtue of Section 23 of the James Bay and Northern Quebec Agreement.

Introduction

In Nunavik, the NNHC is a group of representatives from different regional organizations concerned with health, the environment, and nutritional issues which formed to address concerns regarding contaminants. The NNHC communicates NCP research to the public in order for Nunavimmiut to make informed decisions on their consumption of traditional and store bought foods. The Inuit Research Advisor provides guidance and recommendations related to Inuit needs, priorities, policy development, and research to the NNHC which is then transmitted to the NCP, ArcticNet, ITK and ICC.

Coordination, participation and communication will be key aspects to the evolving responsibilities of the Inuit Research Advisor. The NNHC is a hub for researchers and community members for concerns related to contaminants related research, and the NNHC 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. This engagement of the IRA with the NNHC and NCP places the IRA in an important role in addressing issues related to contaminants, food and health in the region.

ArcticNet and the NCP annually fund many researchers and research activities. The funding programs inform researchers about IRAs and encourage regular contact with them. Funding programs would benefit from knowing which researchers the Nunavik IRA has been in contact with. At the beginning of each fiscal year, a list will be received from the two funding programs outlining the research activities scheduled to take place in Nunavik.

Activities for 2016-2017

This has been a transitional year for the Nunavik IRA Program. Betsy Palliser, the Nunavik Inuit Research Advisor since 2013, resigned in June to pursue other career paths. Minnie Tookalook was hired by the KRG as the Nunavik IRA in September but resigned in October. Following job postings, Robert Watt was confirmed as the Nunavik Inuit Research Advisor at the beginning of March. In the months without a designated Nunavik IRA, Monica Nashak Environmental Technician was available upon request to respond to the requirements of Researchers and Communities. In addition other KRG employees in the Renewable Resources, Environment Lands and Parks Department made themselves available.

During the year, the Inuit Research Advisors and Department staff kept in regular contact and participated with the Nunavik Nutrition and Health Committee in telephone conferences and discussions. Specifically they participated in a two day meeting held in Kuujjuaq in February 2017 which focussed on the review of the 2017-2018 NCP proposals. Other topics addressed include the *Qanuilirpitaa 2017 Health Survey* and its training program for youth, the preliminary results of the Nunavik Research Centers' study on metals in the Arctic char of Deception Bay, and the BRIGHT (*Bridging Global change, Inuit Health and the Transforming Arctic Ocean*) project under Sentinel North, and zoonosis testing. They participated in the ArcticNet Inuit Advisory Committee and in the review of ArcticNet project proposals and reports, in addition to attending Arctic Net's Annual Scientific Meeting in Winnipeg in December 2016. Additionally, the IRAs and Department staff participated as members of the Tukisik Observatoires hommes-milieux international's (OHMI) steering committee in reviewing project reports, funding applications, and research recommendations.

At the regional level contact was maintained with the two other Inuit Research Advisors, ITK and the Nunavik Research Center and staff continued their involvement in the ice monitoring project in Deception Bay, Salluit, and Kangiqsujuaq. They also participated in consultations on the proposal to build a Centre d'études nordiques research center in Kangiqsualujjuaq.

The Nunavik IRA (Robert Watt) attended the Institut nordique du Quebec's (INQ) forum on the research needs of First Peoples in Val-d'Or in March at the Université du Quebec en Abitibi-Temiscamingue. Through this forum, First Peoples' (Inuit, Cree, Naskapi, and Innu) and their representatives as well as researchers were able to identify research needs and align them with INQ's five research priorities. These research priorities include: societies and culture, health, ecosystem functioning and environmental protection, infrastructure and technology, and natural resources.

Consultation

The IRA regularly consults with such entities as KRG departments, Nunavik Inuit Community Governments, the Makivik Corporation as well as the ITK and ICC.

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 from September 26 to 30, 2016. The workshop employed classroom lectures, group discussions, and interactive laboratory activities to teach core concepts, issues, and methodology related to the study and assessment of chemical contaminants in the Arctic environment from both scientific and Inuit perspectives. Students learned

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 au 30 septembre 2016. L'atelier comprenait des cours magistraux, des discussions de groupe et des activités interactives en laboratoire visant l'enseignement des concepts de base, des problèmes et des méthodes propres à l'étude et à l'évaluation des contaminants chimiques présents dans

directly from Northern Contaminants Program research scientists about how contaminant trend monitoring programs are designed and conducted. Students also received hands-on training in specific methods for arctic char sampling and organic contaminant analysis. Students also took part in a unique dialogue with an experienced elder/hunter about traditional methods used 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 evaluation of the workshop found that student self-assessed knowledge of and ability to communicate about contaminant issues as well as dissection skills related to contaminant analysis increased in association with the instruction provided.

l'environnement arctique, du point de vue tant des chercheurs que des Inuits. Les étudiants ont appris directement auprès des scientifiques du Programme de lutte contre les contaminants dans le Nord comment les programmes de surveillance des tendances des contaminants étaient conçus et exécutés. Les étudiants ont aussi reçu une formation pratique sur des méthodes particulières d'échantillonnage de l'omble chevalier et d'analyse des contaminants organiques. Ils ont également eu l'occasion de discuter avec un aîné chasseur d'expérience au sujet des méthodes traditionnelles servant à évaluer la santé de l'animal et à déterminer l'innocuité et la qualité des aliments traditionnels. Pendant l'atelier, on a enseigné aux étudiants des méthodes d'évaluation des risques pour la santé posés par les contaminants dans les aliments traditionnels, et ils ont participé à l'élaboration de stratégies de communication des résultats des recherches sur les contaminants et des 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 leur capacité de communiquer des renseignements sur les problèmes des contaminants avaient augmenté grâce à l'atelier. Il en est de même pour leurs compétences en dissection dans le cadre de l'analyse des contaminants.

Key Messages

- The Wildlife Contaminants Workshop was held at the Nunavut Arctic College as part of the Environmental Technology Program in September 2016.
- Students, elders, community members, and researchers were involved in the workshop with the purpose of building shared knowledge and understanding of contaminants in northern wildlife.
- A structured evaluation was completed to determine the workshop's effectiveness in improving student understanding of

Messages clés

- Un atelier sur les contaminants environnementaux a été donné en septembre 2016 au Collège de l'Arctique du Nunavut dans le cadre du Programme de technologie environnementale.
- Des étudiants, des aînés, des membres de la collectivité et des chercheurs ont participé à l'atelier, qui avait pour but d'améliorer leurs connaissances et leur compréhension des contaminants présents dans la faune du Nord.
- On a procédé à une évaluation structurée pour déterminer dans quelle mesure l'atelier avec réussi à mieux faire comprendre aux

northern contaminant research as well as enhancing student lab/dissection skills, communication skills, and critical thinking.

- Student self-assessed knowledge of and ability to communicate about contaminant issues as well as dissection skills related to contaminant analysis were all found to have improved during the workshop.

étudiants la recherche sur les contaminants dans le Nord, et avait contribué au perfectionnement de leurs compétences en laboratoire, en dissection et en communication ainsi qu'à l'amélioration de leur pensée critique.

- Les étudiants ont évalué leurs connaissances et leur capacité de communiquer des renseignements sur les problèmes des contaminants, ainsi que leurs compétences en dissection dans le cadre de l'analyse des contaminants, 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:

- Build students awareness and understanding of the Northern Contaminants Program (NCP) and to help students contextualize information about contaminants within broader health and environmental contexts.
- Improve students' ability to engage in contaminants research in the future by providing training to students using two applied science projects that demonstrate how research projects in the North are used to study wildlife health and the safety of country foods.

Specifically, the workshop aimed:

- To enhance student knowledge and understanding of contaminant sources and pathways.
- To increase student awareness of contaminants research being done in northern Canada, and its role in informing guidelines and policies.
- To enhance student understanding on how health risks related to contaminants in country foods are assessed.
- To engage students in developing and evaluating materials/strategies to communicate contaminants information to target audiences in their home communities.
- To increase student awareness of how community collaboration is an active and important component of contaminants research.
- To foster student skills in dissection and contaminant tissue collection in two wildlife examples: polar bears and arctic char.
- To provide students an opportunity to interact with contaminant researchers and ask questions about contaminants research in the North.
- To increase student awareness of the value of bringing together local ecological knowledge with science for contaminants research and understanding.

- To carry out a formal evaluation to assess the workshop's ability to increase student understanding of northern contaminant studies as well as related lab/dissection skills, communication skills and critical thinking related to communication.
- The evaluation also aimed to assess the workshop's impact on student knowledge, skill acquisition, and ability to communicate contaminant studies.
- The evaluation built on the evaluation conducted in 2015-2016.

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' awareness of the Northern Contaminants Program and to enhance their capacity to engage with contaminants research and communication efforts through delivery of targeted training. Frontline worker training courses were conducted 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.

Frontline worker training efforts in Nunavut targeted community professionals, elders, and youth, and did not typically include students from Nunavut Arctic College's Environmental Technology Program (ETP) who enter Nunavut's workforce as frontline environmental practitioners upon graduation. The ETP has now been delivered for 26 years, and has produced approximately 100 graduates who have worked in broad ranging occupations including conservation officers, water and fisheries technicians, environmental policy analysts, environmental assessment practitioners, and environmental educators. ETP graduates have also worked as research advisors, have initiated and led their own community based research projects, and have served on the Nunavut territorial contaminants committee among other science advisory bodies.

The *Wildlife Contaminants Workshop (WCW)* is an adaptable, integrative and iterative training program tailored for the specific learning 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 Nunavut's 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 2013 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 and 2016, 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 2016-2017 ETP class represents the tenth 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 for the second year with researchers from Trent University to carry out a formal evaluation of the workshop. The evaluation aimed to assess the workshop's ability to meet its objectives, evaluate its impact on six standard learning outcomes (depth and breadth of knowledge, knowledge of methodologies, application of knowledge, communication skills, limits of knowledge and understanding, and professional capacity and aptitude) and provide recommendations for content and delivery of future workshops.

Activities in 2016-2017

This year again we held a weeklong workshop that covered several wildlife groups, and how we study contaminants in each. Polar bears and arctic char were the focal species and a new laboratory component was added, where the students participated in the measurement of PCBs in polar bear tissue and mercury in arctic char tissue. A contaminant glossary was developed to help the students learn and understand the new vocabulary, and there was an increased focus on encouraging students to vocalize and explain the different concepts as a way to reinforce understanding and communication skills. This included communication games incorporated throughout the week, in addition to the last day of communication discussions. We also included a lunch-time BBQ of the Arctic char the students dissected which were obtained from Pangnirtung, Nunavut. This component was added as a result of the 2015 workshop evaluation and aimed to increase opportunities for the students and researchers to interact in a more informal setting.

Day by Day Breakdown of Wildlife Contaminants Workshop Activities

Monday Sept 26th

Monday morning started with some housekeeping activities which included initiating the workshop evaluation forms with the students. Once these were complete there was a series of lectures and activities to introduce the students to contaminants (what they are, where they come from, and how they travel). Monday afternoon was the introduction to polar bears and the marine food web in the Arctic, which helped prepare the students for the analytical work they would be doing in the following days.

Tuesday September 27th

In the morning the first years took part in some activities in lectures that examined contaminant trend levels in the Arctic in various wildlife with a focus on climate change. Concurrently, the second years worked in the analytical lab to extract and filter polar bear fat tissue samples for PCB analysis (Figure 1). During down time from the analytical lab the students examined polar bear teeth used for aging (on loan from the GN Dept. of Environment), as well as hair samples from Arctic and non-Arctic species using compound and dissecting microscopes. In the afternoon, the first years did the same

Figure 1. Students work with Rob Letcher and Adam Morris to complete a PCB extraction using GC at the Nunavut Research Institute in Iqaluit.

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Figure 2. BBQ event held during the WCW to encourage more student-researcher interaction in a non-formal setting.

exercises in the lab (polar bear fat, teeth, hair examination), while the second years were given time to clean up gear from the previous week's field camp.

Wednesday September 30th

Wednesday morning focused on the biology of arctic char through series of lectures and activities. In the afternoon the first years dissected arctic char, working through tissue and sampling otoliths in groups of two or three. They also examined otoliths that had been prepared for aging using microscopes (on loan from Yukon Environment). In the second half of the afternoon the first years completed further fat fraction clean-up, solid phase extraction and sample fraction concentration in the lab. The second year students first worked on the same laboratory procedures, and were then given time to complete homework from the previous week's marine biology module.

Thursday October 1st

The morning started with the class being visited by Joshua Kango, a member of the Iqaluit Hunter and Trapper Association, and a regular guest to the Wildlife Contaminants Workshop. Joshua talked with the students and researchers about wildlife health in general, changes he has seen during his own lifetime, and some of the lessons he learned about wildlife from his uncle who was a renowned hunter. In the late morning the students were given a lecture about plastics and plastic-associated contaminants research that is ongoing in northern seabirds, followed by a hands-on activity that examined how stable isotopes of carbon and nitrogen can be used to study trophic level. During the lunch period researchers and members from the NRI staff BBQed hamburgers and the Arctic char the students had dissected (Figure 2). In the afternoon the second year students dissected and then later completed the PCB analysis on their extractions. Meanwhile the first year students completed their PCB extractions first, and then had a lecture on national and international action on contaminants.

In the evening Adam Morris from ECCC gave a community lecture at the Nunavut Research Institute. Simultaneous Inuktitut-English interpretation was made available to all who attended. The title of the talk was "Contaminants in Polar Bear and Wolf Food Chains".

Friday October 3rd

On the last day of the workshop, we aimed to synthesize the ideas that had been explored throughout the week, encouraging the students to practice and develop their own contaminant communication skills. In the morning we focused on Health Advisories and examining the Faroe and Seychelle Islands examples of how complex health messaging can be. After the morning break we were joined by Karla Letto (CIRNAC) who spoke about the NCP in more detail. Before break, general communication and risk communication were discussed to prepare for the afternoon activities. In the afternoon, Amy Caughey (GN Health) spoke about contaminants and country food. In order to discuss and practice contaminant communication, the students then spent the afternoon critiquing the NCP 2016 project plain language summaries, creating communication strategies for the standing NU seal liver advisory, and creating pictograms illustrating the NU seal liver advisory.

Incorporating the evaluation results from the 2015 workshop

We altered the workshop program based on the 2015 workshop evaluation. This included:

- Adding a lecture on human health risks to contaminant exposure and assessment of human health risks. The goal was to enhance student understanding of how health risks related to contaminants in Arctic country foods are assessed.
- Increasing purposeful engagement of students in more contaminant communication planning activities that are critically reviewed/evaluated. The goal was to enhance student engagement in

developing and evaluating strategies to communicate contaminants information in their home communities.

- Adding more time for student interaction with NCP researchers in non-formal settings. As a result we planned a lunch time BBQ for everyone to take part in, and for students to bring their family and friends to ensure wider inclusion of the community (Figure 1).

2016 Evaluation

An evaluation researcher from Trent University (Shirin Nuesslein) was present throughout the workshop.

Methods

Evaluation methods consisted of: 1st and 2nd year ETP students' responses on pre- and post-module surveys for each of the three modules (n=159); follow-up semi-directed interviews with 1st and 2nd year ETP students (n=10); semi-directed interviews with workshop core and guest instructors (n=5); classroom observation; and review of curriculum materials.

Pre- and post-module surveys were used to determine knowledge and understanding before and after each module. Modules included: Module 1A-Contaminants 101 + contaminants in polar bear; Module 1B-Contaminants in birds, fish and seals; Module 2-Dissection/lab; Module 3-Communicating about contaminants. Through analysis of data obtained from returning students participating in last year's workshop the evaluation also examined long-term knowledge and skill retention.

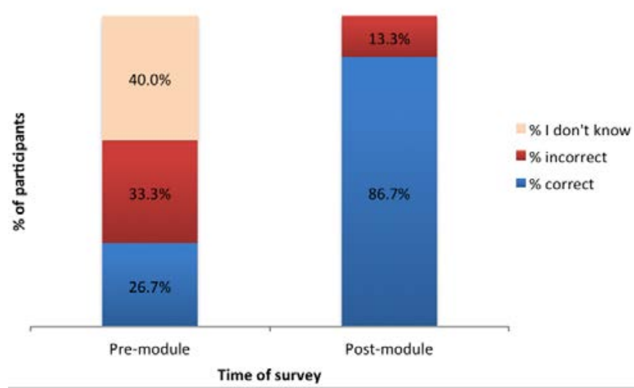
Results

In 2016, the workshop was facilitated by two core instructors, three guest instructors and three guest speakers from local organizations. A total of sixteen 1st year and thirteen 2nd year ETP students participated in the workshop.

Preliminary results give insight to the impact of the workshop on student knowledge of and ability to communicate about contaminant issues, and to perform dissections to prepare tissues for contaminant analyses.

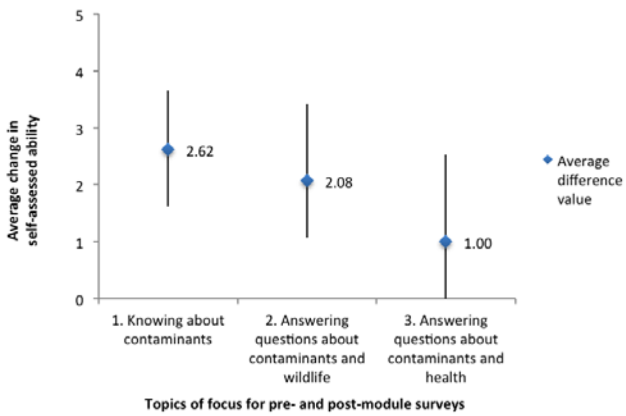
Student ability to answer basic questions on contaminant sources and pathways of exposure improved in association with participation in workshop Module 1. Percentage of correct answered improved by 60% from 26.7% to 86.7% (Figure 3).

Figure 3. Change in responses to multiple-choice question assessing knowledge and understanding on contaminant issues in the Arctic among 1st year ETP students (n=13) pre- and post-Module 1. Question: What is the most important (where they get most of their exposure from) way that people in Nunavut are exposed to contaminants like mercury and PCBs? (n=15 students).



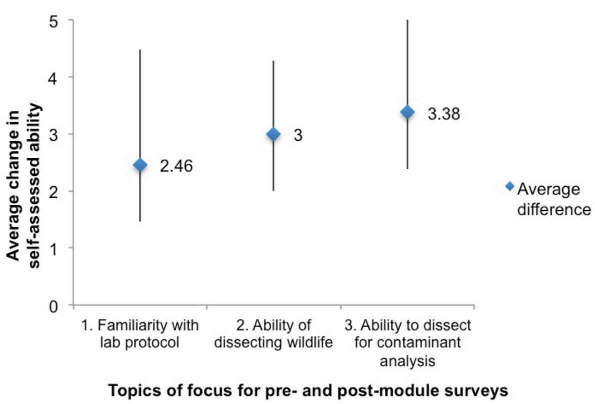
Student self-assessed knowledge of and ability to communicate about contaminant issues increased between the start and end of workshop Module 1. Students reported greater confidence in their knowledge and ability to communicate about contaminants and wildlife as compared to contaminants and human health (Figure 4).

Figure 4. Average change (+/- SD) among 1st year ETP students (n=15) in self-assessed ability on various topics pertaining to contaminant knowledge and communication capacity from pre- and post-module surveys of workshop Module 1. Initial self-assessed ability was reported on a 10 point scale.



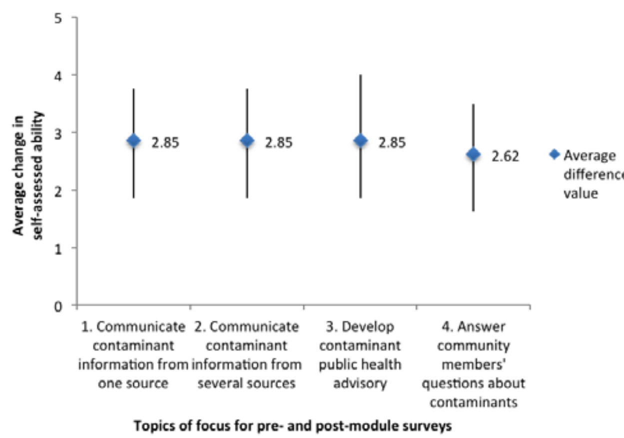
Student self-assessed dissection skill level and familiarity with lab protocols improved in association with participation with workshop Module 2. The most improvement was identified in student ability to dissect animals in preparation for contaminant analyses (Figure 5).

Figure 5. Average change (+/- SD) among 1st year ETP students (n=13) in self-assessed abilities in dissection and contaminant analysis in pre- and post-module of workshop Module 2. Initial self-assessed ability was reported on a 10 point scale.



Student self-assessed ability to communicate about contaminants improved in association with participation in workshop Module 3. Comparable improvement was identified between student ability to synthesize contaminant information from one or several sources, and ability to develop a contaminant-related health advisory (Figure 6).

Figure 6. Average change (+/- SD) among 1st year ETP students (n=13) in self-assessed abilities on various topics pertaining to contaminant knowledge and communication capacity in pre- and post-module surveys of Module 3. Initial self-assessed ability was reported on a 10 point scale.



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 focussed on discussing how researchers communicate their findings using different media, and how these are effective for difference audiences in Nunavut, preliminary results indicate that the workshop is effective in other ways as well. Initial findings of the evaluation indicate that participation in the workshop improves student's self-assessed knowledge of and ability to communicate about contaminant issues and to perform dissections for contaminant analyses, among other things.

Expected Project Completion Date

The workshop component of this project finished in September, 2016. 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 late summer / early fall 2017.

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. Each year, Joshua Kanga provides a valuable discussion where both researchers and students can learn about Inuit traditional knowledge. Also, special thanks to Karla Letto and Amy Caughey for sharing their knowledge with the students.

Learning about ringed seal health from contaminants science and Inuit Qaujimajatuqangit: An educational workshop in Resolute, Nunavut

En apprendre davantage sur la santé du phoque annelé grâce à la science sur les contaminants et aux connaissances traditionnelles des Inuits (Inuits Qaujimajatuqangit) : atelier éducatif à Resolute, au Nunavut

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Abstract

This project addresses a shared interest among Nunavummiut and scientific researchers in enhancing communications and community capacity building related to contaminants research on ringed seals. A workshop was held at the Qarmartalik School in Resolute Bay, Nunavut in the fall of 2016 with the objective of engaging youth, elders, community members and scientific researchers in learning about ringed seals from both Inuit Qaujimajatuqangit and scientific perspectives. The workshop involved students, elders, scientific researchers, school personnel and the local Hunters and

Résumé

Le projet porte sur l'intérêt commun des Nunavummiuts et des chercheurs à améliorer les communications et renforcer les capacités de la collectivité concernant la recherche menée sur les contaminants présents chez le phoque annelé. À l'automne 2016, un atelier a eu lieu à Resolute Bay, au Nunavut, afin d'encourager les jeunes, les aînés, les membres de la collectivité et les chercheurs à s'informer sur le phoque annelé à partir des connaissances traditionnelles des Inuits (Inuit Qaujimajatuqangit) et des avis de scientifiques. L'atelier a permis à des étudiants, à des aînés,

Trappers Organization in a variety of activities designed to give students opportunities to learn about the local environment and wildlife from different perspectives. The main goal of this workshop was to allow scientists working on a NCP core monitoring project on contaminants in ringed seals to share information about the ongoing project with northern residents (with a focus on youth in particular), and provide an opportunity for Inuit elders to share with students their knowledge of seal ecology, and traditional methods for butchering seals, preparing seal skin, and identifying abnormalities in harvested game. The event included interactive presentations made by scientific researchers, as well as seal dissection and seal skin preparation activities guided by local elders. Through a series of surveys and discussions, the project also aimed to identify and inform communication practices and the development of innovative methods of community engagement around contaminants monitoring in wildlife.

à des chercheurs, à des membres du personnel scolaire et à des membres de l'organisation locale de chasseurs et de trappeurs de participer à diverses activités, où ils ont pu en apprendre davantage sur le milieu environnant et la faune selon différents points de vue. Cet atelier avait comme objectif principal de permettre aux scientifiques travaillant à un projet de surveillance de base des contaminants présents chez le phoque annelé du PLCN de communiquer l'information connexe aux résidents du Nord (en particulier les jeunes) et de permettre aux aînés inuits de transmettre aux étudiants leurs connaissances sur l'écologie du phoque et les méthodes traditionnelles de dépeçage des phoques, de préparation de la peau et de dépistage d'anomalies dans le gibier récolté. Cette activité a intégré des présentations interactives de chercheurs ainsi que la dissection d'un phoque et la préparation de la peau sous la direction des aînés locaux. Grâce à une série de questionnaires et de discussions, le projet visait également à établir et à inspirer les pratiques de communication appropriées, et il était axé sur l'élaboration de méthodes novatrices en matière de mobilisation communautaire quant à la surveillance des contaminants chez les espèces sauvages.

Key Messages

- Integration of Inuit Qaujimajatuqangit to the core ringed seal monitoring NCP project was done through a community workshop.
- Teachers, community members, elders and students worked with researchers to increase local capacity in understanding contaminants in ringed seals and its preys.
- Students actively engaged with several types of classroom activities that involved learning about contaminants in the environment and ringed seals.
- Teachers welcomed researcher engagement in the classroom and encouraged the use of science to help improve literacy and numeracy skills.

Messages clés

- L'intégration des Inuits Qaujimajatuqangit au projet de surveillance de base du phoque annelé du PLCN s'est faite dans le cadre d'un atelier communautaire.
- Des enseignants, des membres de la collectivité, des aînés et des étudiants ont collaboré avec les chercheurs au renforcement de la capacité des collectivités locales à comprendre les contaminants présents chez le phoque annelé et ses proies.
- Les étudiants ont participé activement à plusieurs types d'activités d'apprentissage en classe portant sur les contaminants présents dans l'environnement et chez le phoque annelé.
- Les enseignants ont bien accueilli la participation des chercheurs dans la salle

- Teaching tools that re-enforced the use of vocabulary of English and Inuktitut in relation with ringed seals were welcomed and encouraged by school personnel.

de classe et ont encouragé le recours à la science pour contribuer à l'amélioration de l'alphabétisation et des notions de calcul.

- Le personnel scolaire a bien accueilli et encouragé l'intégration d'outils didactiques visant à améliorer l'utilisation du vocabulaire anglais et inuktitut par rapport au phoque annelé.

Objectives

The project aims to engage youth, elders and scientific researchers in learning about ringed seal health from both Inuit Qaujimajatuqangit and scientific perspectives through an educational workshop held at the Qarmartalik School in Resolute Bay, Nunavut.

In the short-term, this workshop pursues the following objectives:

- provide an opportunity for scientists working on contaminants in ringed seals to share information about their work with northern residents (and youth in particular) through synthesized messaging involving seal ecology;
- provide an opportunity for knowledge exchange between Inuit elders, youth, and scientists in seal ecology and traditional methods for butchering seals, preparing seal skin, and identifying abnormalities in harvested game;
- increase the engagement and interest of northern students in contaminants research and traditional seal harvesting;
- identify best practices for communicating with communities, including addressing questions and concerns from community members; and
- identify best practices for engaging and communicating with Inuit youth as part of contaminants research.

Over the long-term, it is hoped that this educational project will expand collaboration and communication between northern residents and scientific researchers working on contaminants in Resolute and beyond.

Introduction

For over two decades, the NCP has been funding a long-term and ongoing research project on contaminants in ringed seals under the Environmental Monitoring and Research subprogram. Northern residents from the communities of Resolute, Arviat, Sachs Harbour and Nain have played a pivotal role in the success of this project by collecting ringed seal samples that were tested for contaminants and reporting biological data from harvested animals. Over the years, the scientific researchers involved in the long-term research project have communicated results from this project to community members mostly through reports and annual community visits. The Nunavut Environmental Contaminants Committee (NECC) has recently suggested increasing community engagement as part of this ongoing work. This suggestion sparked the development of this project. Dominique Henri and Magali Houde (Project Leaders) decided to lead the development of this collaborative project that would directly address a shared interest among Resolute Bay residents and scientific researchers in enhancing communications and community capacity building related to contaminants research in ringed seals. This project was therefore strategically designed to be complementary to an ongoing research project supported under the NCP.

Effective communication and engagement between researchers and community members is central to the success and meaningfulness of contaminants research projects conducted in Northern Canada (CC&O Blueprint 2016-2017). In recent decades, funding bodies and research institutions have increasingly required and encouraged researchers to share information about their projects with interested communities in an effective and timely manner (Aurora Research Institute 1996; ITK and NRI 2007). Researchers also recognize that the meaningful engagement of northern residents can lead to improving research methods and results, as well as enhancing the usefulness of the information generated through the research process (Furgal 2006; Gearhead and Shirley 2007; Pearce et al. 2009). Given the significant role that wildlife plays in Inuit subsistence and cultural identity (Wenzel 1991; Henri 2012), the Inuit, in particular, have a strong interest in understanding and playing an active role in wildlife research projects and to see their traditional knowledge contribute meaningfully to such initiatives (Gilchrist et al. 2005; Henri et al, 2010). However, while efforts have been made to promote greater community engagement in scientific research in northern Canada, recent studies suggest that there is still clearly room for enhancing the involvement of northerners in Arctic science (Brunet et al. 2014; Tondu et al. 2014). This project contributes to addressing this need by offering an educational workshop that will increase the capacity of northern residents (and Inuit youth, in particular) to engage in scientific research on northern contaminants. It will also help for the development of innovative communication and engagement methods related to contaminants monitoring in wildlife.

Activities in 2016-2017

The workshop was entirely dedicated to capacity building, communication and integration of Inuit Qaujimajatuqangit. The design of the workshop, the content and the participants were co-developed between the researchers, representatives from the HTO, and the school staff.

Communications and Capacity Building

The workshop funded by NCP took place on Wednesday, October 5th, 2016 at the Qarmartalik School in Resolute Bay, Nunavut. The scientific team supported by the NCP to attend was composed of Magali Houde, Jennifer Provencher and Mick Appaqaq. Appaqaq was an Environmental Technology Program (ETP) student from the Nunavut Arctic College (NAC) in Iqaluit, who was supported by the NECC to attend and co-teach the workshop.

In the morning, the team worked with the fifteen students from grades 7 to 12. The session started with a short slideshow about contaminants and wildlife in the north. Topics included a brief overview of covered sources and pathways of contaminants, bioaccumulation, biomagnification, and Arctic food webs.

After this introduction, the contaminants in the Arctic food web game was played with the students (Figure 1). Each student was a different animal in the food chain and everyone started with seven elastic bands that represented contaminants. When someone met a person who was higher on the food chain, they had to transfer the contaminants in the right direction (from lower to higher trophic level animal). When they met someone of the same level, they just moved on. After about 3-5 minutes, everyone stopped and put all their elastic bands into the right animal jar. Lower plants and lower trophic level animals had less contaminants (i.e., elastics) compared to upper tropic level animals.

Figure 1. Arctic food web contaminants game played with the students at the Qarmartalik School in Resolute Bay, Nunavut.

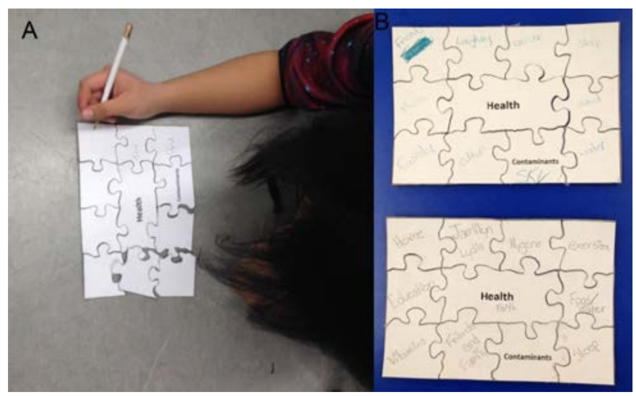
Integration of Inuit Qaujimajatuqangit

After the food web game a hunter from the community dissected the ringed seal which was harvested the day before by another member of the hamlet. The hunter processed the seal while explaining how it was done and what the different parts were for. Two women elders sat by while the dissection occurred and talked, in both Inuktitut and English, about how the different parts were used and prepared for eating. They also discussed how to tell if a seal was healthy and good to eat. One of the students helped pack up small plastic bags with meat and organs that were later distributed to the elders in the community.

After the dissection, the students worked with the Inuktitut teacher to learn and discuss the terminology for seals in their native language. For this lesson the team used a seal poster (without the names of tissues) with the Inuktitut syllabics, roman orthography and English labeled cards. The Inuktitut teacher led the exercise and the students and researchers participated. The teacher again discussed each part of the seal, and had the students sound out the words in syllabics and then practiced the pronunciation with the group.

Lastly, the older students worked on the Health-Contaminants puzzle with the aim to discuss the different components essential for a good health (Figure 2A). Each student put together the puzzle with Health at the centre, and then filled in the blank spaces with elements contributing to their well-being. Students were encouraged to discuss in small groups about the different aspects of life that were important to them and helped contribute to their overall health. Topics that were included by the students were, for example, sleep, exercise, family, friends, etc. (Figure 2B). The seal liver advisory and the nutritive contribution of country food to their diet were also discussed with the students.

Figure 2. A) A student completed the Health-Contaminants puzzle activity. B) examples of completed Health-Contaminants puzzles by students adding in different themes that are related to health, in addition to contaminants.



As the students worked on individual activities, they were also given the opportunity to observe zooplankton through the microscope and light table. Green algae were also brought to feed the plankton and explain food web transfer. This activity was particularly popular with the students with several students lining up multiple times for a chance to observe the zooplankton under the microscope. At the end of the session some of the zooplankton that was brought for the workshop was fed to the classroom guppies, which were part of a year-long ecosystem study unit. The remaining plankton was given to the science teacher who still cultures the organisms in class today.

In the afternoon the team worked with the first to sixth grade students at the Qarmartalik School. The session started with a short presentation about contaminants, sources and pathways as well as a discussion about Arctic food chains. The Arctic contaminants food web game was also done with these younger students. After the game was completed the students were given a ‘blank’ ringed seal on which to colour and draw any ideas about contaminants (Figure 3). Once students completed their ringed seal colouring they could get in line to view the zooplankton. This activity was again popular with a constant line to view the plankton. To wrap up the day, the benefits of country food and the advisory on seal liver were discussed with the students.

Figure 3. Ringed seals coloured by the Grade 1-6 students at the Qarmartalik School in Resolute Bay, Nunavut as part of the workshop on contaminants in ringed seals with elders and researchers.

For the last period, the team went back to the 7 to 12 students group to discuss the different paths to becoming a scientist. The team shared their schooling and experiences and answered students’ questions. Magali Houde, Mick Appaqaq, and Jennifer Provencher each highlighted how they became involved with northern research. The presence of the ETP student was very interesting for the kids who had several questions for him.

At the end of the day, the seal meat was distributed to the community with the help of senior students. The researchers accompanied the students to the families identified by the HTO representative. The following day, Jennifer Provencher and Magali Houde talked with the teachers and the HTO to complete evaluations and get feedback on the workshop i.e., what worked well and what could be done to improve the workshop in the future. Many students suggested that there be another workshop in their community about contaminants in other wildlife such as polar bears and seabirds.

Results

A number of community members, and other visitors to the community, participated during the event at the school. Students, teachers and other education workers took part in the workshop. Additionally, several members of the Canadian Armed forces that were in town for work came by the school to see the workshop after hearing about the planned dissections. Thus, workshops such as this are not only a great way for researchers to work more closely with local community members, but also act as a bridge to community visitors who don’t normally attend events at the school.

While the workshop did involve collecting feedback from the teachers and students involved via surveys, this survey data is still being analyzed. Any results will be shared and validated with the school and HTO and then reported to NCP.

Discussion and Conclusions

This health in ringed seals workshop aimed to integrate contaminants information with other context relevant material, as described in the NCP blueprint. This approach was used in the development of the event which included topics such as Arctic food webs and the importance of traditional foods. Throughout the workshop researchers and elders emphasized the benefits of country food to the students. The larger concept of contaminants, health, and food choices as important components of health, were also important components of the discussion.

Feedback from the community and the researchers, in addition to the active participation of the students of all ages during activities of the workshop, indicated the interest of all parties to continue the work. Active questions from students and community members have encouraged the research team to develop this workshop as a continuing event in each community that contributes towards the NCP ringed seal core monitoring program. Based on the success of the workshop in Resolute Bay in 2016, the team has received funding from NCP to carry out a similar workshop in Sachs Harbour, Northwest Territories in 2017-2018. The long term vision will be to hold a similar workshop in the four communities that contribute to the NCP core ringed seal monitoring project (Arviat, Resolute Bay, Nain and Sachs Harbour) over the next several years.

Expected Project Completion Date

This workshop took place in October 2016 in Resolute Bay and will be ongoing next year in Sachs Harbour, another community involved in the contaminants in ringed seal monitoring project.

Acknowledgments

A special thanks to the Resolute Bay HTA who supported and helped carry out the workshop. Thanks to David Idlout for providing the ringed seal for the workshop, and Peter Amarualik Sr. who shared his traditional hunting skills and knowledge with the group. Thanks also to Zipporah Aronsen and Susan Salluviniq who participated in the workshop by sharing their knowledge and language about ringed seals. We would like to thank the Qarmartalik School in Resolute Bay, Nunavut for their hard work in planning and hosting the workshop, especially Rob Filipkowski and Kevin Xu.

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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 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 research and monitoring of long-range contaminants in the Canadian Arctic, and in making use of the data generated to: (a) 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 (b) inform policy, resulting in action to eliminate

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

contaminants from long-range sources. The NCP Secretariat, within Crown-Indigenous Relations 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 2016-2017 included: (i) funding decisions from the April 2016 Management Committee meeting resulted in funding for 52 projects; (ii) the NCP Human Health Monitoring and Results Communication Workshop held November 22-23, 2016 in Ottawa enabled a dialogue among Indigenous people, researchers, Territorial / Regional Health authorities, and various federal departments, to identify human health biomonitoring needs in the North and how to better incorporate contaminant risk communication into health promotion communication; (iii) the addition of microplastics as a contaminant of emerging concern for the purposes of the NCP; (iv) the removal of the 3-year limit on community based projects; (v) progress on the writing and production of two new reports in the Canadian Arctic Contaminants Assessment Report 2017 series; "Contaminants in Canada's North: State of Knowledge and Regional Highlights" and "Human Health"; (vi) initiatives to mark the 25th anniversary of the NCP; (vii) finalization of the "Principles and Guidelines for Data Management for Polar Research and Monitoring" document which describes the expectations of data archiving for NCP funding recipients; (viii) successful completion of the Phase10 Interlaboratory QAQC study involving 44 analytical labs (including 29 Canadian and 15 international labs) and release of the Phase9 report; (ix) Continued contributions to the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP), through which NCP data and information are put into a circumpolar context and used to inform policy decisions by the Arctic Council; (x) use of NCP data by the POP Review Committee as evidence for basis of recommendations with respect to Deca-BDE going forward for consideration to the UN Stockholm Convention on POPs, and to advance the evaluation of SCCPs and PFOA;

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 du Relations Couronne-Autochtones et Affaires du Nord Canada, assure la coordination et le soutien administratifs, financiers et logistiques nécessaires pour réaliser le PLCN au Canada, 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 2016-2017, sont notamment : (i) les décisions du Comité de gestion (réunion d'avril 2016) concernant le financement ont entraîné le financement de 52 projets; (ii) l'atelier de communication sur la surveillance et les résultats de la santé humaine du PLCN, tenu du 22-23 novembre 2016 à Ottawa, a permis de dialoguer entre les peuples autochtones, les chercheurs, les autorités sanitaires territoriales et régionales et divers ministères fédéraux afin d'identifier les besoins en biosurveillance de la santé dans le Nord et comment mieux intégrer la communication sur les risques de contaminants dans la communication sur la promotion de la santé; (iii) l'ajout de microplastiques en tant que contaminant de préoccupation émergente aux fins du PLCN ; (iv) la suppression de la limite de trois ans pour les projets communautaires; (v) progrès réalisés dans la rédaction et la production de deux nouveaux rapports dans la série du Rapport de l'évaluation des contaminants dans l'Arctique canadien (RECAC) 2017, « Les contaminants dans le Nord canadien : État des connaissances et synthèse régionale» et « Santé humaine»; (vi) initiatives pour marquer le 25e anniversaire du PLCN ; (vii) finalisation du document « Principes et lignes directrices pour la gestion des données pour la recherche polaire et de surveillance », qui décrit les attentes de l'archivage des données pour les bénéficiaires de financement du PLCN ; (viii) la réussite de l'étude interlaboratoire QAQC de phase 10 impliquant 44 laboratoires d'analyse (dont 29 laboratoires canadiens et 15 laboratoires internationaux) et la publication du rapport de la phase 9; (ix) poursuite des contributions au Programme de surveillance et d'évaluation de

(xi) 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 held in March 2017 in Jordan; and (xii) on April 9, 2017 Canada ratified the Minamata Convention, becoming the 41st country to do so.

l'Arctique (AMAP) du Conseil de l'Arctique, grâce auquel les données et les renseignements du PLCN sont placés dans un contexte circumpolaire et servent à éclairer les décisions stratégiques du Conseil de l'Arctique; (x) l'utilisation des données du PLCN par le Comité d'examen des polluants organiques persistants comme base pour la recommandation que le Déca-BDE soit ajouté dans la Convention de Stockholm sur les polluants organiques persistants et pour faire progresser des paraffines chlorées à courte chaîne et de l'acide perfluorooctanoïque ; (xi) 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 sur le mercure aux fins de présentation à la septième réunion du Comité intergouvernemental de négociation en Jordanie en mars 2017; (xii) le 9 avril 2017, le Canada a ratifié la Convention de Minamata, devenant le 41e pays à le faire.

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 ratified by Canada on April 7, 2017. Through use of its data, information and expertise, the NCP made important contributions towards this historic agreement.

Messages clés

- Le secrétariat du PLCN assure la coordination et le soutien administratifs, financiers et logistiques nécessaires pour réaliser le PLCN.
- 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 ratifie par le Canada en avril 2017. Les données, les renseignements et l'expertise issus du PLCN ont grandement contribué à la signature de cet accord historique.

- The Stockholm Convention on Persistent Organic Pollutants (POPs) is an international treaty that entered into force in May 2004, which aims to eliminate or restrict the production and use of POPs. The NCP plays a significant role in producing data that is used to evaluate candidate POPs for the Stockholm Convention.

- NCP continues as Canada's main contributor on contaminant issues to the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP). Contaminants-related efforts in 2016-2017, under the US chairmanship of the Arctic Council, were focused on the production of the AMAP assessments on: Chemicals of Emerging Arctic Concern; Biological Effects of POPs and Mercury on Wildlife; and Adaptation Actions for a Changing Arctic (regional reports).

- La Convention de Stockholm sur les polluants organiques persistants (POP) est un traité international qui est entré en vigueur en mai 2004, qui vise à éliminer ou restreindre la production et l'utilisation des POP. Le PLCN joue un rôle important dans la production de données utilisées pour évaluer les POPs qui sont candidats à la Convention de Stockholm.

- 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 (AMAP) du Conseil de l'Arctique. Les efforts liés aux contaminants en 2016-2017, sous la présidence des États-Unis du Conseil de l'Arctique, ont été axées sur la production des évaluations d'AMAP sur les nouvelles substances chimiques préoccupantes de l'Arctique, les effets biologiques des POP et du mercure sur la faune, et mesures d'adaptation pour un Arctique en évolution (rapports régionaux).

Council of Yukon First Nations Participation in the Northern Contaminants Program

Participation du Conseil des Premières Nations du Yukon au Programme de lutte contre les contaminants dans le Nord

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Abstract

As with the previous year, the Council of Yukon First Nations (the "CYFN") has continued to be an active member on of the Northern Contaminants Program (the "NCP") Management Committee through responding to requests for information, participating in Yukon Contaminants Committee meetings and activities, informing Yukon First Nations and Renewable Resources Councils about the annual call for proposals, maintaining and updating the Yukon NCP website and working with NCP researchers currently active in the Yukon Territory.

Résumé

Comme l'année précédente, le Conseil des Premières Nations du Yukon (« CPNY ») a continué d'être un membre actif du Comité de gestion du Programme de lutte contre les contaminants dans le Nord (« PLCN ») en répondant aux demandes de renseignements, en participant aux réunions et aux activités du Comité des contaminants du Yukon, en informant les conseils des Premières Nations du Yukon et des ressources renouvelables au sujet de l'appel de propositions annuel, en tenant et à mettant à jour le site Web du PLCN au Yukon et en collaborant avec les chercheurs du PLCN qui travaillent actuellement sur le territoire du Yukon.

Key Messages

- Our Traditional Country Foods are safe to eat
- Levels of contaminants are generally low in the Yukon Territory
- We need to continue monitoring as new contaminants are being released into the atmosphere and water and these contaminants may cause challenges in the future.
- The effects of climate change on contaminant mobility and loading needs to be tracked.
- The work of the NCP continues to be relevant at the local, regional, national and international level.
- Yukon First Nations have a role to play in contaminant research through leading or partnering in contaminant research and contributing Traditional Knowledge.

Messages clés

- Nos aliments traditionnels et locaux sont sans danger pour la consommation.
- Les concentrations de contaminants sont généralement faibles sur le territoire du Yukon.
- Il faut continuer la surveillance, car de nouveaux contaminants sont rejetés dans l'atmosphère et dans l'eau, et ces contaminants sont susceptibles de poser des problèmes.
- 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 PLCN sont toujours pertinents aux niveaux local, régional, national et international.
- Les Premières Nations du Yukon ont un rôle à jouer dans la recherche sur les contaminants, en dirigeant ou en établissant des partenariats de recherche et en contribuant aux connaissances traditionnelles.

Objectives

- To enhance the confidence of Yukon First Nations in making informed decisions about Traditional Country Food consumption and other health related factors.
- To ensure that Yukon First Nations are aware of the latest research regarding the transportation of long range contaminants to the Yukon Territory and the effects of those contaminants on the environment and human health.
- To ensure that the programs offered by – and the research done for – the NCP meets the needs of Yukon First Nations.
- To ensure that Yukon First Nations are aware of the funding envelopes and calls for proposals available under the NCP and that these envelopes are relevant for and accessible to Yukon First Nations

Introduction

The CYFN has been a member of the Yukon Contaminants Committee and participated in the NCP as a member of the Management Committee since the program became active in the Yukon Territory. The current NCP focus is addressing northern community concerns as people in the north are being exposed to higher levels of long-range contaminants than the rest of Canada. The Yukon Territory is not a high priority area; however, it is nevertheless important that Yukon First Nations have the information necessary to make informed decisions on the risks and benefits of consuming traditionally harvested country foods.

Activities in 2016-2017

Over the past year, the CYFN participated in NCP Management Committee meetings held in Ottawa in April to review proposals and funding recommendations made for the various envelopes and to advise the Program on the Yukon Contaminants Committee's recommendations. The CYFN also attended the fall Management Committee meeting in Ottawa in October and participated in the Human Health Monitoring and Risk Communication Workshop on November 22-23.

Information on the NCP was shared at the CYFN General Assembly held at Airport Lake near Carmacks (which is located within the Little/Salmon Carmacks First Nation Traditional Territory) in June 28-30. The Circumpolar Relations department had a display booth, and generally relayed information regarding contaminants concerns to interested people. In addition, information packages and literature was made available to CYFN General Assembly delegates. Moreover, Bob Van Dijken attended Yukon First Nation General Assemblies as requested and provided information about contaminant issues. When the annual call for proposals was issued, Bob Van Dijken provided Yukon First Nations with information regarding the call and worked with First Nations interested in submitting a proposal. Bob Van Dijken retired from the CYFN in October and James MacDonald assumed his job responsibilities for the balance of the reporting year.

The CYFN also participated in the work of the Yukon Contaminants Committee, meeting with researchers, discussing communications on contaminants issues and reviewing proposals submitted to the NCP on potential research projects in Yukon. The CYFN worked with researchers to disseminate information on their research and ensured they engaged with communities in all aspects of their work.

The CYFN maintains and updates the website www.northerncontaminants.ca. The site documents activity carried out by researchers on contaminant issues in the Yukon Territory and provides information on contaminants of concern.

The CYFN continued to participate in the deliberations and activities of both the Traditional Knowledge and risk communication sub-committees.

As with the previous fiscal year, the CYFN continued to administer the operating aspects of the Little Fox Lake air quality monitoring site from April 1, 2016 through to March 31, 2017. The Yukon Contaminants Committee, working with Environment and Climate Change 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 in February, 2017. A number of Ta'an Kwäch'än Council citizens visited the site as well.

In addition, the CYFN administered the contract for Aurora Consulting, so that Jamie Thomas could work on a Traditional Knowledge project associated with long-range contaminants and the air monitoring site at Little Fox Lake. This included the staging of a one-day workshop at the Yukon Horse Packing ranch near Fish Lake, as well as several interviews with Ta'an Kwäch'än Council citizens and elders. A report on the Traditional Knowledge project will be filed separately.

Continuing discussions were held with Health Canada about the expansion of health monitoring in the Yukon Territory, perhaps based on the work of the Inuit Health survey. This in part led to the submission of a proposal for biomonitoring in Old Crow, Yukon, under the leadership of the Vuntut Gwitchin First Nation.

In addition, the Yukon Contaminants Committee hosted a two-day workshop on March

1-2 in Whitehorse, Yukon to raise the profile of the NCP and Yukon Contaminants Committee, to present current and past research undertaken in the Yukon Territory, and to encourage Yukon First Nations and Renewable Resources Councils to join the Yukon Contaminants Committee in reshaping its mandate and focus.

Summary of Activities in 2016-2017

- Attended Management Committee meetings to recommend funding for research envelopes.
- Attended the NCP Program Human Health Monitoring and Risk Communication Workshop in Ottawa in November, along with two Yukon First Nation Health Directors and the CYFN Regional Health Surveyor.
- Communicated information on contaminants and the NCP to Yukon First Nations at the CYFN General Assembly and various other Yukon First Nation General Assemblies.

Attended the Yukon Contaminants Committee meetings, reviewed projects proposing to do work in the Yukon Territory, and made comments in writing to the NCP in preparation for the April 2017 Management Committee meeting.

- Attended the NCP mid-year management meeting.
- Updated and revised the northerncontaminants.ca website.
- Administered the Yukon Territory costs of the Little Fox Lake mercury and POPs air monitoring site, including the contract arrangement with Aurora Consulting to include the Traditional Knowledge project.
- Engaged in dialogue with the NCP and Health Canada regarding possible bio-monitoring programs in the Yukon Territory.
- Met with Environment and Climate Change Canada researchers Hayley Hung and Alexandra Steffen about the Little Fox Lake air monitoring site.
- Organized a two-day workshop for Yukon First Nations and Renewable Resources Councils so that they could learn more about the NCP and the Yukon Contaminants Committee and to seek their involvement in reshaping the mandate and focus of the Yukon Contaminants Committee.

Discussion and Conclusions

The NCP plays a vital role in monitoring the health of the Yukon Territory's ecosystems and assuring Yukon Territory residents that traditionally harvested country foods are safe for consumption. In general, levels of contaminants transported to the Yukon Territory through the atmosphere and aquatic sources remains low; however, levels of mercury may still 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 understanding background levels, tracking changes and understanding their relationship with climate change, industrial activity and other factors.

Expected Project Completion Date

March 31, 2017, but this is proposed to be a multi-year project and it is hoped that this project will continue in subsequent years.

Project website

www.northerncontaminants.ca

Acknowledgements

We acknowledge the Northern Contaminants Program's funding of this project.

Dene Nation participation in the Northern Contaminants Program

Participation de la Nation Dénée au Programme de lutte contre les contaminants du Nord

- **Project Leader/Chef de projet**
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- **Project Team/Équipe de projet**
  Bill Erasmus, Dene National Chief/Assembly of First Nations Regional Chief NWT

Abstract

Dene Nation received funding from the Northern Contaminants Program (NCP) for the fiscal year 2016-2017. The funds supported Dene Nation's participation with the NCP Management Committee and the NWT Regional Contaminants Committee (NWTRCC). The funding was available through the Program Coordination and Aboriginal Partnerships envelope.

Dene Nation received this funding to participate in two NCP Management Committee meetings at Whitehorse, YK and Ottawa, ON as well as NWTRCC meetings and teleconferences. In addition, the funding was also provided in order for Dene Nation to report to its Leadership meetings and to the National Assembly, provide information to the communities as needed, enhance communications with the NWTRCC, and to participate with NCP working committees addressing traditional knowledge and other topics.

Résumé

La Nation dénée a reçu des fonds du Programme de lutte contre les contaminants dans le Nord (PLCN) pour l'exercice 2016-2017. Ces fonds ont appuyé la participation de la Nation dénée au Comité de gestion du PLCN et au CRCTNO. Le financement a été offert dans le cadre de l'enveloppe Coordination du programme et partenariats autochtones.

La Nation dénée a reçu ce financement pour participer à deux réunions du Comité de gestion du PLCN à Whitehorse (Yukon) et à Ottawa (Ontario), ainsi qu'aux réunions et téléconférences du CRCTNO. De plus, le financement a été accordé afin que la Nation dénée puisse faire rapport à ses réunions sur le leadership et à l'Assemblée nationale, fournir des renseignements aux collectivités au besoin, améliorer les communications avec le CRCTNO et participer aux travaux des comités de travail du PLCN sur les connaissances traditionnelles et d'autres sujets.

Key Messages

- Dene Nation participated on the NCP Management Committee.
- Dene Nation participated on the NWTRCC.
- Dene Nation provided advice to NCP on contaminant issues in the communities.
- Dene Nation acted as a liaison between NCP activities and the Dene Nation membership.

Messages clés

- La Nation dénée a participé au Comité de gestion du PLCN.
- La Nation denée a participé au CRCTNO.
- La Nation dénée a fourni des conseils au PLCN au sujet des contaminants dans les collectivités.
- La Nation dénée a assuré la liaison entre les activités du PLCN et les membres de la Nation dénée.

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.

Introduction

The 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 radionuclides – 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 NCP for 2016-2017 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 also enabled Dene Nation to consider internal capacity and coordination issues, for the Dene Nation and the NWTRCC to work toward developing a proposal for a regional workshop to inform the Dene communities about the NCP funded projects, and to get community input on future studies needed in the Dene regions.

Activities in 2016-2017

The Dene Nation participated with the NWTRCC and the NCP Management Committee meetings and teleconferences scheduled between April 01, 2016 and March 31, 2017.

- The Dene Nation representative attended all NWTRCC meetings during the fiscal year including the February 14-16, 2017 meeting to review proposals.

- The Dene Nation representative did not attend the Ottawa April 12-14, 2016 meeting due to a health issue.
- The Dene Nation representative did attend the NCP Management Committee meeting at Whitehorse, YK during October 2016.
- The Dene Nation representative participated in a NCP working group teleconference call on Indigenous Knowledge (IK) on June 7, 2016.
- The Dene Nation representative was not available to participate with the NCP working group follow up IK teleconference call on July, 2016.
- The Dene Nation commenced establishment of its Land and Environment Committee.

Discussion and Conclusions

The funding from the NCP supported the Dene Nation's participation in a NCP Management Committee meeting (one meeting was not attended due to health issues), NCP IK working group teleconference (Dene Nation representative was not available for one teleconference) and NWTRCC in person meetings and teleconference calls.

The Dene Nation was much more engaged with the NWTRCC and the NCP Secretariat by the end of the fiscal year. Dene Nation also became further engaged with its membership by communicating with the regional governments about its Land and Environment Committee and its mandate to northern contaminants and other environmental themes.

Inuit Tapiriit Kanatami National Coordination

Coordination nationale d'Inuit Tapiriit Kanatami

Project Leader/Chef de projet

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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. These roles include but are not limited to the following:

- ITK provides guidance and direction to CIRNAC and the other NCP partner's (HC, DFO, ECCC, etc.) bringing Inuit interests to the NCP management and liaison committees of which we are active members. As a result, the NCP can better respond to the needs and concerns of Inuit.
- ITK is dedicated to facilitating appropriate, timely communications about contaminants in the North.

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. Ces rôles sont notamment les suivants :

- ITK fournit de l'orientation et des conseils à Affaires autochtones et du Nord Canada (AANC) et à d'autres partenaires du PLCN (Santé Canada, Pêches et Océans Canada, Environnement et Changement climatique Canada, entre autres), et présente les intérêts des Inuits aux comités de gestion et de liaison du PLCN dont nous sommes des membres actifs. En conséquence, le PLCN peut mieux répondre aux besoins et mieux réagir aux préoccupations des Inuits.

- ITK works 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.
- ITK works with other research programs to ensure that research on contaminants is conducted in a coordinated approach.

- ITK s'emploie à faciliter des communications adéquates et opportunes au sujet des contaminants dans le Nord.
- ITK collabore avec ses partenaires inuits au sein du CCI-Canada à l'international pour persuader les pays de réduire leur production et emploi de polluants organiques persistants (POP) et de métaux lourds (p. ex. le mercure) qui finissent par se retrouver dans les aliments des Inuits.
- ITK collabore avec d'autres programmes de recherche pour veiller à ce que la recherche sur les contaminants soit menée de façon coordonnée.

Key Messages

- ITK provides a voice for Inuit Nunangat during NCP discussions.
- As an active and constructive member of the NCP Management Structure, ITK ensures 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.
- ITK contextualizes contaminant information in a broader communication process using the Inuit Knowledge Centre and other ITK structures (i.e NICoH)
- ITK develops the confidence of Inuit in making informed decisions about Country food use.
- ITK coordinates contaminants activities with other research programs.

Messages clés

- ITK se fait le porte-parole d'Inuit Nunangat dans les délibérations du PLCN.
- En tant que membre actif et constructif de la structure de gestion du PLCN, ITK veille à ce que les questions relatives aux contaminants ainsi que les recherches et les résultats du PLCN soient communiqués aux Inuits, et que les Inuits soient représentés aux principales réunions et dans les initiatives importantes à l'échelle régionale, circumpolaire et internationale.
- ITK contextualise les renseignements relatifs aux contaminants dans un contexte général par l'intermédiaire du CSI et des autres structures d'ITK (p. ex. Comité inuit national de la santé [CINS]).
- ITK renforce la confiance des Inuits dans leur prise de décisions éclairées au sujet de la consommation des aliments traditionnels.
- ITK coordonne les activités sur les contaminants avec d'autres programmes de recherche.

Objectives

Long Term objectives

- Ensure that Inuit are equal, meaningful, and effective partners in decision-making on environmental policy and research within Inuit Nunangat.
- Protect and promote the inclusion of and respect for Inuit knowledge, perspectives, and interests in the development of environmental and wildlife related research, policy, legislation, and programs.
- Actively communicate on environmental and wildlife issues affecting Inuit.
- Support the enhancement of Inuit capacity to better address environment and wildlife priorities.

Specific objectives

- Participate in the NCP Management Committee
- Participate in Regional Contaminant Committees
- Participation on NCP Review Teams
- Consultation with Inuit Research Advisors
- Participate in ArcticNet Annual General Meeting/Research Management Committee (AGM/RMC) and Board of Directors (BOD) meetings. Review of Integrated Regional Impact Studies (IRIS) reports
- Participate in NCP reports
- Participate in teleconferences and in person meetings with Inuit Research Advisors
- Participate in the Nasivvik Research Chair in Ecosystem Approaches to Health
- Promote and provide NCP information to regular ITK BOD meetings
- Participate at the ArcticNet general meeting/ RMC and IRIS preparations
- Participate in and provide a voice for NCP at Public Health Task Group
- Participate in and provide a voice for NCP at National Inuit Committee on Health
- Participate in and provide a voice for NCP at Inuit Early Childhood Development Programs
- Participate in and provide a voice for NCP at the National Inuit Food Security Group
- Participate in the National Inuit Climate Change Committee
- Provide a voice for NCP in the Inuit Qaujisarvingat: Inuit Knowledge Centre (IKC)
- Participate in the IKC BOD meetings
- Participate in the National Wildlife Committee meetings
- Participate in Health Canada/CIRNAC Climate Change Programs
- Participate in and provide a voice for NCP at the Canada's Chemical Management Plan
- Help researchers
- Continue with mentorship and education

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. These contaminants are of concern for Inuit as these contaminants have been found in the fat-rich country foods that the Inuit depend 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 experience 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 are involved throughout the program in order to provide advice, direction, and information to Inuit.

Activities in 2016-2017

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.

ITK continues to provide advice and direction from Inuit to the NCP and additional federal agencies, the territorial governments, and other partners. We believe firmly that our involvement in the program enables the NCP to better respond to the needs and wishes of Inuit with respect to the design and delivery of specific projects, and in defining Canadian positions in international processes.

As well, we are committed to facilitating appropriate and timely information about contaminants and the NCP to communities and appropriate international organizations. By improving and systematizing communications at the regional, national, and international levels we are better able to represent Inuit needs and interests within the NCP. Equally, Inuit organizations and communities can make better use of NCP information and funding.

Some key activities this year includes the following:

- The ITK weekly management meetings provide updates to ITK directors and President on NCP research which will feed into ITK Executive speeches and policy forums and social media.
- We continue to work with the Chief medical officers to explain the NCP program and research when needed.
- We provided critical updates to other programs like Inuit early childhood development and food security.
- With NCP information we developed a Climate Change Strategy and are working on an Inuit research strategy for 2017 with the IKC.
- We continued upkeep of IKC Online Contaminants Course (www.inuitknowledge.ca).
- We have a close working partnership with the Inuit Knowledge Centre (IKC). We use the NCP as a "model" program for other research program development at the IKC. As well the IKC can provide help to the NCP in guiding and directing both the program and researchers and at training Inuit at the community and regional level so they can be more active members on NCP research.
- ITK taught Inuit students at Nunavut Sivuniksavut (NS) which is a unique eight-month college program based in Ottawa. It is for Inuit youth from Nunavut who want to get ready for the educational, training, and career opportunities that are being created by the Nunavut Land Claims Agreement (NLCA) and the new Government of Nunavut.
- We were able to continue to play a key role with ArcticNet to ensure that the research being conducted there avoids overlap and duplication and to assist with the ArcticNet Students Association in doing research in Inuit communities. This student mentorship has made great strides as evident in past Inuit Award recipients like Lisa Loseto and

Shawn Donaldson who have bridged NCP, ArcticNet, and Inuit communities into their research.

- We also continue to work with Carleton University in teaching arctic and Inuit contaminant issues to university students (presentation of this year's presentation is available).

Our main body of work continues to focus around the heart of the NCP which is the Regional Contaminants Committee. Although illness force us in some instances to participate over teleconference rather than face to face, we were still able to accomplish a lot through these committees. The ability to contextualize information has always been critical for us here at ITK and to do this, ITK made connections with 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 to bring concerns to the 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 deliver NCP environment information. 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 guide the 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, develop priorities and issues within NCP framework, develop confidence in Inuit about their ability to making informed decisions on their food, and coordinate 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 an Inuit "voice" and direction at the NCP management table, and to ultimately allow Inuit to have confidence in their ability to making good informed decisions about their food use.

Working with Scientist and projects

Last year there were over 54 projects that took place in Inuit regions, and expectations for this year suggest that it will be roughly the same with a big emphasis on the health survey in Nunavik. While some of these are laboratory studies that needed little engagement from Inuit Nunangat, others like the Nunavik Health Survey and Nunavik Child Cohort required substantial time and expertise from Inuit. This year we expect the same from these projects, and time will be needed to participate in a meaningful way with the Health Survey project. We plan to work closer with many of the wildlife projects that are being conducted in order to inform our new National Wildlife Inuit Committee on the health and wellbeing of many key Arctic species. Other projects include working with the beluga monitoring team, working on local observations and traditional knowledge elements, and meetings are planned in the Nunavut and the NWT Region. We are also hoping to bring over some Inuit from the eastern Arctic to begin fostering ideas across Inuit regions.

Training Inuit Researchers

With the launch of the Inuit Qaujisarvingat: Inuit Knowledge Centre (IKC), the Amaujaq National Centre on Inuit Education and the announcement of the Canadian High Arctic Research Station, there are more activities, training and education available to Inuit (for example, the IRA, frontline workers, community representatives). With the ultimate goal of making research in the north one that is led and developed by Inuit, ITK, with support from the NCP, will continue in its process of mentoring, training and fostering Inuit researchers at the national, regional, and community levels. It's vital that training activities are conducted and viewed at this scale (National-Regional-Community) as this is the established network that Inuit have organized and developed in order to take information at the community level to inform policy at the national-international level as well as taking information at the National level and bringing it back to the community. When any link of this network is compromised then information flow is jeopardized. With the influx of research from various arctic programs like the NCP, and ArcticNet, it is critical that we continue to find ways to mentor, engage, and train Inuit. This year training will be in support of Trent and the NNHC in order to train Inuit youth to work and assist with the Nunavik Inuit Health Survey.

Youth Engagement and Capacity Building

Working with the National Inuit Youth Council, the Project Team will allow for the incorporation of youth input and direction into NCP and ITK programs, for instance updating messaging for the original NIQIIT course. The project team will also utilize forums at ITK like the Amaujaq National Centre for Inuit Education and the National Inuit Educational Strategy to determine how best to relate these activities to developing curriculum, as well as the National Inuit Committee on Health and the National Inuit Climate Change Committee. As a follow up to a June 2013 meeting of the IRAs in which Inuit Qaujisarvingat presented the NIQIIT course, the Project Team will work to incorporate IRA involvement in all aspects of this project in order to further build their capacity. Plans are in the works to work with NCP researchers in revamping the NIQIIT course to help some of the planned communication and training activities taking place in Nunavut in 2018.

Inuit Research Advisors

The Inuit Research Advisors are a key component to the success of the NCP; in order for the IRA to be successful it has been reported from the recent IRA training manual that they need consistent training and support from the National organization (ITK). Since many of the best examples of training, communication and education come from the NCP, it is expected that the Inuit Qaujisarvingat: Inuit Knowledge Centre (IKC) will work a lot with NCP researchers and NCP frontline workers to establish needs and address concerns.

In its 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 engaging in research in Inuit regions. This year there were close to 40 projects that 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 researchers in various environmental monitoring programs on how to communicate to communities, translating scientific information, making links to other research programs, and 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 NCP Risk Communication Workshop.

Discussion and Conclusions

In a time of great turn over and changing personnel, ITKs engagement to the NCP committee's has been the one constant over the last 20 years. This has provided each of the contaminants committees with some record of history. This year ITK worked and helped each of the four regional committees (Nunatsiavut, Nunavik, Nunavut, and the NWT), engage with the NCP review teams, helped with the development of the new Risk Communication Subcommittee, and participated/helped with any issues that the NCP might need assistance with. ITK will continue to sit on all contaminant committees (Nunatsiavut, Nunavik, Nunavut and Inuvialuit), NCP Management team, and NCP review teams (Human Health, Community Based Monitoring, and Education and Outreach). ITK will continue to bring to the contaminant committees, NCP Management and review teams information learned from participating in 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, First Nations and Inuit Health Branch (FNIHB) community based climate change program, and 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 contextualize the NCP program and other national programs, like the Chemicals Management Plan and the Commission for Environment Cooperation (CEC), to Inuit regions.

Expected Project Completion Date

Ongoing

Project websites

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 contaminants instruments and activities

Conseil circumpolaire inuit – Canada: activités en appui aux activités et aux outils visant les contaminants circumpolaires et mondiaux

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Abstract

This report outlines ICC Canada's activities funded by the Northern Contaminants Program (NCP) in fiscal year 2016-17. ICC Canada is working nationally and internationally to address the issue of contaminants in the Arctic. National activities include support to the NCP on the Management Committee, blueprint and proposal reviews, and input into the Canadian Arctic Contaminants Assessment 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 Organic Pollutants (POPs) is ongoing, with ICC Canada attending the 12th POP Review Committee (POPRC) in September 2016. ICC Canada continued to support Arctic Council activities, and attended several meetings of the Arctic Monitoring and Assessment

Résumé

Ce rapport fait état des activités du CCI Canada financées par le Programme de lutte contre les contaminants dans le Nord (PLCN) pendant l'exercice 2016-2017. Le CCI Canada travaille à l'échelle nationale et internationale à régler les questions relatives aux contaminants dans l'Arctique. Les activités nationales comprennent l'appui au PLCN au Comité de gestion, l'examen des plans et des propositions, et la contribution au Rapport de l'évaluation des contaminants et de la santé de l'Arctique Canadien (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 sont en cours, et le CCI Canada a assisté à la 12e réunion du Comité d'examen des POP en septembre 2016.

Programme (AMAP). ICC Canada was very active on the Sustaining the Arctic Observing Networks (SAON) Board, the SAON Executive Committee, and continues to lead the SAON task force on community-based monitoring.

Key Messages

- ICC Canada actively supported NCP by working on the Management Committee, Environmental Monitoring and CBM technical review committees, and led Chapter 4 (on Chemical management, risk management, and contaminant communication) for the CACAR IV report (Human Health).
- ICC Canada attended the 12th POP 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.
- ICC Canada was very active in the AMAP Human Health Assessment Group (HHAG) and co-led "Chapter 6 on Risk Communication for the AMAP Assessment 2015: Human Health in the Arctic". A special issue was published from this assessment in the International Journal of Circumpolar Health, including a paper on risk communication (led by ICC Canada).
- A publication on mercury isotopes in ice cores and snow samples to identify mercury pathways and sources to the Arctic (Historical variations of mercury stable isotope ratios in arctic glacier firn and ice cores (Zdanowicz et al. 2016) was

Le CCI Canada a continué d'appuyer les activités du Conseil de l'Arctique et a participé à plusieurs réunions du Programme de surveillance et d'évaluation de l'Arctique (PSEA). 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 le groupe de travail des SAON concernant la surveillance communautaire.

Messages clés

- Le CCI Canada a activement appuyé le PLCN en participant au Comité de gestion et aux comités d'examen technique en matière de surveillance environnementale et de surveillance communautaire. De plus, il a dirigé la rédaction du chapitre 4 (sur la gestion des produits chimiques, la gestion des risques et la communication au sujet des contaminants) du RECAC IV (Santé humaine).
- Le CCI Canada a assisté à la 12e réunion du Comité d'examen des POP, 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.
- 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. Un numéro spécial de cette évaluation a été publié dans l'International Journal of Circumpolar Health, y compris un article sur la communication des risques (dirigé par le CCI Canada).
- Une publication sur les isotopes de mercure dans des carottes de glace et des échantillons

published in 2016 in the journal Global Biogeochemical Cycles.

de neige employés pour déceler les trajets du mercure et les sources du métal vers l'Arctique (« Historical variations of mercury stable isotope ratios in arctic glacier firn and ice core » [Zdanowicz et al., 2016]) a été publiée en 2016 dans la revue Global Biogeochemical Cycles.

Objectives

Short-term objectives

- To ensure Inuit are aware of global, circumpolar and national activities and initiatives on contaminants.
- To ensure Inuit viewpoints and interests are represented in contaminant-related matters, and are considered and included in relevant research, reports, assessments, and meetings pertinent to policy development.
- To ensure scientific research in the Arctic is addressing Inuit needs and is done with Inuit support and involvement.

Long-term goals

- to ensure Inuit have the capacities, resources and knowledge necessary to support their participation and involvement in national and international policy development on contaminant issues
- to assist in the development of a framework that allows for sustained and integrated community-based research and includes the use of Indigenous 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 their 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 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 Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC), 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 the Arctic Council, and represents Inuit at the United Nations Environment Programme (UNEP) and related meetings.

Activities in 2016-2017

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 fiscal year 2016-17.

NCP

Proposed activities

i. ICC Canada will continue to support NCP's work through the Research Managers, blueprint and proposal review processes (particularly in the Environmental Monitoring Envelope) as in past years.

ii. ICC Canada was involved in the development of the Canadian Arctic Contaminants Assessment 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, as well as work on the CACAR IV Human Health report.

iii. 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

i. 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 12–14, 2016 in Ottawa and October 4 – 5, 2016 in Whitehorse, reviewed proposals and documents (such as blueprints) as required, provided comments, and updates on POPRC activities. ICC Canada further participated in the NCP Health and Risk Communication workshop November 11 – 12, 2016 in Ottawa.

ii. ICC Canada finalized the chapter on chemical management and contaminant communication for the CACAR IV Human Health report, which it had been leading. Several drafts of this chapter have been completed, extensively reviewed, and revised. A final draft was submitted to the NCP in May 2016.

iii. ICC Canada constructively contributed to, and participated in, the Human Health Monitoring and Risk Communication Workshop on November 22-23, 2016 in Ottawa.

AMAP

Proposed activities

i. General: ICC Canada will attend Working Group and Heads of Delegation meetings if resources permit, and will review and comment on related documents, as necessary and possible. At the last AMAP WG meeting, ICC Canada proposed the development of a TK utilization framework and implementation plan for AMAP. ICC Canada and ICC Alaska have agreed to work together on this in 2016/17, which would also be useful for Conservation of Arctic Flora and Fauna (CAFF) and other Arctic Council working groups.

ii. Adaptation Actions for a Changing Arctic-C (AACA-C): ICC Canada was part of the development process, is part of the Integration Team, and coordinated activities with the other ICC offices. Currently, the pan-Arctic report is being prepared and ICC-Canada will continue its work to provide input, as resources permit.

iii. Sustaining the Arctic Observing Network (SAON): Eva Kruemmel is part of the SAON Board, the SAON Executive Committee, and will assist in follow-up work as SAON's co-chair of the organizing committee for the Arctic Observing Summit (AOS).

iv. **Health Expert Group**: ICC Canada remains active with the Sustainable Development Working Group (SDWG) and AMAP Human Health Expert Groups and will attend meetings as possible.

v. **POPs Expert Group**: ICC Canada will be involved in the development of the upcoming AMAP POPs assessments (such as the biological effects assessment) as much as possible. In particular, ICC Canada will work on the inclusion of the Inuit perspective on POPs and biological effects, review chapter drafts, include content related to the Stockholm Convention on POPs and the POP Review Committee, and attend meetings.

Work undertaken

i. General: ICC Canada participated in the AMAP Working Group meeting (and the HoD meeting preceding it) November 28th – December 1st, 2016, in Helsinki, Finland. ICC reviewed and provided input into AMAP documents before and after the meetings, in particular for AMAP reports, such as the AACA, Snow, Water, Ice, Permafrost in the Arctic (SWIPA) and Chemicals of Emerging Arctic Concern summary reports. Together with ICC Alaska, ICC Canada started working on an Inuit knowledge framework document which is still in development.

ii. ICC Canada also attended Arctic Council's Scientific Cooperation Task Force meeting July 6th – 8th 2016 in Ottawa, where the final agreement text was discussed.

iii. AACA-C: ICC Canada continued to be involved in the development process, Stephanie Meakin is a member of the integration team and organized and attended teleconferences. Stephanie Meakin edited all chapters of the AACA Baffin Bay/ Davis Strait Assessment, the Summary for Policy-makers and other documentation. ICC also facilitated comments on the BCB from ICC Alaska. ICC attended AACA-related meetings in Tromsø, and provided comments for the pan-Arctic prospectus, regional and summary reports.

iv. SAON: ICC Canada took part in teleconferences of the SAON Executive Committee, SAON Board, as well as some teleconferences of the AOS organizing committee and the Arctic Observing Framework Initiative by the U.S.A.

v. Health Expert Group: ICC Canada is active in the SDWG and AMAP Health Expert Groups (Arctic Human Health Expert Group (AHHEG) and Human Health Assessment Group (HHAG), respectively).

- The HHAG wanted to publish the AMAP 2015 Health Assessment in the International Journal of Circumpolar Health, and Eva Kruemmel prepared the associated manuscript for the risk communication chapter (which ICC Canada has been co-leading). The paper got published as part of a special issue in December 2016 (see References for full citation).
- ICC Canada attended the HHAG meeting December 7 – 8, 2016 in Copenhagen, Denmark, reviewed associated documents and provided comments. ICC is also planning to participate in the upcoming AMAP conference: Bringing Knowledge to Action in Reston, Virginia (pending funding availability). A presentation on the Risk Communication chapter of the AMAP Health Assessment 2015 at the conference has been accepted by the conference organizers, and ICC Canada is planning to attend a HHAG meeting prior to the AMAP conference on April 23 – 24th.

vi. POPs Expert Group: ICC Canada fully reviewed the technical chapters of the Chemicals of Emerging Arctic Concern assessment and provided comments. ICC Canada further submitted text for a section on knowledge gaps (co-authored with ICC

Alaska and Saami Council) in the POPs/Hg Biological Effects assessment.

UN related

Proposed activities

i. 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.

ii. Persistent Organic Pollutants Review Committee (POPRC): ICC Canada is planning to attend the 12th POPRC meeting taking place September 19 – 23, 2016 in Rome, Italy, and is looking forward to keeping 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 PFOA and dicofol, as well as the risk management evaluation of short-chained chlorinated paraffins (SCCPs).

Work undertaken

i. Minamata Convention: So far, there has been very little development on further work, but ICC Canada continues to review the progress and review associated documents. ICC Canada participated remotely in a Mercury Fate and Transport Partnership meeting on October 13th, 2016.

ii. 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 August 25th. ICC Canada attended the 12th POPRC meeting September 19 – 23, 2016 in Rome, Italy, and gave a presentation on effective participation of non-governmental organizations during the pre-sessions on September 19th. Eva Kruemmel further arranged a group of five students at the University of Ottawa (Institute of the Environment) to help with the review of chemicals for POPRC as part of a course within their program.

Other mercury and POPs related work

Proposed activities

i. ICC Canada is continuing to analyze results from the mercury study investigating the sources of mercury to the Arctic. Two publications on some of this work have been published, and another one is currently being developed, as outlined above. 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.

ii. 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 undertaken

i. A paper on the mercury isotope results (Historical variations of mercury stable isotope ratios in arctic glacier firn and ice cores (Zdanowicz et al. 2016) was submitted in March 2016 to the journal Global Biogeochemical Cycles and got published in August 2016 (see full citation in References).

ii. 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.

Communication

Proposed activities

i. ICC Canada has been slowly improving its web presence with a revamped website (http://www.inuitcircumpolar.com) and now also has Facebook and Twitter accounts. ICC Canada is planning to publish newsletters that give regular updates and brief overviews of the most recent activities. Further communication efforts 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, and teleconferences etc.

Work undertaken

i. ICC Canada's general communication efforts are ongoing, but need improvement. 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 through the internet, meetings, emails and teleconferences, in the form of briefing notes, presentations, meeting reports, and press releases etc. as required and possible. Communications, including with our partner national and regional governments and organizations, is an area that requires significant improvement going forward.

   Examples of presentations given:

   - February 15th, 2017: Guest lecture by Eva Kruemmel on "International Research and Policy Development on Contaminants" at University of Ottawa course "Toxicology and Regulation".
   - January 19th, 2017: Introduction on POPRC work by Eva Kruemmel for a Capstone Course at the University of Ottawa.
   - September 19th, 2016: Presentation by Eva Kruemmel on "Effective Participation of NGOs in POPRC" at a POPRC meeting pre-sessions organized by the BRS (Basel-Rotterdam-Stockholm Conventions) Secretariat.
   - June 6th, 2016: Presentation by Eva Kruemmel on "Contaminants, the Arctic, and International Policy Development" at a Biology Departmental Seminar of the University of Ottawa.

Discussion and Conclusions

With support from the NCP, ICC Canada worked successfully in many international fora to ensure that Inuit perspectives were brought forward. Examples include POPRC-12, where ICC Canada presented on its work in a pre-meeting session, and in doing so, brought forward Arctic research (such as from NCP and AMAP) and the Inuit perspective on POPs under review. At POPRC-12, the committee decided to advance dicofol and PFOA in the review process and recommended deca-BDE and SCCPs for addition to Annex A of the Stockholm Convention. At the Arctic Council, ICC Canada contributed to and reviewed AMAP assessments (such as the Chemicals of Emerging Arctic Concern assessment) and actively contributed to other initiatives, such as SAON and AACA. ICC Canada supported the NCP with contributions to CACAR IV and the management structure of the NCP program itself. ICC Canada is looking forward to continuing these activities in the coming years to ensure that Inuit perspectives are recognized in international policy development on contaminants and Arctic research.

Expected Project Completion Date

Ongoing

Project website

ICC Canada's website:
www.inuitcircumpolar.com.

Acknowledgments

NCP was acknowledged in presentations and publications.

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